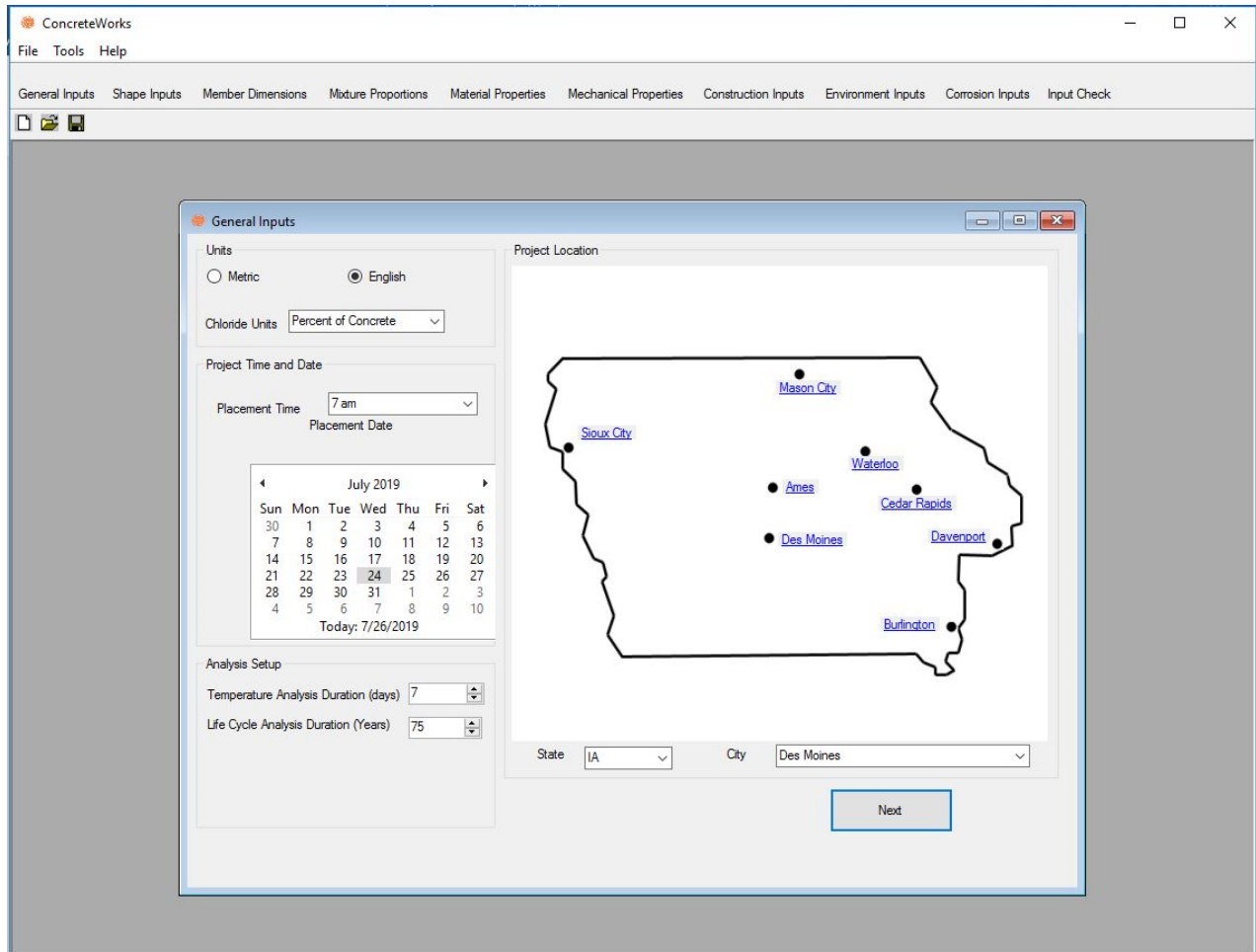# ConcreteWorks

Version 3.1.0[1]
Operator's Manual

This program is modified for Iowa through funding by the Iowa Department of Transportation
under IHRB Project TR-712

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1. Operator's Manual

1.1. Getting Started

1.1.1. Introduction to Using ConcreteWorks

ConcreteWorks is a suite of Windows®-based concrete technology programs intended for use by engineers, researchers, inspectors, contractors, and precasters already familiar with concrete materials and construction practices. The first program in the series is the self-titled ConcreteWorks program. ConcreteWorks is a concrete durability design tool that may be used to predict temperature development, thermal stress cracking probability, or the concrete chloride service life for various concrete members, as explained in the software introduction. ConcreteWorks is meant to be used by operators described above that have a working knowledge of concrete behavior. It is recommended that ConcreteWorks users thoroughly read the background information on the software to understand some of the limitations and the assumptions made in the software.

Mix Proportions is a program that assists the user in concrete mixture design and proportioning. *Mix Proportions* is based on the procedures outlined in ACI 211 (1991) and National Highway Institute (NHI) Course 15123 (Hover, 2003). This operators' manual provides help with using the program ConcreteWorks. No warranty of the accuracy of results calculated by any of the ConcreteWorks programs is given or implied.

1.1.2. Installation

To install ConcreteWorks, the target computer must be running the Microsoft .NET Framework v3.5. The .NET Framework should be updated through automatic updates.

Once the target computer is running the .NET Framework, you may install ConcreteWorks. ConcreteWorks may be downloaded from https://iowadot.gov/bridge/Mass-Concrete-Fundamentals-November-2019. Once downloaded, the user should unzip the downloaded file and double-click on the setup.exe file to begin installation. The program should then start the Installation Wizard.

The installation wizard will guide you through all of the necessary steps to install ConcreteWorks. The first screen is the installation welcome screen. Click the *Next* button to continue with the installation. The second screen contains the End-User License Agreement (EULA). Click the *I Agree* button if you agree with the terms of the EULA, and then click *Next*. If you do not agree with the terms of the EULA, click *I Do Not Agree* and then *Cancel*, ending the installation process. The software will not install unless you signify that you agree to the terms of the EULA by clicking, *I Agree*. Internet Explorer must be on the computer to access the official ConcreteWorks website from ConcreteWorks as described in Section 1.4.7. Lack of access to Internet Explorer could result in an error and/or the program crashing.

Adobe Reader® is also required to be installed on the computer to access the ConcreteWorks *User Manual* as described in Section 1.4.7. Failure to have Adobe Reader® installed on the computer could result in an error and/or the program crashing.

1.1.3. Navigating the Program

There are two methods of opening a new or saved file in ConcreteWorks. The first method is to click on the *New File* or *Open Existing File* toolbar button. The second method is to click *New* or *Open* under the *File* Menu. Figure 1 shows a zoomed in view of the upper left side of ConcreteWorks. The red arrows point to the different menus and toolbars available in ConcreteWorks. If a file is already open, the program will prompt to save the current file. If the *Yes* button is clicked, the program follows the save procedure outlined in Section 1.4.4. If a file is not already open, the program will prompt the user for a filename and location, as described in Section 1.4.3.
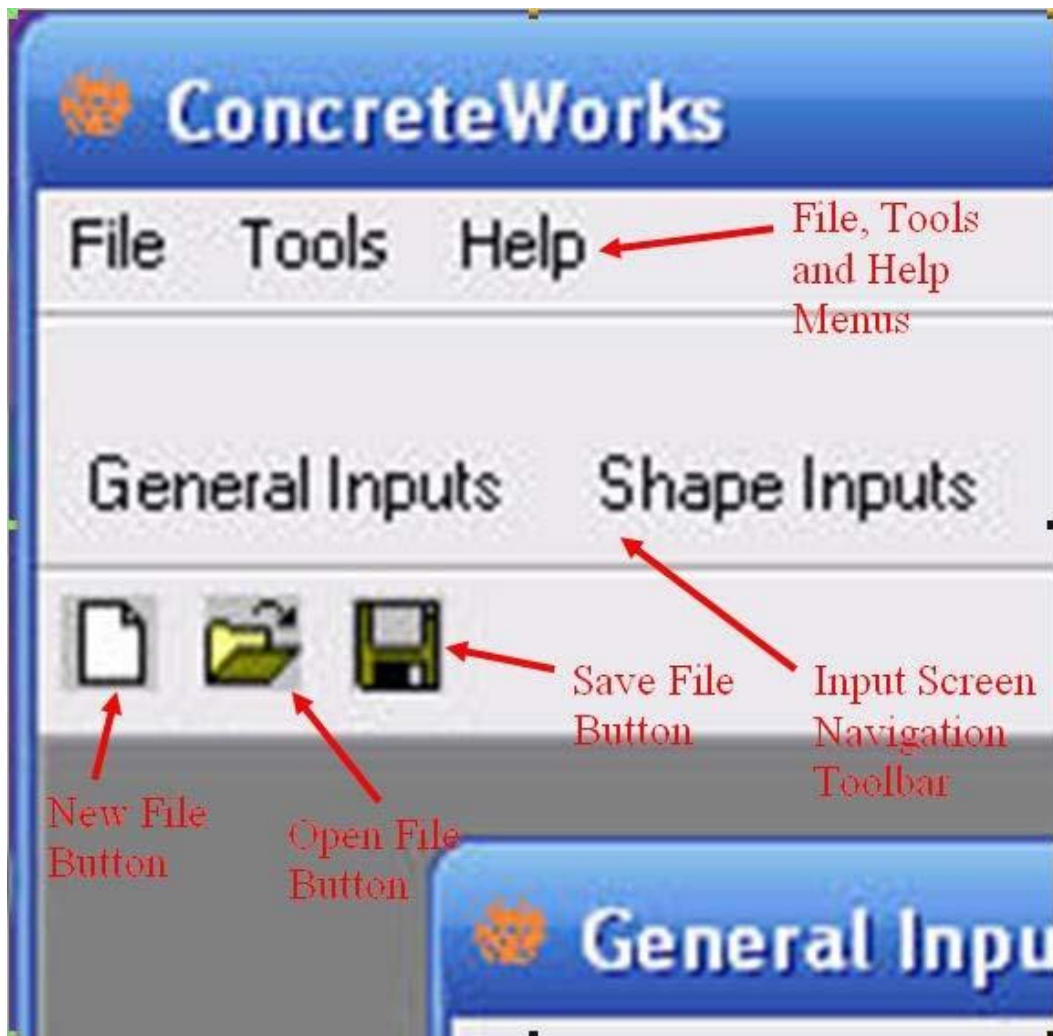

Figure 1 - Close-up view of toolbars and menus

There are also two methods of changing the current input/results screen in ConcreteWorks. The navigation toolbar found at the top of the program allows the user to quickly navigate between input/results screens. Each button, when clicked, displays the corresponding input/results screen. Clicking on the *Next* button displays the next chronological input screen. Clicking the *Back* button displays the previous screen shown. The navigation toolbar shows the order the screens are displayed.

For more information on the printing features found in the *File* menu, see Section 1.4.1. See Section 1.4.6 for more information on the *Tools* menu and Section 1.4.7 for more information on the *Help* menu.

1.2. Inputs

1.2.1. Member Type

When a new file is selected, the user is prompted to select the type of member to analyze. In ConcreteWorks v3.1.0, the user may select from four basic types of concrete members: mass concrete, bridge decks, pavements, or precast beams. The input screens available will depend on the type of member selected and will only be shown if needed. For example, the *Corrosion Inputs* screen is not available when the user selects the *Precast Concrete* member type because ConcreteWorks does not contain a chloride service life module for precast beams. This manual will explain the inputs for all member types; note that if the input is not applicable for a particular member type, it will simply not be shown in the software. Additionally, the *next* and *back* buttons will show the next input screen available in the same order as the order of inputs shown in the input screen navigation toolbar shown in Figure 1.

1.2.2. General Inputs

The basic model settings and project inputs are all done in the *General Inputs* screen, as seen in Figure 2. The *General Inputs* screen is the first screen shown after opening a new or saved file, which is why there's not a *Back* button shown. Changing the inputs in the *General Inputs* screen will fundamentally change other data entered later in the program. Changing the *placement date*, *analysis duration*, or *project location* will cause the weather data to change, even if maximum or minimum values have been entered earlier.
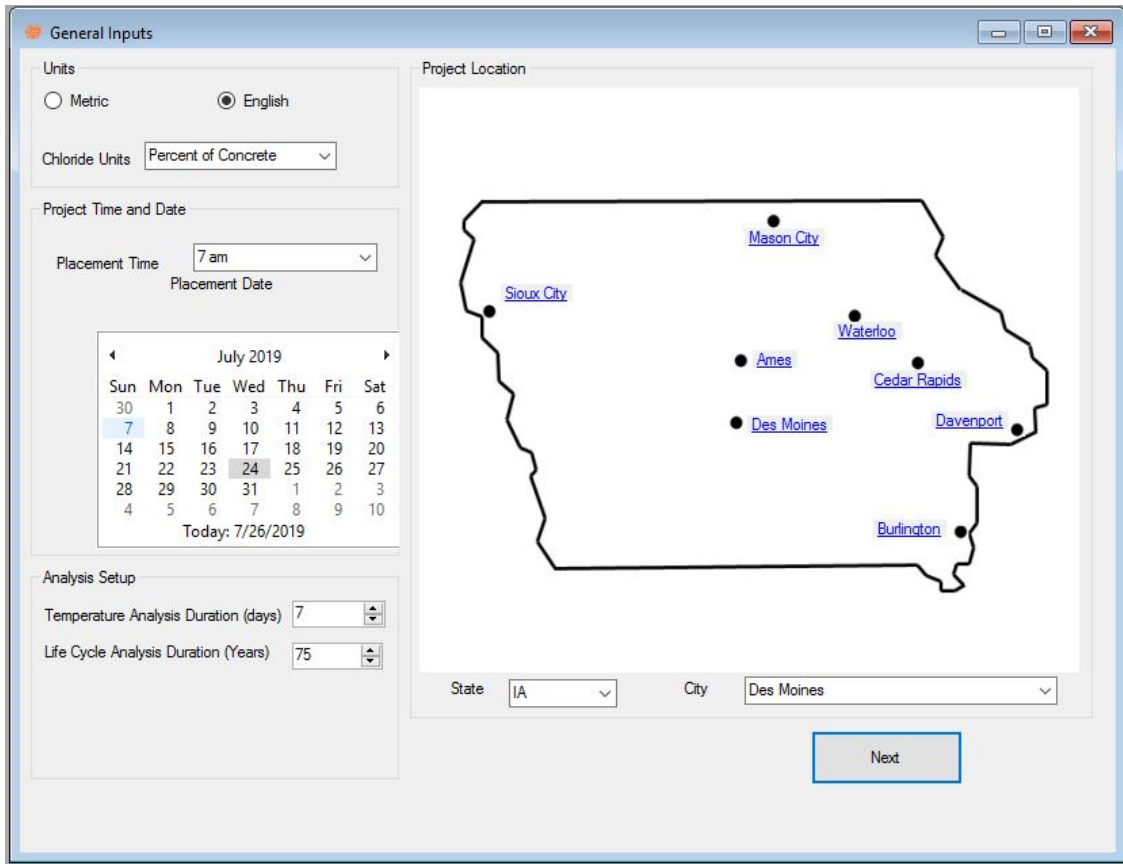
Figure 2 - General Inputs screen

Units

Many inputs in ConcreteWorks can be entered in either English units or Metric (S.I.) units. The English units' system is the default units system in ConcreteWorks. When the system of units is changed, the program will prompt the user to change all values or cancel to stay in the current unit system. If the user chooses to change the values entered, the program assumes that the user entered the correct values for the old unit system and will then multiply the entered values by the appropriate conversion factor for the new unit system. The *Chloride Units* input allows the user to select to perform the chloride service life calculations by % Chlorides by mass of concrete, or by mass per unit volume. The chloride surface concentration inputs in the *Corrosion Inputs* will be in the units chosen, as will the steel chloride threshold at corrosion initiation values, and the initial chloride concentration values.

Project Time and Date

The *Placement Time* box allows the user to enter the time concrete placement is started on the element being analyzed. If the cross section being analyzed is a horizontal cross section (such as a column), then the user should input the time concrete is placed at the particular cross section being analyzed. The default time is 7:00 a.m.

The *Placement Date* is entered by clicking on the number corresponding to the date of concrete placement. The month or year of placement can be changed by either clicking on the appropriate arrow or by clicking on the month or year. The default date is the current date.

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Accurate results in ConcreteWorks depend on the user entering the correct time and date. Even if the minimum and maximum weather data is entered later in the program, the correct date and time must still be entered. The shape of the weather data plots is extracted from 30-year average data. Because of the changing sunrise and sunset times, every day has fundamentally different shape of the weather data plot. Entering the correct maximum and minimum weather data later in the program will give the correct overall magnitude for the weather data plots but will not change the weather data's fundamental shape.

Analysis Setup

ConcreteWorks predicts the temperature development of a concrete cross section for the number of days selected under the *Analysis Duration* option. The default number of days is 7. The *Chloride Service Life Analysis Duration* input allows the user to select the number of years that are used to calculate the chloride ingress into the concrete. If the steel chloride threshold has not been exceeded during the time period selected for the *Chloride Service Life Analysis Duration*, then the results will show that the time to corrosion initiation will be greater than the *Chloride Service Life Analysis Duration*.

Project Location

Under the *Project Location* option, the user should select the closest city to the construction site that has a similar climate. Besides using the drop-down list of cities to select the project location, cities in the currently selected state can be selected by clicking on the city name in the city map. When installed, ConcreteWorks automatically installs weather data files for eight Iowa cities (as shown on the map on the *General Inputs* screen). The files are located in the same folder as the ConcreteWorks application. Weather files for states other than Iowa may be installed during the installation process. ConcreteWorks automatically detects all weather files located in the same folder as ConcreteWorks and adds them to the drop-down list of available cities. Caution: only genuine ConcreteWorks weather files can be recognized by ConcreteWorks. Other weather files may cause an error in the program.

1.2.3. Shape Inputs

ConcreteWorks can predict the temperature distribution for several types of mass concrete elements. All available concrete shapes available according to the type of concrete member selected are listed in the *Shape Inputs* screen.

Available Shapes

ConcreteWorks has the capability of predicting temperature development in six unique mass concrete member types, four types of bridge decks, and four precast beam shapes. ConcreteWorks also has a pavement temperature prediction built in, but because only one concrete pavement type is allowed, the *Shape Inputs* screen is not shown when pavement member types are selected. Figure 3 shows the mass concrete shapes available in the *Available Shapes* frame. Figure 3 shows the four types of bridge deck types available in the *Shape Inputs* screen, while Figure 4 shows the precast beam types available. When a shape is checked, a picture of the shape is shown to the right for confirmation. Once the desired shape is selected, proceed to the next screen.
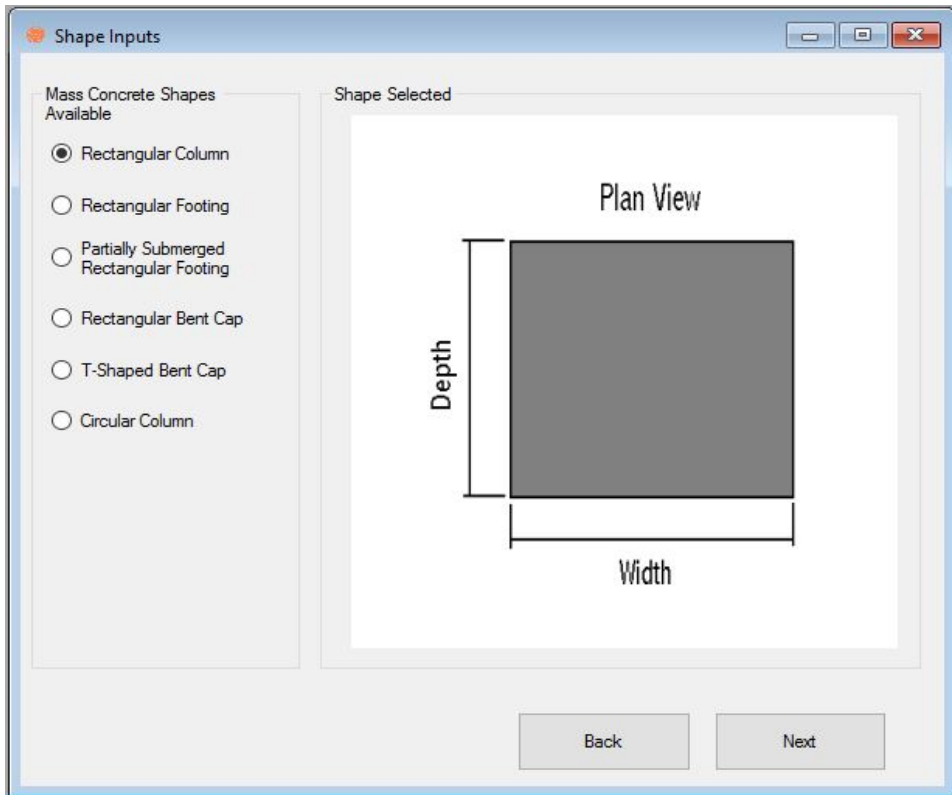
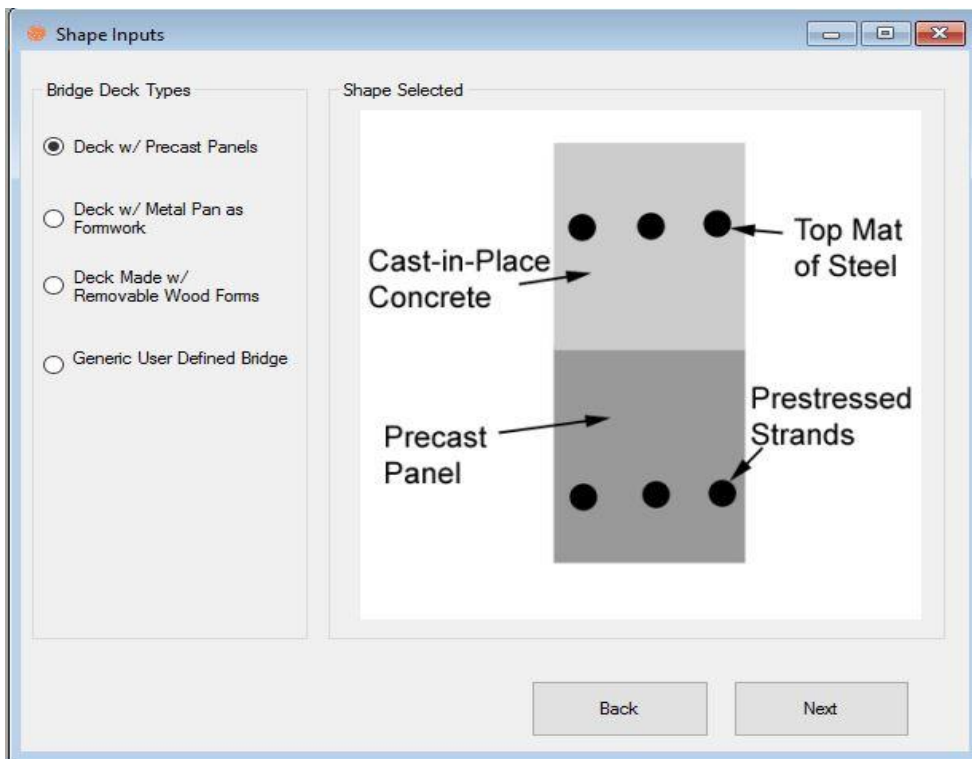*Figure 3 - Shape Inputs screen for mass concrete member types*

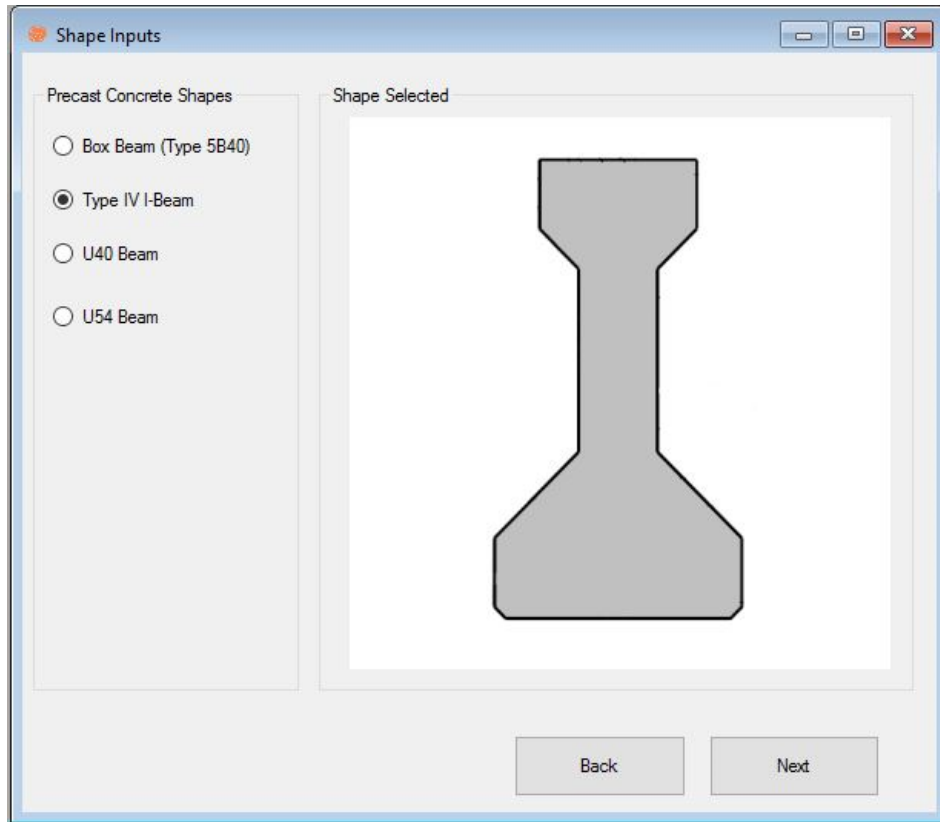Figure 4 - Shape Inputs screen for bridge deck member types

Figure 5 - Shape Inputs screen for precast beam member types

1.2.4. Member Dimensions

Each unique concrete cross section type will display a different picture and inputs on the *Member Dimensions* screen. All shapes, however, use the same basic format. Figure 6 shows the *Member Dimensions* screen for the Rectangular Column member.
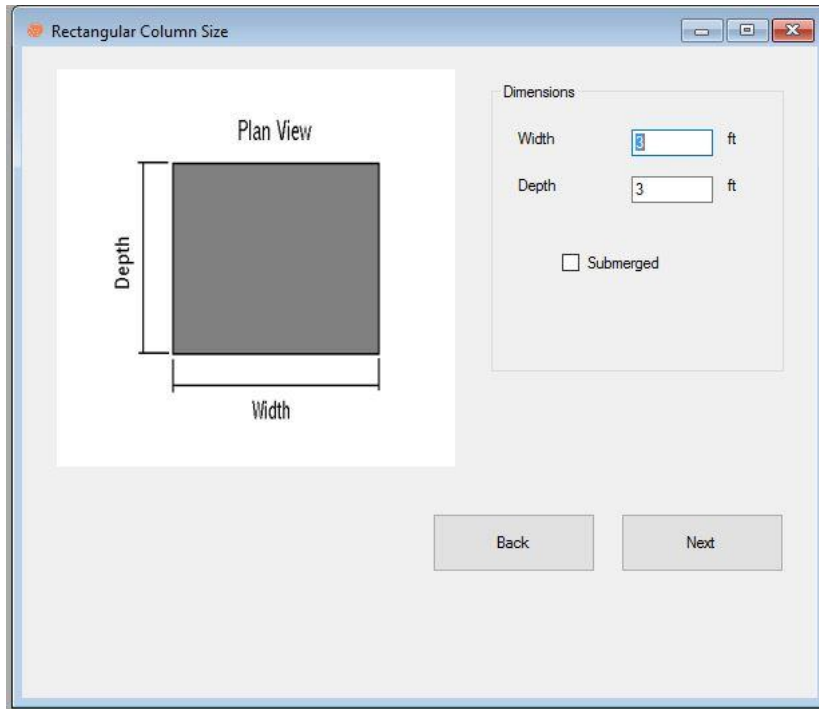
Figure 6 - Member Dimensions screen for the Rectangular Column element

Dimensions

Each shape will require the user to enter the member cross-sectional dimensions. All dimensions input will correspond to the same dimensions on the picture on the left side. Because the program's focus is on transportation-related concrete (bridges and pavements), ConcreteWorks limits the size of some member dimensions. The Rectangular Column, Rectangular Footing, Partially Submerged Rectangular Footing, and Rectangular Bent Cap have minimum dimensions of three feet each. The Circular Column has a minimum diameter of three feet. The T-Shaped Bent Cap has a minimum seat height of 9 in. and a minimum top width of 1.5 feet. The overall cap height must also be 1.5 feet taller than the seat, and the overall cap width must be 1.5 feet greater than the top width. If an invalid dimension is entered, an error will appear when the user attempts to calculate the member temperature development using the *Calculate Temperatures* button on the *Input Check* screen. Member dimension limits for decks and pavements are enforced by the numeric-up-down control used to input the dimension. The *Overall Deck Thickness* is limited to 14 in., while the *Precast Panel Thickness* is limited to 8 in. The *Pavement Thickness, Subbase 1 Thickness*, and *Subbase 2 Thickness* are all limited to 24 in.

Pavement analysis is broken up into different layers with different material properties, as shown in Figure 7. Users may select up to two types of subbase materials, in addition to the pavement and subgrade. The subgrade material is assumed to extend infinitely beneath the subbase layer(s). Pavement layer dimensions and types are not changed in ConcreteWorks until the user clicks on the *Re-Draw Pavement System* button. The figure to the right of the pavement dimensions inputs will then update, allowing the user to check the currently selected inputs.
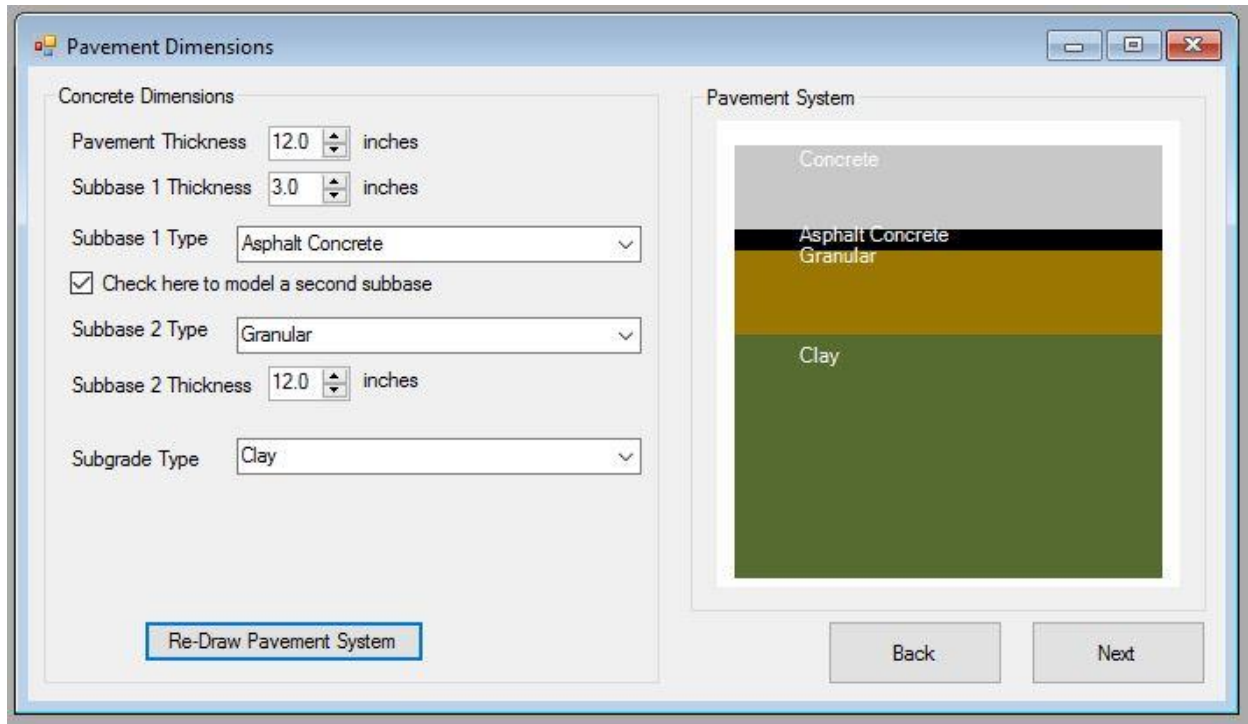
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Figure 7 - Pavement Dimensions Input screen

Submerged

Some of the available member types have the option of being submerged in water. This means that the cross section being modeled is completely immersed in water. One example of when the submerged option would be selected is when a column is placed in a lake or ocean.

Soil on the Sides

Some member types have the option of modeling soil on the sides of the member. This option is selected when earthwork is used instead of formwork. Figure 8 shows an example of the type of member that would use soil on the sides instead of formwork.

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Figure 8 - Example of a footing that would use the "soil on the sides" option

Cross Sections Analyzed

Temperature predictions are in some cases based on one- or two-dimensional cross sections of the member. When ConcreteWorks does not calculate the temperature distribution for a direction in a concrete member, the program assumes that there is no heat loss in that direction (i.e., perfectly insulated). For example, with the rectangular column, ConcreteWorks calculates the temperature profile of a horizontal cross section of the column. The program assumes that there is no heat loss from the top of the column to the air or from the bottom of the column to the footing. This assumption is a valid assumption for the vertical middle of the column and becomes less accurate towards the ends in the column.

When the user decides to analyze a rectangular footing or partially submerged rectangular footing in three dimensions, the temperature distribution in the footing is calculated for all three directions. Calculating the temperature in three dimensions can give slightly better results in some cases, but significantly increases the calculation run time. The user only has the option of calculating the footing temperature in three dimensions when the user does not select soil on the sides of the footing. When the user selects to calculate a two-dimensional cross section of the footing temperatures, as seen in Figure 9, the width side is used in calculations. The length dimension entered is then ignored. The user should enter the smaller dimension of the two horizontal footing dimensions in the width text box. The user can also opt for a one-dimensional analysis of the rectangular footing, as shown in Figure 9.
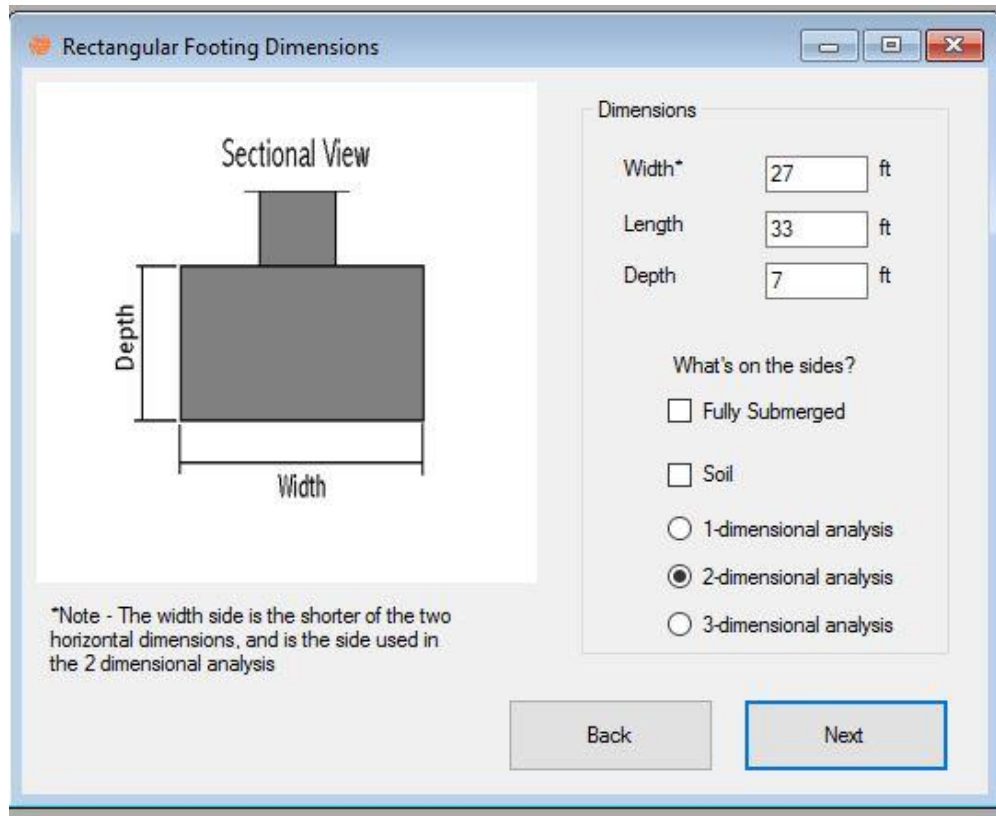
Figure 9 - Rectangular Footing screen with Two-Dimensional Analysis selected

Precast Panel Inputs

When the user selects a *Generic User Defined Bridge* on the *Shape Inputs* screen, then the user has the option of selecting to use a precast panel and the number of mats of steel. Figure 10 shows the *Bridge Deck Dimensions Inputs* screen when the *Generic User Defined Bridge* deck type is selected. When the user selects two mats of steel and a precast panel, the bottom mat of steel is assumed to be made of prestressed strands.
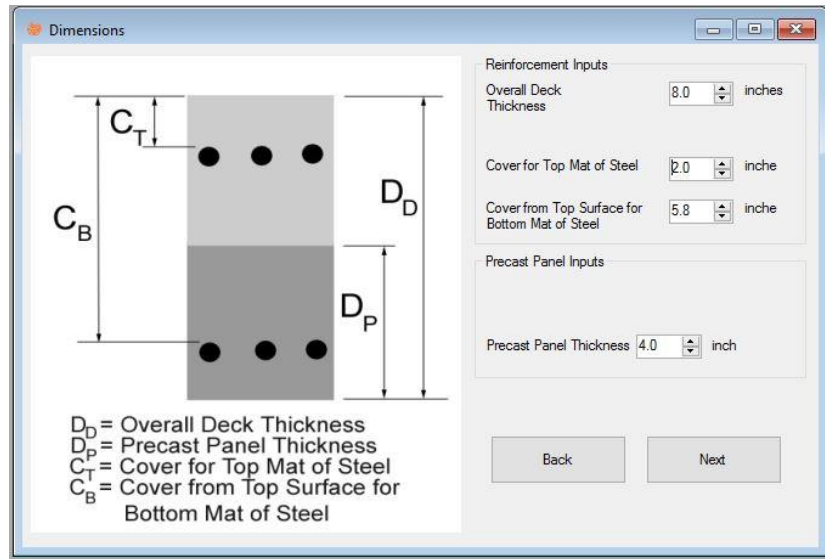
Figure 10 - Bridge Deck Dimensions Input screen when the Generic User Defined Bridge Deck Type is selected

1.2.5. Mixture Proportions

The *Mixture Proportions* screen is where the user inputs the concrete batch information, as seen in Figure 11. If blended cement is used, the user should enter the fly ash and cement quantities separately, as if they were added to the concrete completely separate.

Figure 11 - Mixture Proportion Inputs screen when a rectangular footing type is selected with mass concrete member

Mix Proportion Inputs

All information found in the *Mix Proportion Inputs* area must be inputted correctly for the program to generate a heat signature curve for the concrete. Mixture information is entered by the amount of weight of a particular material for every unit volume (pounds per cubic yard for English units, kilograms per cubic meter for SI units). The aggregate contents are entered assuming the aggregate is saturated surface dry (SSD). The water is entered based on total amount of free water available for hydration (aggregate moisture not absorbed + water/ice added).

Supplementary Cementing Materials

The *Supplementary Cementing Materials* (SCM) frame is where SCMs are input. To include an SCM in the batch, check the box corresponding to the particular SCM. Enter in the amount of SCM used in the batch. The program defaults the free lime content of the ASTM Class C fly ash to 29% and the ASTM Class F fly ash to 19%. These values can be changed if the free lime content of the fly ash used is known. To remove the SCM from the batch, simply uncheck the corresponding box or set the amount used to zero.

Calculated Mixture Proportions

The *Calculated Mixture Proportions* frame displays calculated mixture ratios based on the current values entered. The *Sacks of Cement*/volume quantity is based on the total number of 94-pound sacks of cementitious materials used in the batch (cement + SCMs) per cubic yard/meter. The number of *Gallons of water per sack/liters per sack* figure is the amount of water per sack of cementitious materials. The density of the water is assumed to be $1g/cm^3$ (62.43 lb/ft^3). The *Water/Cement Ratio* is equal to the water content entered divided by the cement content. The *Water/Cementitious Ratio* is equal to the water content entered divided by cementitious materials content.

Chemical Admixture Inputs

Chemical admixtures are entered by checking on the admixture. To simplify mixture proportion inputs, typical values of chemical admixture doses are assumed as shown in Table 5.

Bottom Panel Mixture Proportions

When a bridge deck member type with precast panels is selected, the user may change the bottom panel mixture proportions by clicking the button *Click to Change Bottom Panel Mixture Proportions*. When this button is clicked, an input screen similar to the *Mixture Proportion Inputs* screen is shown. Figure 12 shows the *Precast Panel Mixture Proportions Inputs* screen that is displayed. Here, the user may enter the mixture proportions used in the precast panel concrete. Although the precast panel is assumed to not generate any heat, the concrete diffusion coefficients used in the chloride service life analysis is determined from the concrete panel mixture proportions.
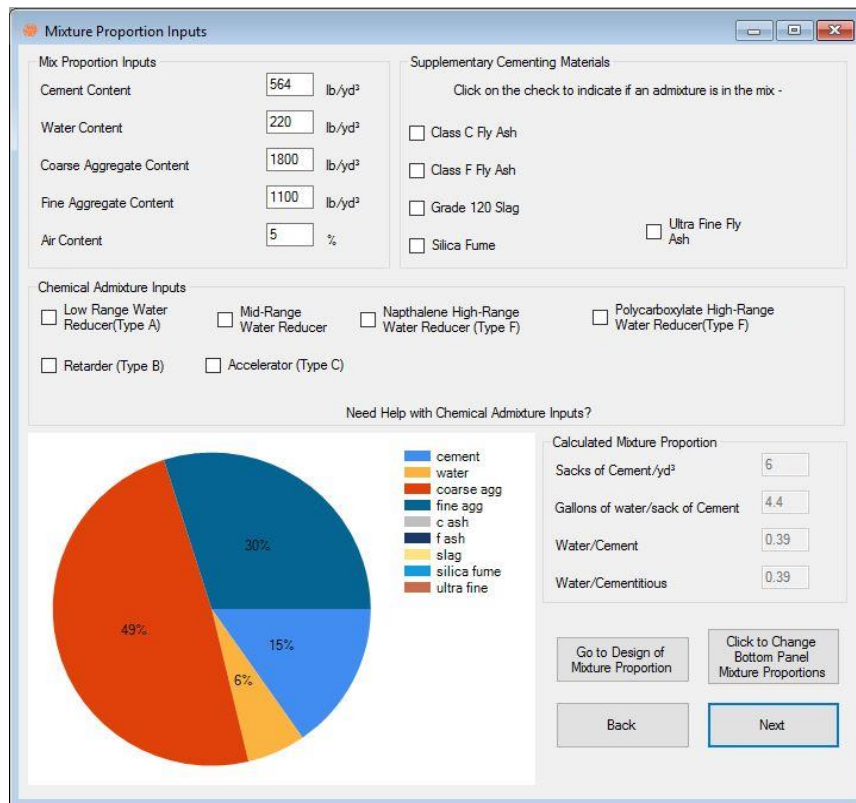

Figure 12 - Precast Panel Mixture Proportions Inputs screen

1.2.6. Concrete Mixture Proportioning

If the user needs help with the concrete mixture design and proportioning, the user may click on the *Go to Design of Mixture* Proportion button on the lower right corner of the *Mixture Proportions* screen, as seen in Figure 13. The *Design of Mixture Proportion* screen will appear, as seen in Figure 13. The *Design of Mixture Proportion* screen guides the user through the mixture proportioning steps as found in ACI 211 (1991) and NHI Course 15123 (Hover, 2003). For a more detailed presentation of the mixture proportioning procedure and limitations, please refer to ACI 211 (1991). The most important thing to remember about the mixture proportion calculations is that they are only designed to create the proportions for making and testing a trial batch. The calculations in the *Design of Mixture Proportions* screen can never be used as a substitute for local knowledge of material properties or for trial batches. This is designed to be a user-friendly tool as the first step in designing mixtures for field applications.

The *Cancel* button on the *Design of Mixture Proportion* screen sends the user back to the *Mix Proportions Inputs* screen without any changes being made to the material weights. The *OK* button sends the user back to the *Mixture Proportions Inputs* screen, changing the material weights to those shown in the *Final Volume Calculations*. When a chemical admixture is checked in the *Water Adjustment* tab, the admixture is then checked on the *Mix Proportions Inputs* screen. When the *High-Range Water Reducer (Type F)* box is checked in the *Design of Mixture Proportion* screen, ConcreteWorks assumes that a Naphthalene-based admixture is used.

Figure 13 - Design of Mixture Proportion screen—General Mix Information inputs

General Mix Information

The *General Mix Information* tab of the *Design of Mixture Proportion* screen displays all of the general material specifications. If not entered manually, the *w/cm ratio* is calculated from the *Target Strength* shown in the *Strength Requirement* frame, the air content, and any minimum w/cm ratios imposed by selecting a severe exposure condition from ACI 318-05 Tables 4.2.2 or 4.3.1.

The target strength is calculated by default on the specified f'_c increased by the percent increase in target strength value. Alternatively, the user may calculate the concrete target strength by checking the box for using the concrete standard deviation, and then entering the standard deviation.

Aggregate Properties

The *Aggregate Properties* tab allows the user to either input the aggregate properties or calculated some of the inputs needed from an aggregate sieve analysis. Figure 14 shows the *Aggregate Properties* tab. *Sieve Analysis Data* for each aggregate type used should be entered as percent passing. Additionally, the percent of each aggregate used should be input as percent of the coarse or fine aggregate used, not the total amount of aggregates used. When the *Update Agg. Properties* button is clicked, the combined *Coarse Aggregate Specific Gravity*, combined *Fine Aggregate Specific Gravity*, and *Maximum Size Aggregate* inputs are updated. Additionally, the aggregate gradation charts are updated when the *Update Agg. Properties* button is clicked. An error is generated when the user enters a percent passing value that is larger than that from a larger size sieve, when the sum of coarse aggregate percent used values does not equal 100 percent, or when the sum of fine aggregate percent used values does not equal 100 percent. When the user checks the button that states *Instead of ACI 211, optimize aggregate weights by:* the software will calculate the aggregate amounts to use by optimizing the selected aggregate gradation index selected instead of the ACI 211 methods.
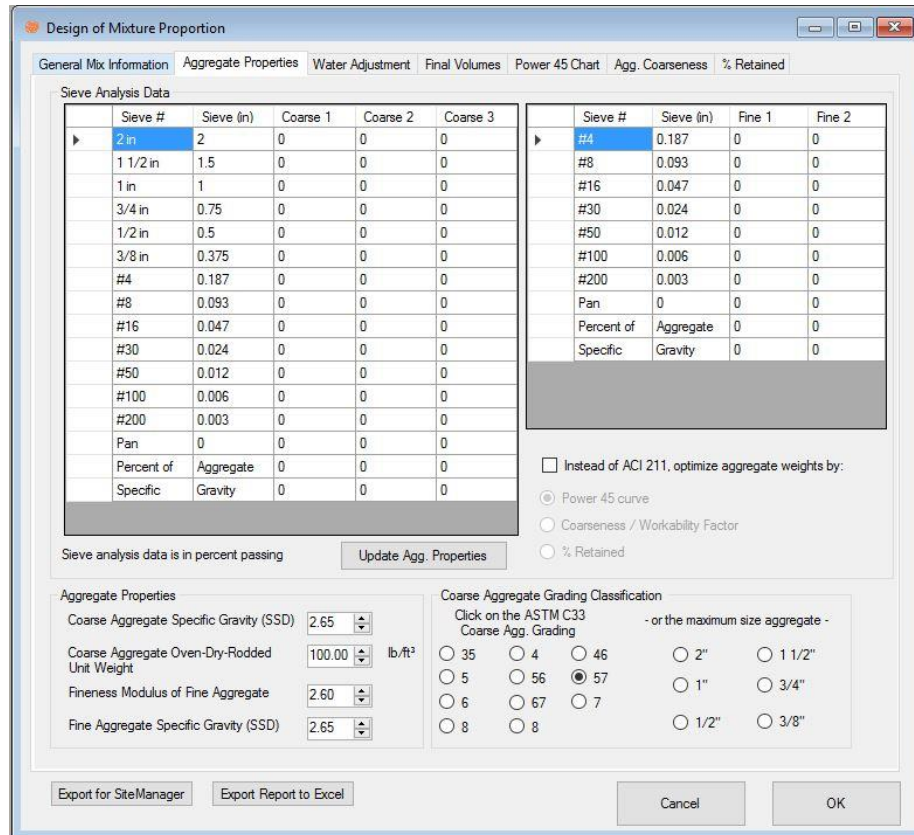
Figure 14 - Aggregate Properties tab on the Design of Mixture Proportions Inputs screen

Water Adjustment

The *Water Adjustment* tab contains tracking bars that let the user adjust the water requirements for the concrete by moving the tracking bar values, as seen in Figure 15. To use a water reducer, check the corresponding box on the *Water Adjustment* tab. Then move the track bar value to correspond to the water reduction gained from that particular admixture. The values used for maximum and minimum water reduction for all factors come from the NHI Course 15123 (Hover, 2003). A local knowledge of the water reduction properties for all the materials is extremely important. The quality of the concrete mixture designed will depend greatly on the accuracy of the inputs. Trial batches should always be made to verify the slump and strength properties of the concrete.

The *Adjusted Water Content* shown in the *Paste Content* frame is calculated based on the desired slump, the percent air, the aggregate gradation, and any water requirement adjustments made in the *Water Adjustment* tab (as described in Section 1.2.6). The cementitious material content is calculated by dividing the *Adjusted Water Content* by the *w/cm ratio*.
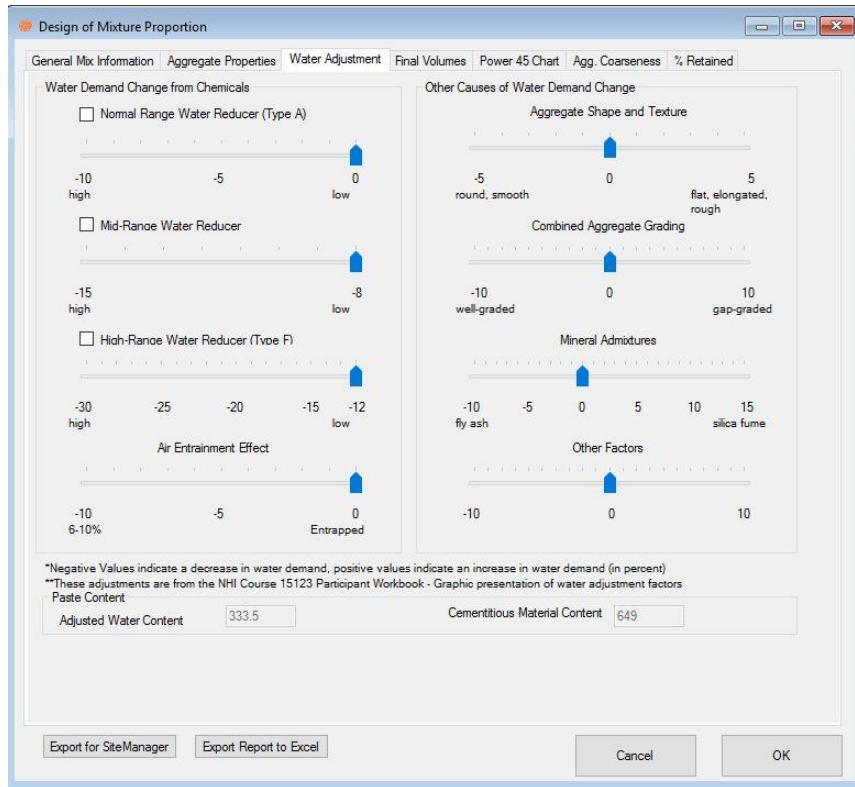
Figure 15 - Water Adjustment tab on the Design of Mixture Proportion screen

Final Volume Calculations

The final volume calculations for the concrete mixture are calculated based on the aggregate properties, cement content, adjusted water content, mineral admixture replacement, and air content. The batch weights per yard of concrete are shown in the *Final Weights* frame. The pie graph shows the percent of each material in the concrete mixture by volume. Figure 16 shows the *Final Volume Calculations* tab. When the total calculated paste content exceeds 30% by volume a warning appears to warn the user that the concrete mixture may be more susceptible to drying shrinkage. This does not preclude the use of the concrete mixture, but caution should be used for concrete members with a high surface area-to-volume ratio when exposed to low relative humidity.
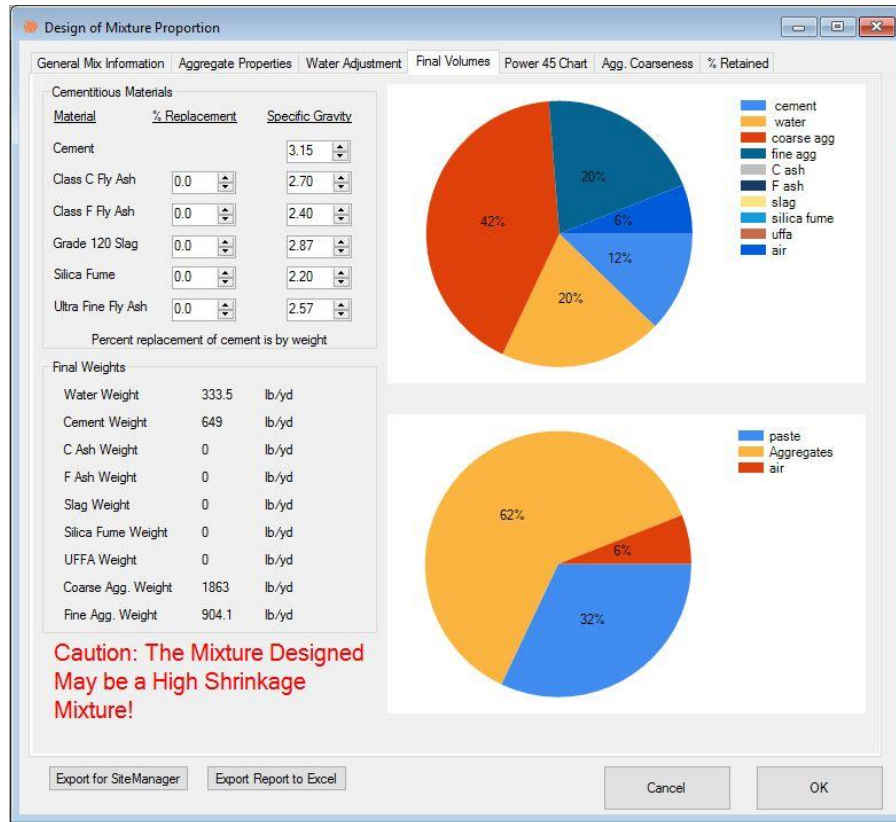
Figure 16 - Final Volume tab of the Design of Mixture Proportion screen

1.2.7. Material Properties

The material characteristics are entered in the *Material Properties* screen. Figure 17 shows the *Material Properties* screen. To manually override the default cement chemistry and hydration parameters, check the corresponding boxes and enter in the desired values, as seen in Figure 18.

Figure 17 - Material Properties screen

Figure 18 - Material Inputs screen with manual adjustment checkboxes checked

Cement Chemical/Physical Properties

The *Cement Chemical/Physical Properties* frame is where the cement type, composition, and physical properties are entered. To change the cement properties to those for the cement used, check the *Check to manually enter cement chemical/physical properties* box. If the user unchecks the *Check to manually enter cement chemical/physical properties box*, the cement properties revert back to the default values for the cement type selected. When the Bogue method is selected under the *Cement Analysis Method* found in the *Tools* menu, the Bogue values and oxide contents for the cement properties are displayed. If the Rietveld method is selected instead of the Bogue method, then the cement composition phases corresponding to that method is displayed. Actual cement properties estimated using the Bogue method can be found on mill sheets shipped with the cement.

Hydration Calculation Properties

Hydration Calculation Properties are based on equations developed as part of TxDOT research project 0-4563 and are described in Section 3.1.5. Different models that describe the Hydration Calculation Properties are used depending on whether the Bogue method of the Rietveld method is used to define the cement properties. If the user has performed a semi-adiabatic calorimetry test on the concrete mixture used, then the calculated hydration properties can be changed by checking the *Check to manually enter hydration properties* box. When the *Check to manually enter hydration properties* box is checked, the hydration parameters do not change when the mixture proportions is changed, or the cement type changes. The semi-adiabatic calorimetry test performed to determine hydration parameter equations for ConcreteWorks Version 3.1.0 came from mixes that used Iowa materials. If the concrete material properties deviate substantially from those used in Iowa, a semi-adiabatic calorimetry test should be performed to determine the hydration parameters.

Aggregate Factors

Choose the type of coarse and fine aggregates used in the concrete batch. Up to three coarse aggregates types can be blended, while up to two fine aggregate types may be used. The user may change the number of coarse aggregates blended by changing the number in the *# of Coarse Aggregate Types* drop-down menu, and the number of fine aggregates blended by changing the number in the *# of Fine Aggregate Types* drop-down menu. When more than one type of aggregate type is selected to be blended, additional corresponding drop-down menus will appear that prompt the user for the type of additional aggregate used. The coefficient of thermal expansion (CTE) and material thermal properties are calculated based on the mixture proportions and the coarse aggregate types. The CTE and material thermal properties may be input by the user if a hardened concrete CTE test, hardened concrete thermal conductivity test, or aggregate specific heat test is performed. The combined aggregate c_p value shown in Figure 18 is the C_a parameter shown in Equation 24. It is highly recommended that the user performs a hardened concrete CTE test on the concrete mixture to be used, as the thermal stresses calculated are very sensitive to the concrete CTE. When the checkbox *Check to Manually Enter the Concrete Coefficient of Thermal Expansion and Thermal Properties* is unchecked, the concrete CTE and thermal properties revert to default values as calculated according to the chosen aggregate types.

1.2.8. Mechanical Properties Inputs

The *Mechanical Properties Inputs* screen allows the user to input the type of maturity method used, the maturity-strength relationships, and the early age creep parameters as shown in Figure 19.

Figure 19 - Mechanical Properties inputs

Maturity Functions

The *Maturity Functions* frame allows the user to select between the Nurse-Saul method of maturity and the Equivalent Age method, both as described in ASTM C 1074 (2004). For the Nurse-Saul method, a reference temperature of 0°C is used when metric units are selected and 0°F is used as the reference temperature when English units are selected. If the user has a maturity curve already calculated for the given concrete mixture, the user may enter the *a* and *b* strength parameters according to the equation shown on the *Materials Inputs* screen. The *Check to calculate thermal stresses when temperatures are calculated* checkbox must be checked for the software to calculate the concrete member cracking probability failure classification. When thermal stresses are to be calculated, the equivalent age maturity method must be used. The elastic modulus and splitting tensile strength equations are calculated from the concrete compressive strength fit parameters entered. At a minimum, the compressive strength/maturity relationship must be entered for the concrete mixture proportions and materials used. The accuracy of the thermal cracking probability analysis increases when the elastic modulus and splitting tensile strength are measured and input in the software.

Early Age Creep Parameters

The concrete early age creep is calculated using the Modified Linear Logarithmic Model (MMLM). The early age creep parameters for the MLLM are calculated from the mixture proportions and material properties entered. Different equations are used, depending on whether the Bogue method or the Rietveld method is selected.

1.2.9. Construction Inputs

The *Construction Inputs* screen is where the construction-related options are entered. Each type of concrete member will have different construction options to choose from. ConcreteWorks will automatically display the needed inputs based on the other options selected by the user, such as member type or whether the member is submerged. Do not be alarmed if a particular set of inputs does not appear with the particular choices made. If you change the member shape or submerged status, the available construction inputs will change. Even small mistakes, such as the form type, or blanket insulation, can yield dramatically different results. Figure 20 shows the *Construction Inputs* screen for a rectangular column.

Figure 20 - Construction Inputs screen for a rectangular column

Concrete Placement Temperature

The *Estimated Placement Temperature* is the temperature of the concrete when it arrives on the jobsite. The concrete placement temperature can be calculated three ways.

The first way is to click on the *Calculate* button. After it is clicked, the *Raw Material Temperature Inputs* screen will pop up. The temperature of the cementitious materials, aggregates, and water must be entered. Aggregate moisture contents and absorptions must also be entered. Optionally, ice may be entered if it is used in the batch. The *OK* button will not work until all of the required information is entered. After all of the required information is entered and the *OK* button is clicked, the calculated placement temperature will be displayed in the *Estimated Placement Temperature* box. ConcreteWorks uses the ACI 305 model for predicting the fresh concrete temperature (ACI 305R, 1991). When the *Mixture Proportion* inputs are changed, the predicted fresh concrete temperature will also change, if all of the required inputs are entered in the *Raw Material Temperature Inputs* screen. Note: if all of the required inputs in the *Mixture Proportion Inputs* screen are not entered, ConcreteWorks will not be able to calculate the fresh concrete temperature.

The second way is to calculate the concrete placement temperature from the ambient temperature. In this method, the concrete fresh temperature is estimated as the ambient temperature at the time of placement.

The third way to enter the concrete placement temperature is to check the *Check here to manually enter Fresh Concrete Placement Temperature* box. After the box has been checked, the user may enter the concrete placement temperature in the *Estimated Placement Temperature* box. If the *Check here to manually enter Fresh Concrete Placement Temperature* box is checked, the value in the *Estimated Placement Temperature* box will only change when manually entered by the user.

Formwork

The *Concrete age at Form Removal* input requires the user to input the concrete age when formwork is removed (at the cross section being analyzed), starting from the time the concrete was first mixed. The form type and form color must also be input in their corresponding boxes.

Surrounding Temperature

If the element selected is a footing or the element is submerged, the *Construction Inputs* screen will have inputs for the soil temperature and water temperature. The soil temperature refers to the average soil temperature for the time being modeled. A good estimate of the soil temperature for most footings is the average of the maximum and minimum ambient temperatures during the time period in question. The water temperature refers to the temperature of the water surrounding a concrete element. For example, if a column was being placed in a lake, the user would enter the average lake water temperature for that time period.

Curing Methods Applied after Forms Are Stripped

The *After Forms Are Stripped* area asks the user to input what kind of curing methods are applied to the member after the forms are removed. ConcreteWorks requires the user to enter a

time in the box *Time between form removal and curing method applied* if a cure method is checked. If the user enters a delay time, but does not check a cure method box, ConcreteWorks assumes that no cure methods are used. The user cannot check both the *Black Plastic* option and the *White or Clear Plastic* option at the same time. If for some reason, both types of plastic are used in construction, the user should check the type of plastic used as the outside layer. All curing methods applied after forms are stripped are assumed to remain on the concrete member until the end of the analysis duration. The default time between removing forms and applying the cure method is one hour.

Footing Inputs

When a footing is selected as the member type, the *Footing Inputs* frame becomes visible on the *Construction Inputs* screen, as seen in Figure 21. The input *Type of footing subbase* asks the user to select the type of soil or rock on which the footing is built. If a plastic sheet is also used in curing, the user should select which color plastic is used. If both types of plastic are used, the user should select the color of the plastic placed on top. The input *Concrete age when cure blanket is placed* is the number of hours between concrete placement time and when cure methods are applied (the cure methods applied to the top before form removal). This input allows the concrete to set before placing the cure blankets on top of the footing.

If the sides of the footing are shaded from the sun because of scaffolding or the ground, the user should check the input *Footing Sides Shaded*.
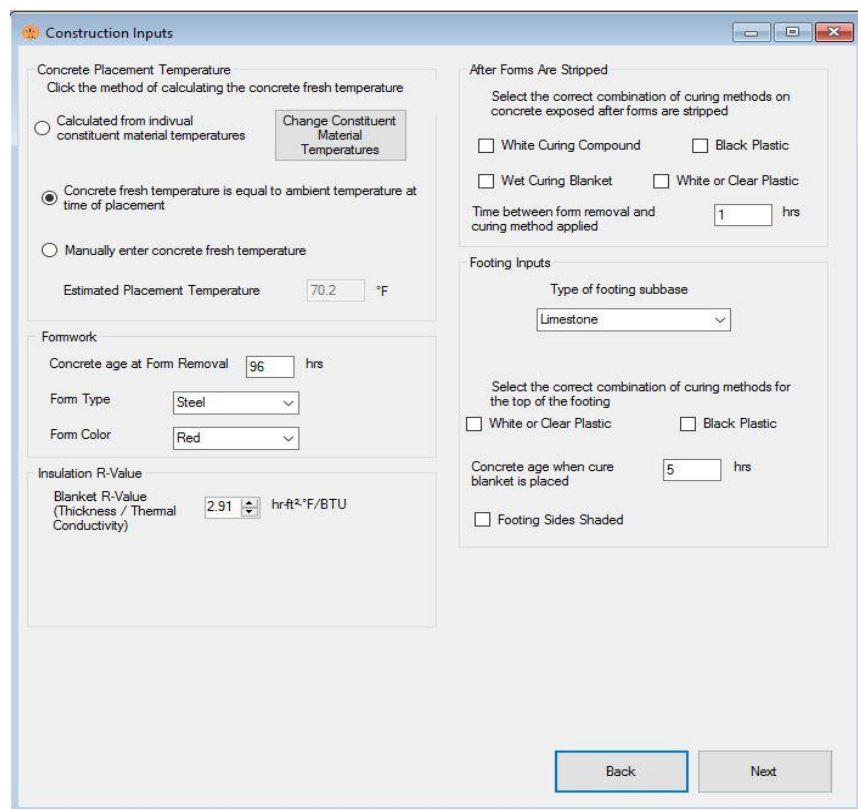

Figure 21 - Construction Inputs screen shown when the rectangular footing member shape is chosen

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Bent Cap Inputs

The user must select which type of form is used for the bottom of the bent cap. This allows the user to use different forms for the sides and bottom of a bent cap. For example, the user could select steel forms for the sides of the bent cap, and wood for the bottom. If the user selects *Precast Concrete* for the bottom form of the cap, the *Precast Concrete Section Thickness* input box appears, as seen in Figure 22. The default cap bottom form type is steel. The default precast concrete thickness is two feet. The *Concrete age when cure blanket is placed* is the number of hours between concrete placement time and when cure methods are applied (the cure methods applied to the top before form removal). This input allows the concrete to set before placing the cure blankets on top of the bent cap. If a plastic is used on top of the cure blanket before form removal, the user should select which color plastic is used. If more than one color of plastic is used, the user should select the plastic placed on top.

Figure 22 - Construction Inputs screen for a rectangular bent cap with pre-cast concrete selected as the bottom form

Bridge Deck Inputs

ConcreteWorks assumes that a cure blanket is used on top of bridge decks. The user may additionally select to use a layer of plastic on top of blanket, the time the blanket is placed, and the concrete age when the cure blanket is removed. If wood forms are selected for the bridge deck, the user may additionally specify the concrete age at the wood form removal, as shown in Figure 23.

Figure 23 - Bridge Deck inputs when wood forms are selected

Precast Concrete Construction Inputs

Precast concrete members allow the user to specify a tarp or blanket to be used on the member sides. When a tarp or blanket is used on the sides of the precast beam, the same R-value is used for the blanket on the top and sides of the beam. The software also allows the user to select the subbase underneath the precast member, and the age when the cure method is started. The cure method is assumed to end when the forms are removed.

Pavement Construction Inputs

ConcreteWorks asks the user to input the type of cure method used as shown in Figure 24. The other pavement curing options depends on the curing method selected, and may ask the user

for the application rate, the time of cure method application and removal, and the cure method color.

Figure 24 - Pavement Construction inputs

Blanket Insulation R-Value

The *Blanket Insulation R-Value* frame allows the user to select the R-Value of all cure blankets used during the concrete member construction. The R-Value is a measure of the blanket's thermal insulation. A high R-Value indicates a good insulator. Recommended R-values are 3 in.^{2}hr-F/BTU for a thick, good quality cure blanket and 1 in.^{2}-hr-F/BTU for burlap or worn cure blankets.

Form Liners

The *Form Liners* frame asks the user to input which sides of the member use form liners. The width and depth sides correspond to the width and depth sides input in the *Member Dimensions* screen. ConcreteWorks assumes that the form liners are solid rubber reusable form liners (such as the Symons brand Elasto-Tex™[2] form liner).

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[2] The Elasto-Tex™ trademark belongs to the Symons Co.

1.2.10. Environment Inputs

The *Environment Inputs* screen is where all weather inputs are entered. All weather inputs are entered in tables that function similar to cells in a spreadsheet. ConcreteWorks requires that the user enter one more day than the number of days selected for analysis. The first day entered is the day selected as for the project date. Default values are the average 30-year weather data for the days selected for each individual city. When the user changes the *Placement Date*, *Temperature Analysis Duration*, or project location on the *General Inputs* screen, the environment inputs are automatically updated to the 30-year average values. The environmental inputs will always be updated, even if the user checks the boxes to input maximum and minimum weather values manually. Care should be taken to manually input environment values last. Clicking on the table headings will sort the table by the values of the column clicked on. The overall data will not be affected by sorting the data.

Temperature

The maximum and minimum temperature for each day is shown in the table on the *Temperature* tab. Default values can be overridden by checking the *Check to manually enter temperature data* input. Next, click on the table cell desired, and change the maximum or minimum value. Figure 25 shows the *Environment Inputs* screen with the *Temperature* tab selected.
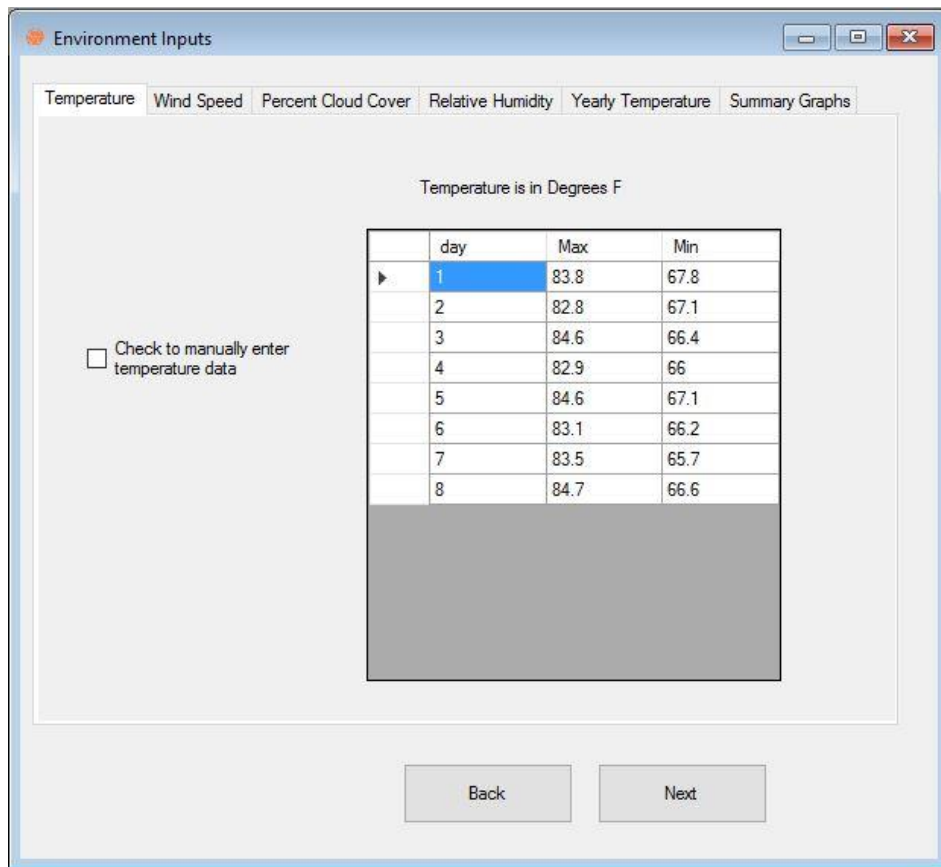
Figure 25 - Temperature tab on the Environment Inputs screen

Relative Humidity

The maximum and minimum relative humidity for each day are shown in the table on the *Relative Humidity* tab. Default values can be overridden by checking the *Check to manually* enter humidity data box. Next, click on the table cell desired, and change the maximum or minimum value.

Percent Cloud Cover

Average daily cloud cover value for each day is shown in the table on the *Percent Cloud Cover* tab. Default values can be overridden by checking the *Check to manually enter cloud cover data* box. Next, click on the table cell desired, and change the average cloud cover value. Enter cloud cover according to the scale shown. A zero-cloud cover value is entered for sunny conditions, 50 for partly cloudy, and 100 for overcast. Figure 26 shows the *Environment Inputs* screen with the *Percent Cloud Cover* tab selected.
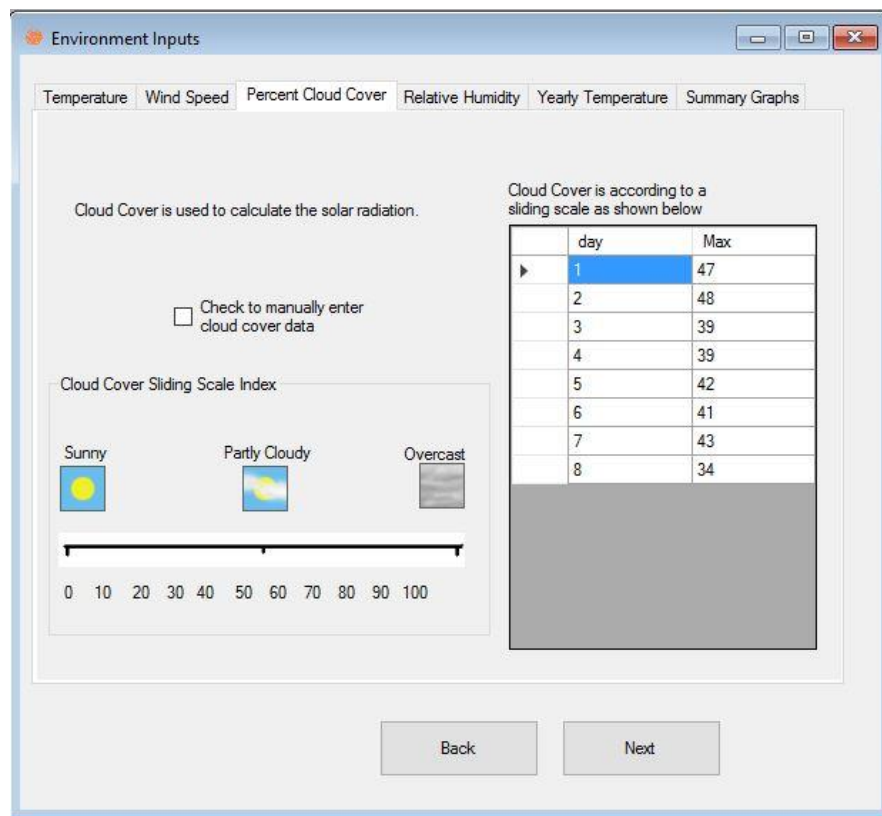
Figure 26 - Percent Cloud Cover tab on the Environment Inputs screen

Wind Speed

Maximum wind speed value for each day is shown in the table on the *Wind Speed* tab. Default values can be overridden by checking the *Check to manually enter wind speed data* box. Next, simply click on the table cell desired, and change the maximum wind speed value.

Yearly Temperature

The yearly temperature profile is calculated based on the number of temperature points per year selected as shown in Figure 27. Additionally, under the input *Temperature Value to Use*, users can select to use the average temperature values, the average temperature plus one standard deviation, or the average plus two standard deviations. The yearly temperature profile is used in calculating the chloride service life. The estimated chloride service life is not very sensitive to the number of data point per year selected but is moderately affected by using the average temperature plus one or two standard deviations.

Figure 27 - Yearly Temperature inputs

Summary Graphs

The *Summary Graphs* tab can display the updated weather data on a graph. All plots start at 1:00 a.m. on the project date selected. The *Temperature* button shows a plot of temperature data with time. The *Humidity* button displays the relative humidity data with time. The *Wind Speed* tab shows a plot of wind speed with time. The *Solar Radiation* tab shows a plot of solar radiation with time. The solar radiation values are calculated based on the cloud cover data and relative humidity data. Figure 28 shows the *Environment Inputs* screen with the *Summary Graphs* tab selected. The graph shown in Figure 28 is a plot of the temperature.
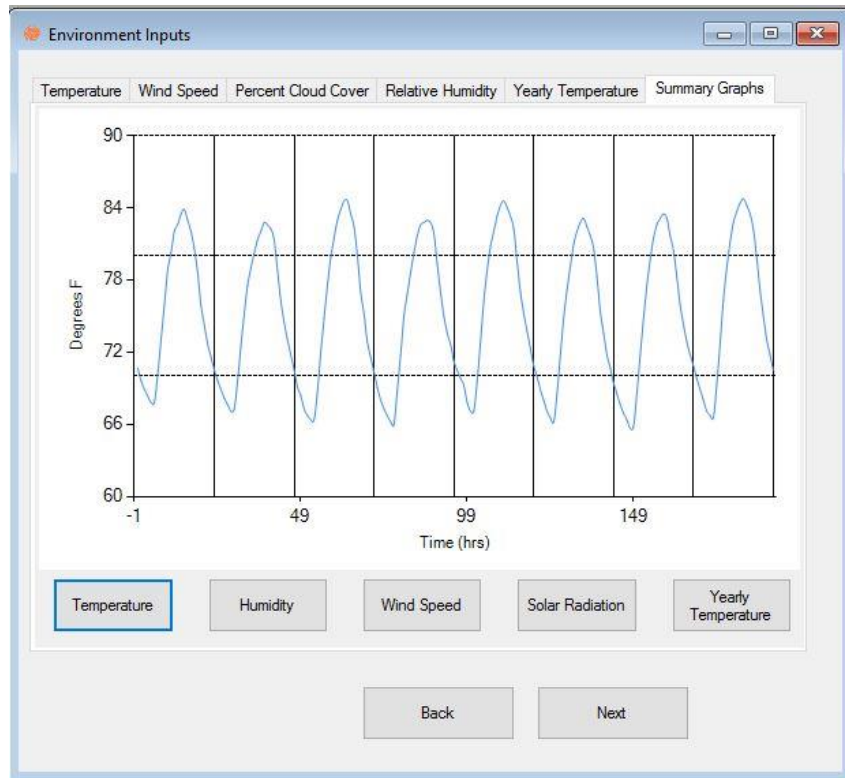
Figure 28 - Summary Graphs tab on the Environment Inputs screen (the temperature graph is currently displayed)

1.2.11. Input Check

The *Input Check* screen shows the values that have been entered, providing the user an opportunity to catch any mistakes made in the inputs section of ConcreteWorks. Anytime a user enters a character not allowed, ConcreteWorks assumes the value of the input to be zero. For example, if the user types "78u" on the *Cement Content* input in the *Mixture Proportion Inputs* screen, the *Input Check* screen would show that the cement content is "0". Figure 29 shows the *Input Check* screen. Notice the default values are highlighted green, and the questionable values are highlighted red.
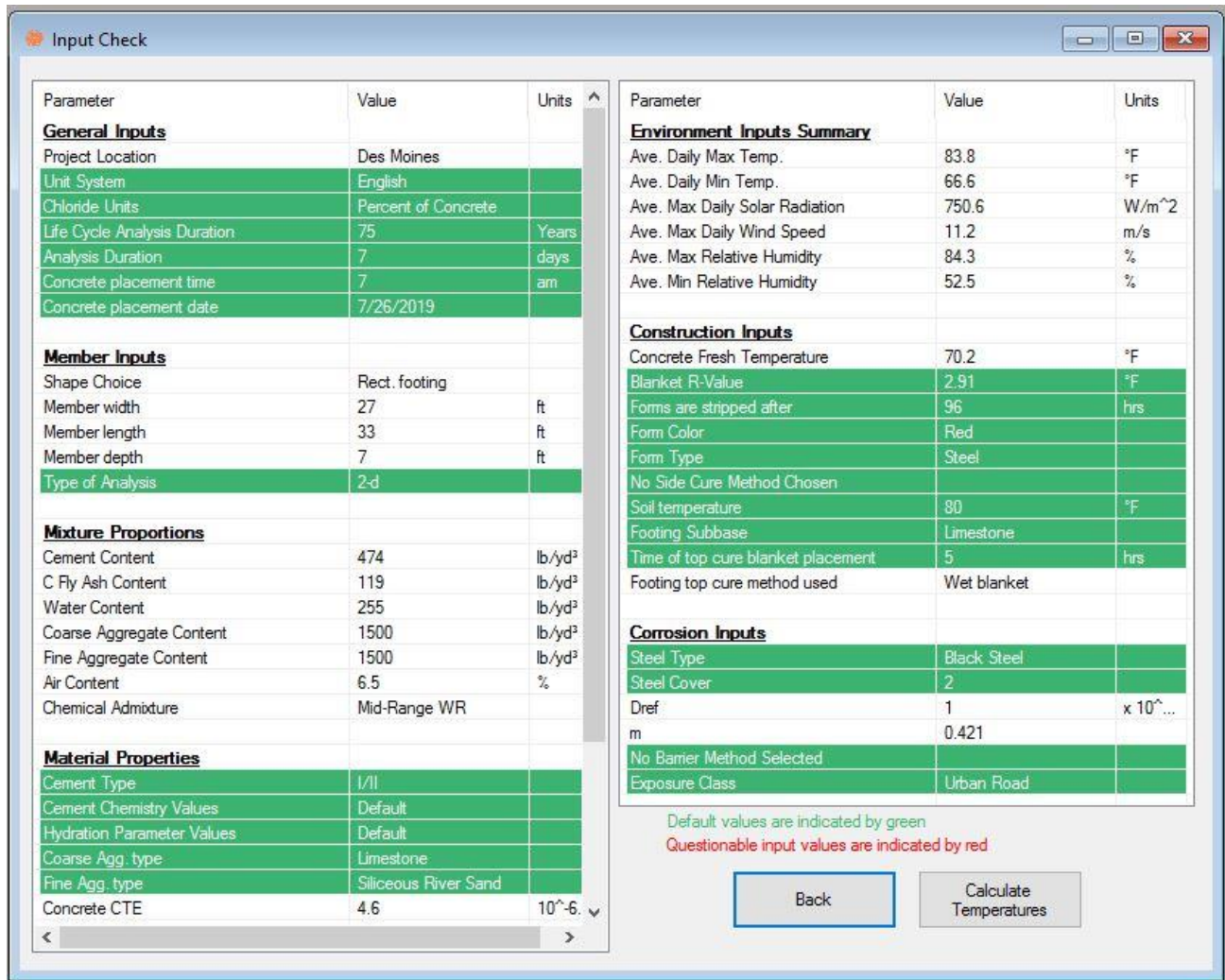
Figure 29 - Input Check screen

Default Check

Anytime the user chooses to use the default program value for an input, the *Input Check* screen will highlight that value in green. This feature makes it easy for the user to see how many entries the user actually made.

Questionable Values

Anytime the user enters a value that the program deems questionable, ConcreteWorks highlights that value red. Just because ConcreteWorks deemed the value questionable does not always mean that the program will not calculate temperature profiles for the element. A red value simply means that the user should check to make sure that the value is indeed what the user wanted. Caution: questionable values can (but not always) cause instability in ConcreteWorks or give unrealistic results. This feature makes it easy for the user to quickly scan the *Input Check* screen for common mistakes in entering data.

Table 1 shows which values are considered questionable by ConcreteWorks.

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Table 1 - Values deemed questionable by ConcreteWorks

Input	If the input is less than this value	If the input is greater than this value
Rectangular Column Width or Depth	3'	30'
Rectangular Footing Width, Length	3'	80'
Rectangular Footing Depth	3'	30'
Rectangular Bent Cap Width or Depth	3'	30'
T-Shaped Bent Cap Width	3'	15'
T-Shaped Bent Cap Height	3'	15'
Circular Column Diameter	3'	15'
Cement Content	100#	1200#
Water Content	100#	1200#
Coarse Aggregate Content	100#	4000#
Fine Aggregate Content	100#	4000#
Air Content	0%	10%
Class C Fly Ash Content	0#	1200#
Class C Fly Ash CaO	20%	30%
Class F Fly Ash Content	0#	1200#
Class F Fly Ash CaO	0%	20%
Slag Content	0#	1200#
Silica Fume Content	0#	1200#
Ultra-Fine Fly Ash	0#	1200#
Any Bogue Compound Content	0%	100%
Any Bogue Compound that does not meet ASTM C 150		
C_3A	1%	
Blaine Fineness	280(m^2/kg)	1000(m^2/kg)
Alkali Content	0%	100%
Fresh Concrete Placement Temperature	32°F	212°F
PCC age at form removal	0 hrs	
Delay between removing forms and cure method application	0	
Hydration Parameter alpha	0	1

1.3. Results

1.3.1. Results Summary

After clicking the *Calculate Temperatures* button on the *Input Check* screen, ConcreteWorks will begin performing model calculations for the member type selected. A progress bar will appear in the lower left corner of the *Results* screen, showing the calculations' progress. If a serious error was made in entering an input, a message box will appear describing the error. The *Results* screen has a different heading, depending on the type of member shape chosen.

Mixture Checks

The *Mix Checks* tab shows a summary table of the calculated results, as seen in Figure 30. The first section in the *Mix Checks* table states the set of specifications used to check the calculated results (for example, the IADOT 2018 specifications), the maximum temperature in the concrete member during the analysis period, the maximum temperature difference at time *t* anywhere in the concrete member, and the original concrete materials CO_2 emissions. The second section in the *Mix Checks* table tells the user the time to corrosion initiation and damage estimated in the concrete member. The last section gives the cracking risk classification. A low or moderate cracking risk classification does not guarantee that the structural member will be free of cracks. A low cracking risk classification only indicates that the probability of cracking is lower than if the concrete cracking risk classification were moderate, high, or very high. Any classification, including the low cracking risk classification, includes some chance that cracking will occur. When the IADOT 2018 specification is selected, the maximum temperature difference line in the *Mix Checks* table will be highlighted red if the value exceeds 20°F in the first 24 hours, 30°F in from 24-48 hours, 40°F in from 48-72 hours, and 50°F after 72 hours. The maximum temperature in the member line will be highlighted if the value exceeds 160°F.
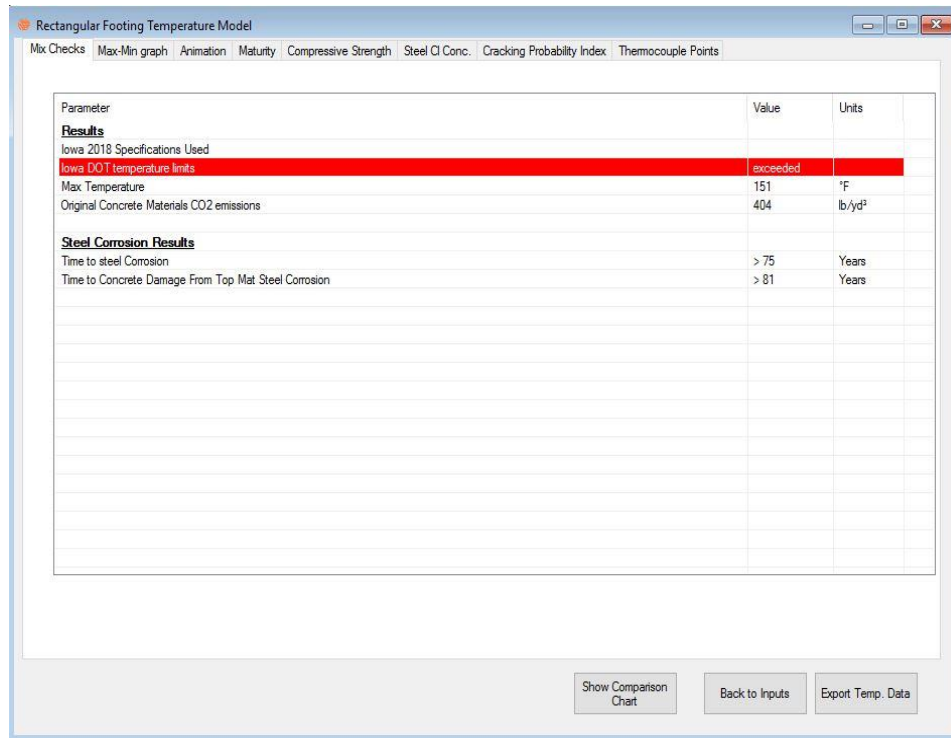
Figure 30 - Mix Checks tab shown on the Rectangular Footing Temperature Model screen

Max-Min Graph

The *Max-Min Graph* tab shows the user a graph of the important calculated values with time, as seen in Figure 31. The values shown are the maximum temperature anywhere in the concrete member at each point in time, the minimum temperature anywhere in the concrete member at each point in time, the maximum temperature difference in the concrete member at each point in time, and the ambient temperature. Also shown in the graph is the IADOT 2018 temperature differential limits for evaluation purpose.
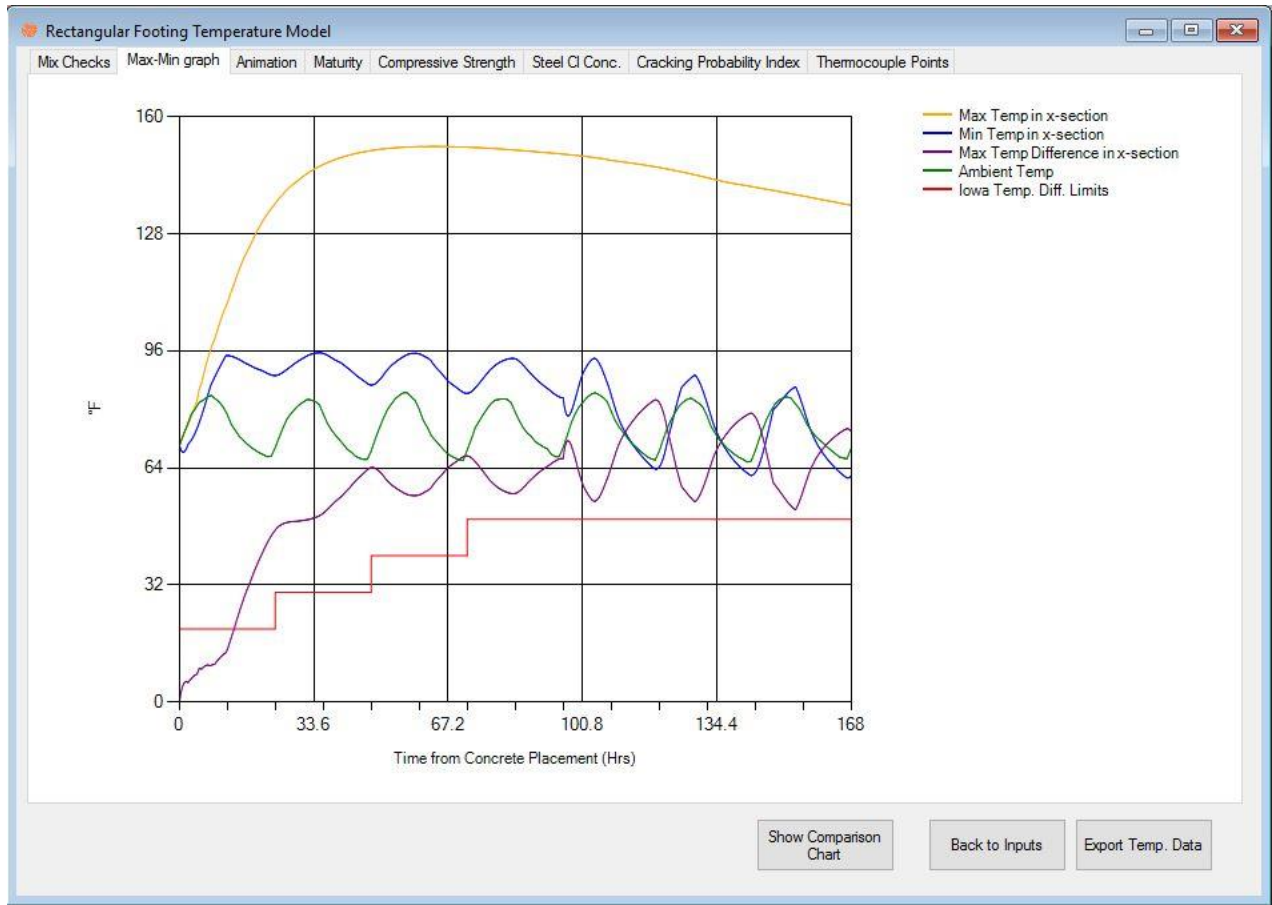
Figure 31 - Max-Min Graph tab as shown on the Rectangular Column Temperature Model screen

Maturity

The *Maturity* tab contains a graph that shows the calculated maximum, minimum, and maximum maturity difference for the concrete member, as seen in Figure 32. The maturity is calculated from the strength parameters chosen on the *Material Inputs* screen (see Section 1.2.8). The calculated maturity is only an estimate, and only applies when the maturity parameters entered are from same concrete mixture as the one entered.

Figure 32 - Maturity tab as shown on the Rectangular Column Temperature Model screen

Compressive Strength

The *Compressive Strength* tab shows the maximum compressive strength, minimum concrete strength, and the average compressive strength of the concrete member, as seen in Figure 33. The average compressive strength is a weighted average of the compressive strength in the member. This means that the compressive strength of the concrete member is integrated, and then divided by the total area. The compressive strength is calculated using the calculated concrete temperature, the calculated concrete maturity, and the compressive strength parameters entered on the *Mechanical Properties Input* screen. If the user does not enter the compressive strength parameters in the *Mechanical Properties Input* screen, the concrete compressive strength is not calculated. The compressive strength graph on the *Compressive Strength* tab is then not visible.
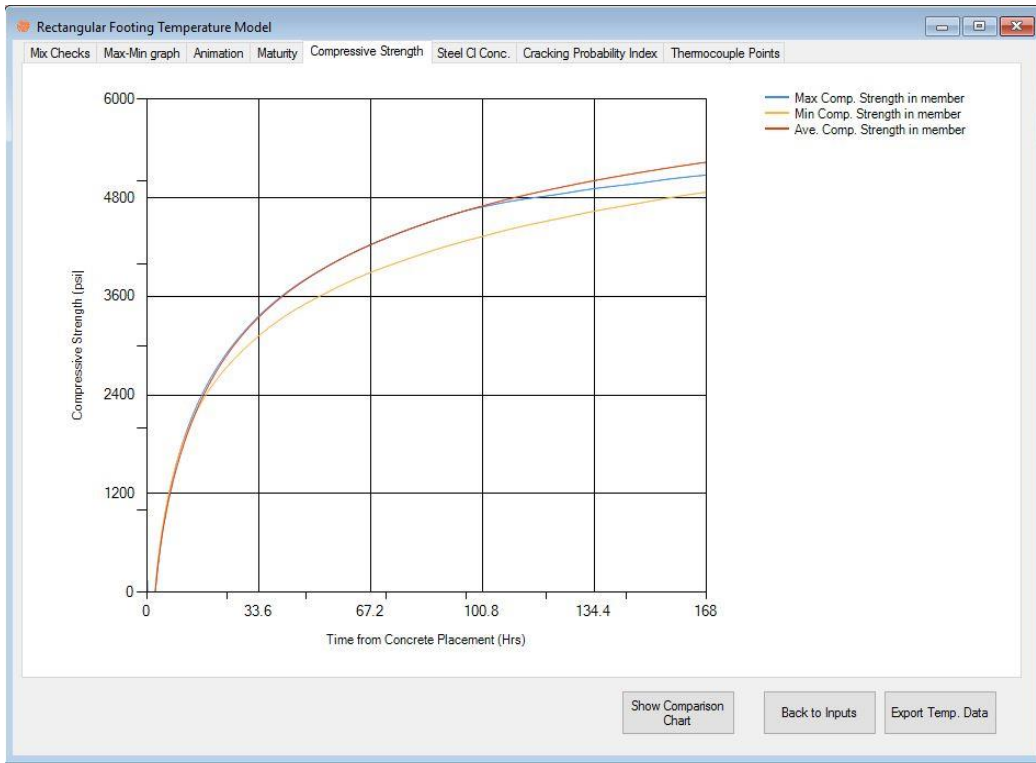
Figure 33 - Compressive Strength tab with compressive strength calculated as shown on the Rectangular Footing Temperature Model screen

Chloride Concentration at the Steel

As part of the chloride service life analysis, ConcreteWorks calculates the chloride concentration at the steel. When the chloride concentration reaches the chloride threshold level, corrosion is considered to have initiated. The chloride concentration at the steel level value will turn orange once corrosion exceeds the chloride threshold level, as shown in Figure 34.
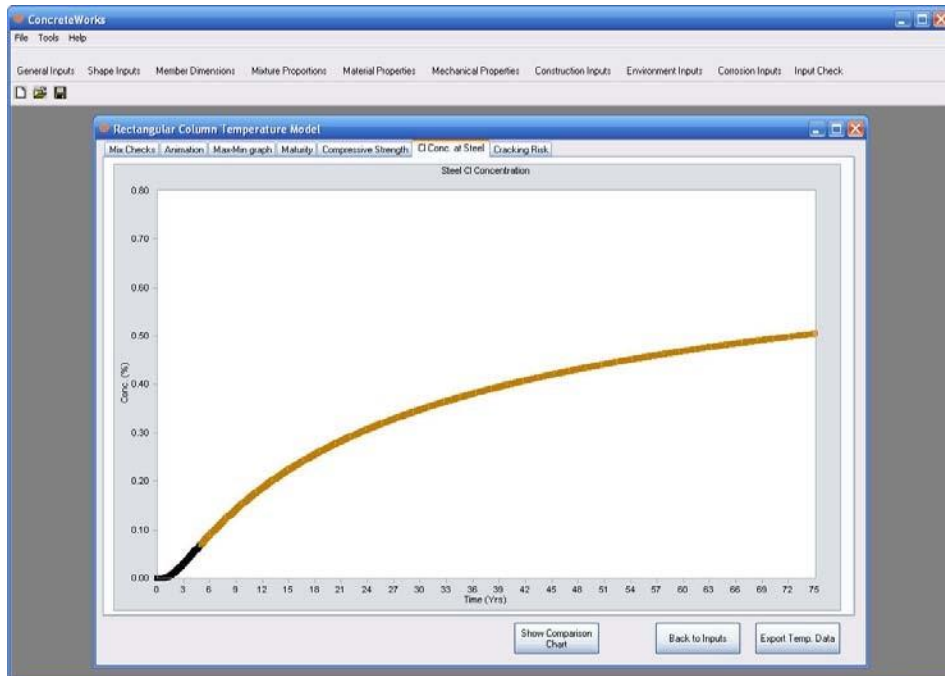
Figure 34 - Graph of chloride concentration at steel

Cracking Probability Index

The cracking probability index at different times is plotted as a bar chart, with the maximum temperature difference plotted as a blue line on the same graph to show how the temperature gradient in the concrete affects the cracking risk classification. Figure 35 shows the graph used to show the cracking risk classification and maximum temperature difference. The bar color shown for the cracking risk classification corresponds to the classification shown at the bottom of the chart. The methodology used to determine the cracking risk classification is discussed earlier. A green color corresponds to a low cracking risk classification, yellow to moderate, orange to high, and red to a very high cracking risk classification.
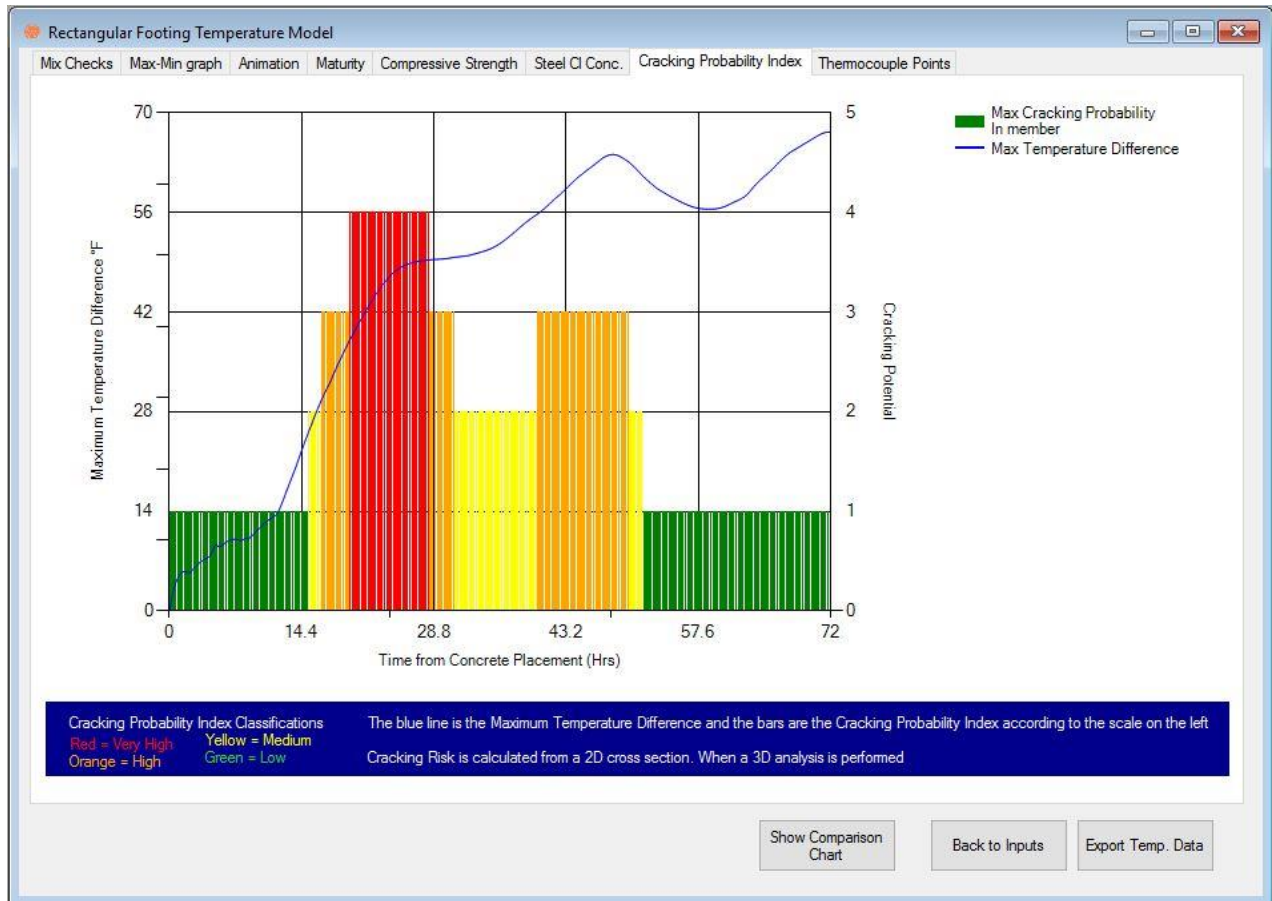
Figure 35 - Cracking risk classification chart

Thermocouple Points

The *Thermocouple Points* tab can be used to generate plot of the temperature profile at any two points and the temperature differential between these points of the mass concrete member as shown in Figure 36. This feature is useful especially for the analysis of a rectangular footing. There are two methods of thermocouple point selection. The *Point Selection Method* can be used to choose one of the two options – *Click on Position* and *Enter Position*. *Click on Position* enables the user to click on the sectional view of the mass concrete member and select two points for analysis. After this, *Change Core Point* and *Change Edge Point* can be selected to change the position of thermocouples on the sectional view figure, as shown in Figure 36. Alternatively, *Enter Position* can be used to manually enter the exact location of thermocouples. Changing the thermocouple location will automatically change the chart shown on the right side. The data of any combination of two core and edge points can also be extracted as a .txt or .xls file and can be analyzed.
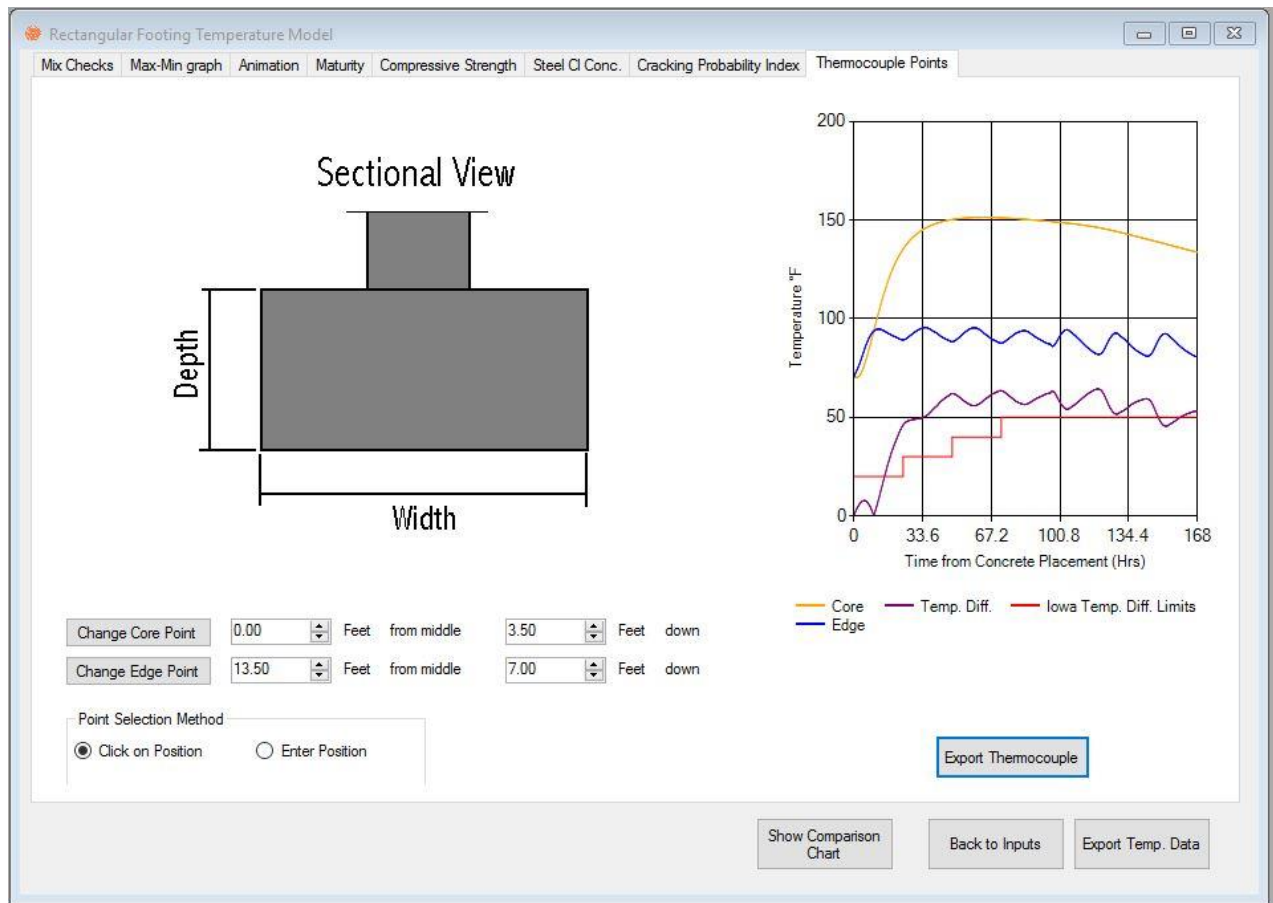
Figure 36 – Thermocouple points chart for a Rectangular Footing Temperature Model

1.3.2. Results Screen Buttons

The buttons found on the *Results* screen give the user choices on how to view and manipulate the calculated temperature data.

Show Comparison Chart

The *Show Comparison Chart* button displays a form that allows users to compare the results from different analysis runs as seen in Figure 37. The *Show Comparison Chart* screen allows the user to compare calculated maximum temperatures, maximum temperature differences, cracking probability classifications, and chloride concentration levels at the steel from one model calculation run to another. Graphs comparing the results will also be displayed. The *Print Chart* button on the *Comparison Chart* screen will print the comparison chart results and charts on the *Comparison Chart*. A PDF report of the printout will be created when the user clicks on the *PDF Comparisons* button and will prompt the user for a location to the save the PDF file. The user may name an analysis run by typing in a name under the *Series Name* textbox, selecting the number of the analysis run in the *Selected Analysis Number* input, and clicking on the *Update Series Name* button.

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When a user selects the *Delete Series* button, the analysis run number selected under the *Selected Analysis Number* will be deleted.
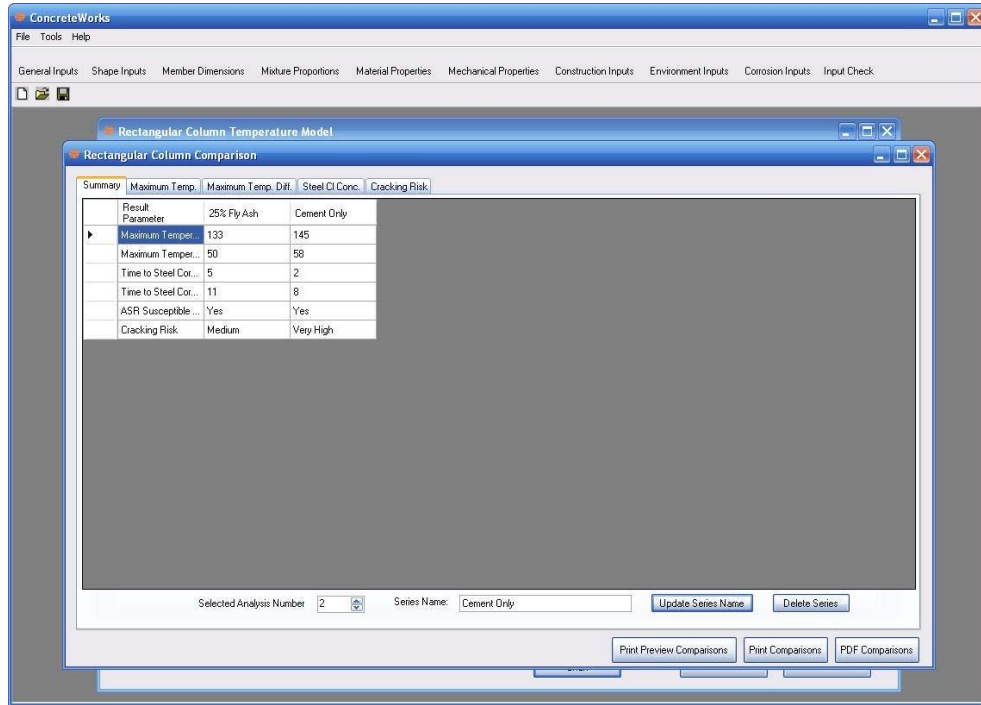
Figure 37 - Comparison chart screen

Export Temperature Data

To export the temperature data calculated, click on the *Export Temperature Data* button on the *Results* screen. ConcreteWorks saves the data in an ASCII text file when the extension .txt is used. ConcreteWorks will also save the data as an excel spreadsheet when the extension .xls is used. Data will be shown for discrete points in the member with time. The default file extension for data exported is ".xls".

Cross Section to Be Displayed

ConcreteWorks only displays data in the graphs from two-dimensional cross sections. When a footing temperature distribution is calculated in three dimensions, the user may change which cross section is shown in the graphs by changing the *Cross-Section Number to be Displayed* value, and then clicking on the *Display new cross-section* button, as seen in Figure 38. The *Mix Checks* values are calculated for the full three-dimensional temperature distributions, however, and will not change when the *Display new cross-section* button is clicked. The temperature data exported when the *Export Temperature Data* button is clicked (as explained in Section 1.3.2) only exports the temperature data from the two-dimensional cross section currently selected.
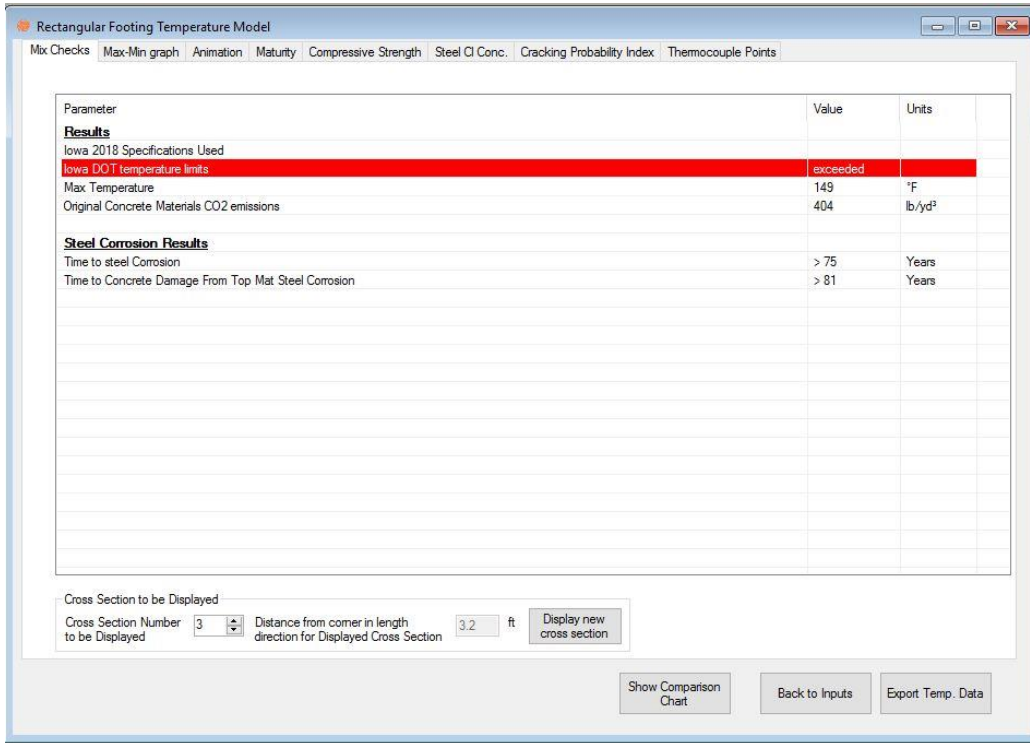
Figure 38 - Rectangular Footing Results screen with the Cross-Section to be Displayed frame showing

1.4. Program Features

1.4.1. Printing

While the *Results* screen is displayed, the user can print out the results and inputs entered in a report format.

Print
To print the report, click *Print* under the *File* menu.

Print Preview
To see of preview of the printed report, click *Print Preview* under the *File* menu, as seen in Figure 39. The report may be printed from the *Print Preview* window by clicking on the *Print* button in the *Print Preview* window.
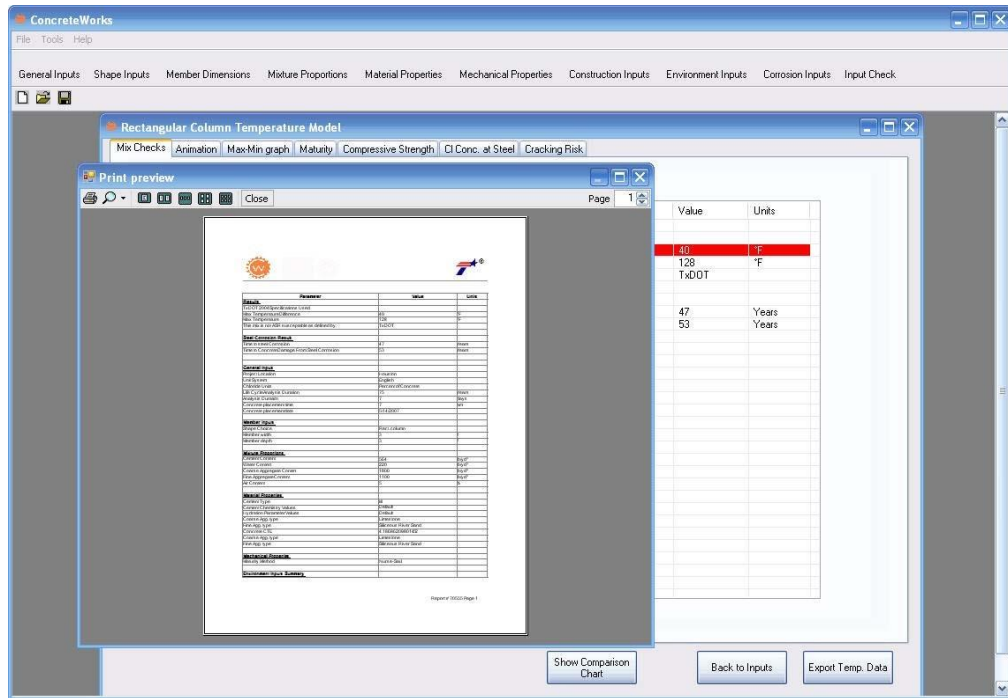
Figure 39 - Print Preview screen

Print Setup

The *Print Setup* screen allows the user to select which graphs to print in the report. The *Print Setup* dialog can be opened by clicking on *Print Setup* under the *File* menu. If compressive strength parameters are not entered in the *Mechanical Properties* screen, then the *Compressive Strength* graph will not print, even if the user selects to print it on the *Print Setup* dialog. The *Print Setup* dialog can be seen in Figure 40.
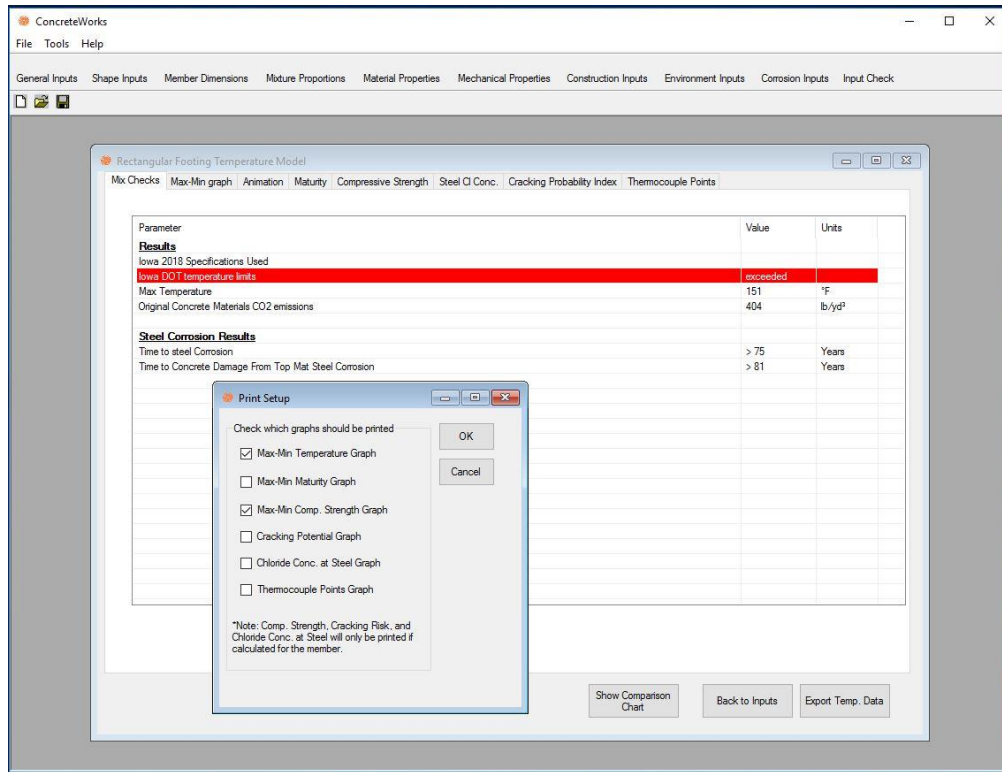
Figure 40 - Print Setup dialog

1.4.2. Export

The ConcreteWorks inputs and results can be exported to a PDF file. The PDF file exported is similar to the printed reports. To make the PDF report, select "PDF" from the "Export to" option under the *File* menu. The software will then prompt the user for a location to save the PDF file. It may take a few minutes for the software to generate the PDF file. After the file has been generated and saved, ConcreteWorks will display a message that the PDF file was generated.

ConcreteWorks also contains an option to export the inputs to SiteManager™. SiteManager™ is an AASHTOWare® product used by several state departments of transportation. The export to SiteManager™ function in ConcreteWorks will create an XML file that can be used to import ConcreteWorks inputs into SiteManager™.

1.4.3. Save As

To save the inputs entered in a new file, click *Save As* under the *File* menu. The default file extension for an inputs file is ".dat".

1.4.4. Save File

To save a currently opened file, click the *Save* button, or click *Save* under the *File* menu. If the *Save* button is clicked and the file has not previously been saved, the program will prompt for a name and location.

1.4.5. Change Defaults

Click the *Change Defaults* item under the *File* menu to change the default values used for inputs to custom values. All values entered in the *Change Defaults* screen are input in English units but are displayed in the correct units in the inputs section of ConcreteWorks the next time a new file is opened. All units stay the same in the *Change Defaults* screen, except for the *a* and *b* strength parameters under the *Mechanical Properties* tab. The *a* and *b* parameters change units depending on the type of maturity function chosen under the same tab. The *Material Inputs* tab on the *Change Defaults* screen is seen on Figure 41.
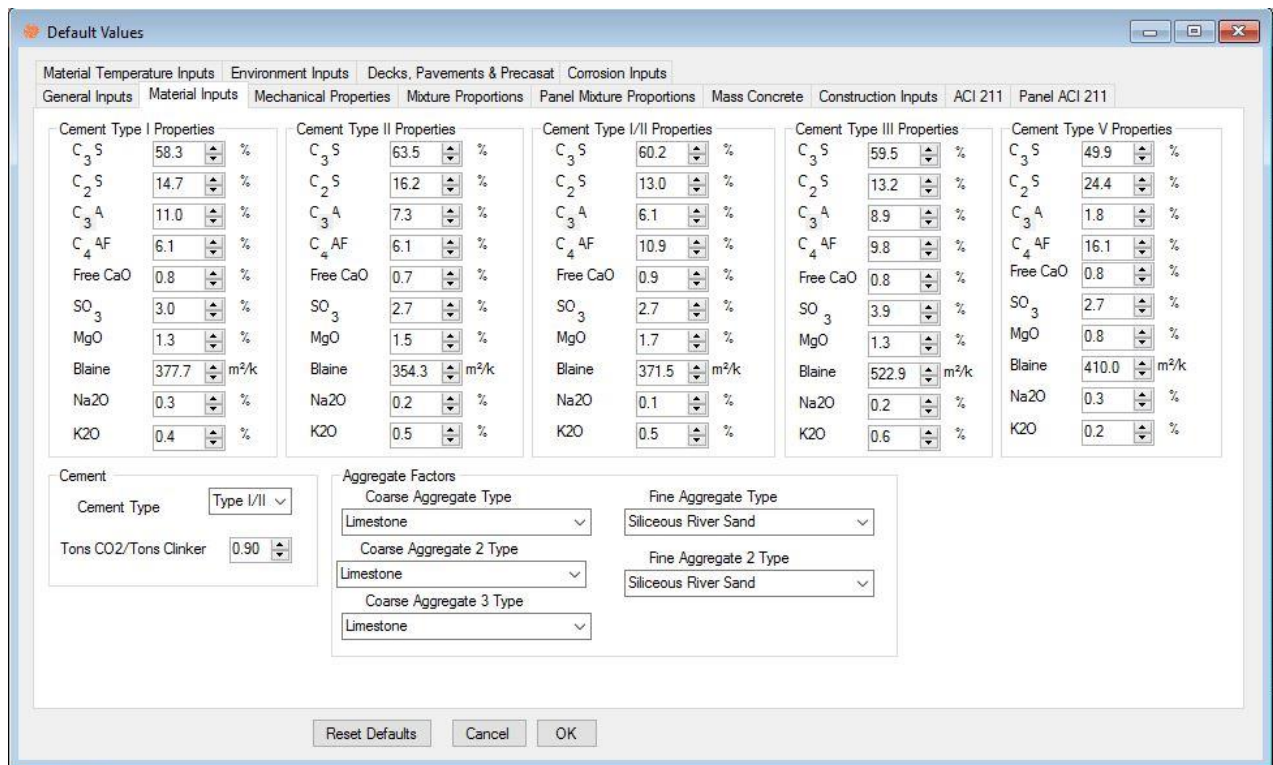
Figure 41 - Material Inputs tab on the Change Defaults screen

1.4.6. Tools Menu

The *Tools* menu contains a few options that increase the power and versatility of ConcreteWorks. The first is the analysis method used to calculate the cement chemical properties. To select the Bogue method of determining the cement composition, select *Bogue (ASTM C 150 2005)* under the *Cement Analysis Method* under the *Tools* menu. To select the Rietveld method of determining the cement chemistry, select *Rietveld* under the *Cement Analysis Method* under the *Tools* menu. Different equations are used to determine the concrete heat of hydration and early age concrete creep properties based on the cement analysis method selected, as explained in Sections 3.1.5 and 4.5.1.

The specification used in the results check section can be changed by selecting the desired specification from the *Specifications Used* option under the *Tools* menu. ConcreteWorks currently

only contains the 2004 specifications for the Texas Department of Transportation. If the *Basic ASR and DEF* specification is selected, ConcreteWorks will check to see if the predicted maximum temperature exceeds 160°F, and if the minimum amounts of SCMs prescribed by TxDOT in the 2004 specification are used. If the minimum amounts of SCMs are not used, then a warning that more investigations should be done is shown. Caution should be used in interpreting this check for alkali-silica reaction (ASR). Specifications that require the use of minimum amounts of supplementary cementing materials or maximum cement alkali levels to reduce the likelihood of ASR do not guarantee that this deleterious reaction will be prevented. Alkali silica reaction is highly dependent on the aggregate type, type, and quantity of supplementary cementing materials, alkali loading, and exposure environment.

1.4.7. Help Menu

The *Help* menu provides the user with useful information about the ConcreteWorks program.

About ConcreteWorks

When the user clicks on the *About* ConcreteWorks item under the *Help* menu, a splash screen appears with information on the ConcreteWorks version being used, a link to the official ConcreteWorks website, www.texasconcreteworks.com, and a button that shows the End-User License Agreement. When the link to the official ConcreteWorks website is clicked, ConcreteWorks uses Internet Explorer® to navigate to the website—which is why Internet Explorer is required for using ConcreteWorks (as described in Section 1.1.2).

View User Manual

When the user clicks on the *View User Manual* item under the *Help* menu, the ConcreteWorks User Manual is opened as a new Adobe Reader® process (which is why Adobe Reader® is required for using ConcreteWorks, as described in Section 1.1.2).

1.5. Input Sensitivities

ConcreteWorks asks the user to input a great deal of data. To receive a correct answer, the user must enter correct data. Some of the data needed may be hard to obtain. Other data have less of an effect on the calculated results and performance of the model. This section contains some comments on these input sensitivities.

1.5.1. Environment Inputs Sensitivity

All of the *Environment Inputs* directly affect the way heat is transferred to or from the concrete member to the surrounding environment. Of the four types of environmental inputs, the temperature inputs have the greatest impact on the resulting temperature distribution in the element. The relative humidity and cloud cover inputs have a moderate effect on the data. A percent cloud cover value within 30% is generally acceptable. The wind data can also have a moderate effect on the calculated temperatures.

1.5.2. Run Speed

The run speed of the program is one of the biggest concerns to many designers. Following are the six factors that most influence the run speed of the program:

1. The computer speed and computer RAM

2. Analysis duration—A 14-day duration takes longer to run than a 5-day duration. When a thermal stress analysis is performed, the analysis duration has a very large impact on the run time. Because of the numerical methods used, an analysis duration of 4 days may have a run time several times that of a 3-day analysis, instead of the expected 33% longer runtime.

3. Member size—the larger the element, the longer the run-time.
4. Concrete age at form removal–the greater the time before form removal, the greater the run-time.

5. Cure method after form removal–if a cure blanket is used after form removal, the run-time is longer.

6. Three-dimensional analysis greatly increases the run-time compared to a two-dimensional analysis.

1.6. Troubleshooting

1.6.1. Installation Problems

If more than one version of the .NET Framework is installed, errors may occur during installation or when the ConcreteWorks is started. To resolve the issue, try deleting the folder containing the old version of the .NET Framework, usually found in the directory C:\WINDOWS\Microsoft.NET\Framework. Before installing or deleting any files or folders, make sure that the owner of the computer or appropriate network administrator is contacted to obtain permission and/or assistance.

1.6.2. Screen Settings

The screen settings on the computer running ConcreteWorks may adjust the program's appearance. Some of the buttons may be cut off or not visible. The problem may be corrected by either manually resizing the program windows or adjusting the screen settings on the computer. To adjust the screen settings on the computer, open up the display settings window by right clicking on the desktop. Then click on the *Settings* tab. Then adjust the screen resolution for optimal software viewing.

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