Concrete Mix Development Tracker

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The Problem

In the field of construction, managing materials is critical to the success of a project. The most widely used material in the construction of roads, dams, bridges, and other civil projects is concrete. To a person outside the industry, concrete may seem simple. Materials are mixed with water to produce a grey substance like stone. To an industry insider however, concrete is far more complex. Tracking materials, mix design formula prototypes, testing, and approvals requires a strict process management system. Unfortunately, many organizations rely on, at best, a combination of spreadsheets and ill-fitting document control software, or at worst, a collection of folders. A concrete specific solution is required.

The Concrete Development Process

The concrete mixes used for large scale projects have a multi-stage life cycle that must be tracked carefully. The engineer must select the appropriate materials, proportion those materials into a proposed mix design, test the mix design, submit the mix design to the project owner for approval, then track the formula as an approved mix design available for use on the project.

Material Tracking

At the beginning of a project, materials are selected for use in concrete mixes. Without updated information on the materials used, and the properties of those materials, the design engineer cannot develop mixes for the project. In many cases the number of materials can prove extensive, and the properties of those materials can be complex and ever-changing. If material data is not stored in an organized manner, it can lead to additional work for the design engineer.

Mix Proportioning

Tracking of materials is important but becomes even more so when one considers the next step in the concrete mix development process: mix prototype development. In the development phase, the engineer must take the materials and proportion them correctly to achieve the desired concrete properties. This process requires extensive mathematical calculations. Often several iterations are required to create the desired mix. Errors can occur and ideas for potential mix options can become confused.

Test Batches

Once one or more prototypes are developed, the engineer will want to proceed with testing the properties of those mix designs. Each of these tests must be carefully tracked and the results logged in association with the prototype from which the test was derived. Changes are made to correct properties during these tests. These on-the-fly changes can result in confusion for the engineer as it may be difficult to determine what changes were made and which property outcomes were the result of these changes. Strict, detailed recordkeeping is the only solution.

Mix Design Approval

Once the design engineer achieves desirable results, the mix design must be packaged with the test results and material data for submittal to the owner. This submittal is typically multiple pages submitted in *printable document format* or "pdf" via the owner's document control software. The engineer must gather all relevant data without error or unnecessary re-submittals will result. If the owner requests changes, multiple revisions will occur. Sorting and saving the data from materials, tests and revisions may result in errors in storage and recordkeeping, overwritten files, or poorly named files.

Mix Design Tracking

After the owner approves a submittal the mix design is sent to the concrete batch plant for use on the project. As the project continues, the document will need to be available for reference by interested parties. The information on mix proportions and testing must remain intact as a source of "truth" regarding the proper proportioning of concrete mixes.

The Solution

While an engineer could create a system of logs, prototype records and server folders to keep records of mix designs, this solution can only be as good as the person supporting it. It is likely that a change in personnel could result in a jumbled practice, or that another engineer seeking mix information would be met with the unfamiliar system, creating difficulties for both the mix design engineer and the outsider looking for information. The best solution is to have a software solution tailored specifically to the development of concrete mix designs.

Concrete Mix Design Processing Software

A mix design tracking application should address the challenges at each phase of the concrete mix design development life cycle. It should include a way to track material properties, to assist in mix proportioning, to track test results, to export submittal packages, and to store information about finalized mixes.

Material Database

A software solution would include an editor for a database of materials properties, particularly the properties necessary for proper mix proportioning. For example, a crushed limestone aggregate would contain fields for specific gravity, dry rodded unit weight, absorption, and percent of voids. This information could be displayed to the user or called for use in mix proportioning.

Proportioning Application

The industry standard for selecting mix proportions is the ACI 318 document. ACI 318 uses a series of standard calculations and reference charts to determine proportions for a concrete mix based on the properties of the materials used. An effective software solution would take the information entered for the concrete materials and specification requirements to perform automatic calculations to streamline development. Once all necessary calculations are done, the result could then be saved as a "prototype".

Relational Test Result Tracking

Once the prototype has been saved laboratory testing of concrete mix properties will begin. While a solution to store all concrete test data is far beyond the scope of this project, it is reasonable to have all the relevant test data used to vet the prospective concrete mix design stored for reference and submittal. The software solution should allow the user to enter concrete air content, mix temperature, slump or slump flow, density, and permeability. This test data must be stored relationally with the prototype data so that the user can view the test data for each mix proportion or vice versa.

PDF Submittal Export

When concrete testing is complete and the engineer is satisfied with the outcome of the tests and the final proportions of the prototype, it is necessary to submit the mix proportions and test data to the project owner for review. As mentioned above, this is typically done in PDF format. To minimize the amount of document processing that must be done in a PDF editor such as Adobe Acrobat, the software should export a package a sheet detailing the mix design proportions and all test results for direct submittal.

Finalized Mix Design Database

After the owner has reviewed the submittal, the user would then be able to identify the submittal as approved. Once approved the mix would then be stored in a database of approved mixes for recall and review later in the project.

Work Plan

Dustin Inkster can make this software a reality. Dustin proposes development of a Microsoft Windows based application using C#, LINQ to SQL and Microsoft Sequel Server that would meet each of the software needs listed above.

Developer Information

Dustin Inkster will be the solo developer for the project.

Bio

After a childhood hobby in computer programming, Dustin landed a job at an electronics fabrication shop in Shreveport LA at the age of 18. There his interest in programming led to projects coding computer interfaces for the hardware the shop produced using Microsoft Visual Basic. His success in this area led to additional programming projects in Assembly and C for the Pic 16 microcontroller. Dustin later left the electronics industry but continued studying C++ and C# while working in the field of Quality Control at a concrete plant during the day. Nineteen years later, Dustin has earned a position planning and developing concrete mix

designs for challenging and specialized projects, while simultaneously working to earn an AS in Computer Programming at Lone Star College, specializing in C# and C++. Dustin works to combine his love of construction materials and software development to fill obvious voids in effective software in the civil engineering field.

Strengths

Dustin's main strength is area knowledge in the field of concrete materials. His 19 years of concrete experience on some of the most challenging projects has yielded a high degree of expertise about concrete mixes. Combined with a passion for programming and particularly a passion for Microsoft .Net applications, Dustin is the best choice for development of a concrete mix design software solution.

Advantages of Solo Development

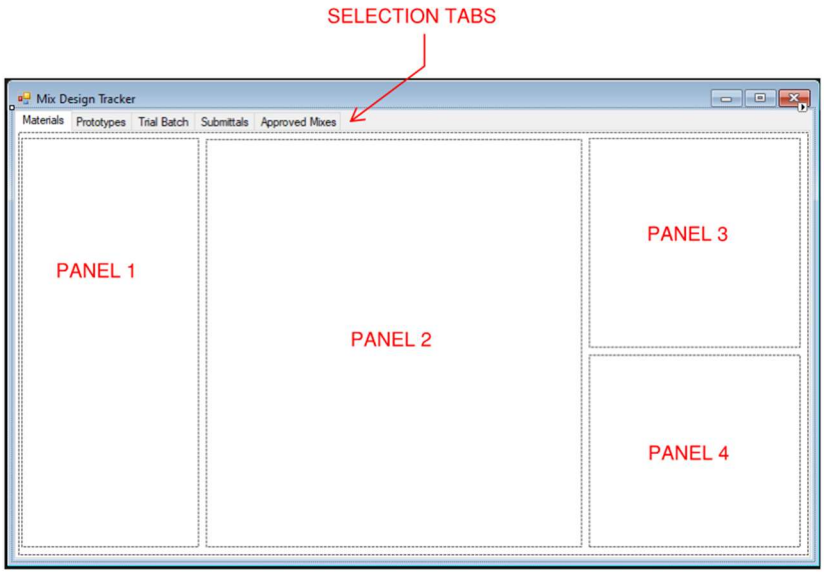
Dustin is a driven and capable student that will not only develop the proposed software, but also use it in his current role as concrete manager for Traylor Brothers Inc. He has unique insight into the specific requirements of the use case and can quickly deploy the software in the most streamlined state.

Application Structure

The application will consist of a user interface that will allow the user to view the various items and perform functions as described above. A MS SQL database will contain the stored information for each item. When the program starts, the initialization module will load information from the SQL Server database and data files containing the materials lists for each iteration of the mix design.

User Interface

The basic user interface will consist of selection tabs and four panels arranged as shown below. Selection tabs will determine what stage of the process. Panel 1 will contain a list of IDs for the user to select. The main information will be displayed in the large Panel 2 based on the selection from Panel 1. Panel 3 will contain a relevant photo or graphic, and Panel 4 will have a list of properties like what you'd find in other applications such as AutoCAD, Visual Studio, or Microsoft Access.



Selection Tabs

Selection tabs will activate a layout for the stage of the mix design process indicated on the tab. Each panel will be filled based on the tab chosen. The breakdown below details what information will appear in each tab.

Materials

Panel 1. A listbox containing the Material ID number and a shortened version of the Material Name. Above the listbox will be a combobox (dropdown) that will allow the user to narrow the list by specific type of material such as aggregate, cementitious material, admixture, etc. The number the user selects will determine the information displayed in the other panels.

Panel 2. Main material information consistent with all materials. Example fields are vendor, source, type, etc. Below this will be a listbox with a list of the currently approved mix designs in which the material is used.

Panel 3. A photograph of the material.

Panel 4. A properties gridview with all of the unique materials properties such as relative density, class, fineness modulus, etc.

Prototypes

Panel 1. A listbox containing the Prototype ID number and a shortened version of the Prototype Name. Above the listbox will be a combobox (dropdown) that will allow the user to narrow the list by specific class of concrete. The number the user selects will determine the information displayed in the other panels.

Panel 2. Headings for materials with options to add materials to the prototype. Materials additions will be handled in a separate form. When materials are added, they will have controls to enter proportions or override calculated proportions.

Panel 3. A chart displaying a graphic of proportions of materials with statistics such as paste quantity and coarse aggregate percentage by volume.

Panel 4. A Properties gridview with all of the required properties, specifications and other parameters of the mix design.

Trial Batch

Panel 1. A listbox containing the Trial Batch ID numbers and a shortened version of the Prototype Name used in the trial. Above the listbox will be a combobox (dropdown) that will allow the user to narrow the list by specific class of concrete. The number the user selects will determine the information displayed in the other panels.

Panel 2. Headings with the materials used in a similar layout to the Prototype Panel 2, but with places to indicate changes made during the trial batch process.

Panel 3. A place to upload photographs of the mix.

Panel 4. A Properties gridview to enter test data and other concrete properties.

Submittals

Panel 1. A listbox containing the Submittal ID number and a shortened version of the Prototype Name. Above the listbox will be a combobox (dropdown) that will allow the user to narrow the list by specific class of concrete. The number the user selects will determine the information displayed in the other panels.

Panel 2. Headings with the materials used in a similar layout to the Prototype Panel 2 and 3, but with places to indicate changes required by the Owner.

Panel 3. An interface to upload documents associated with the submittal such as batch tickets, test reports, etc.

Panel 4. A Properties gridview with important information about the submittal such as submittal date, submittal number, etc.

Approved Mixes

Panel 1. A listbox containing the Submittal ID number and a shortened version of the Prototype Name. Above the listbox will be a combobox (dropdown) that will allow the suer to narrow the list by specific class of concrete. The number the user selects will determine the information displayed in the other panels.

Panel 2. Headings with the materials used in a similar layout to the previous tabs, but in this tab no changes can be made.

Panel 3. The list of test documents can be viewed here.

Panel 4. A Properties gridview that will collect and display all relevant information from the previous tabs properties.

SQL Database

The SQL database will consist of the following tables:

Aggregates. A table with fields for all the basic aggregate properties shared by all aggregates.

Fine Aggregate. A table with fields for properties specific to fine aggregates and an Aggregates foreign key.

Coarse Aggregate. A table with fields for properties specific to intermediate and coarse aggregates and an Aggregates foreign key.

Cementitious Materials. A table with fields for all the basic cementitious material properties shared by all cements and SCMs.

Cements. A table with fields for properties specific to conventional cements and a Cementitious Materials foreign key.

SCMs. A table with fields for properties specific to supplementary cementitious materials and a Cementitious Materials foreign key.

Admixtures. A table with fields for properties for chemical admixtures.

Prototypes. A table with basic properties for each prototype made.

Trial Batches. A table with test results for trial batches.

Submittals. A table with properties for submittals.

Other Data

Prototypes. A data file with the materials list and quantity for each Prototype.

Trial Batches. A data file with the materials list and quantity for Trial Batches.

Mix Designs. A data file with the materials list and quantity for each finalized Mix Design.

Application Development

Tools

A number of software development tools will be used on the project. All the tools are developed by Microsoft and have a high level of interoperability, allowing for rapid development.

Visual Studio Community 2019. The primary tool used to create the application. Visual Studio will be used for the actual C# coding, GUI design with the design tool, and as a database toolset using the SQL Server Data Tools for Visual Studio.

SQL Server Express. The database server used to store information about materials and mixes. Database management will be handled through the database tools in MS Visual Studio.

MS Project. The project management software used to manage the project schedule.

Github. All project code will be stored in the cloud on Github. Github will also handle version control. VS Studio has in-app support for Github and version control will be managed from within Visual Studio rather than on the web application.

Development Schedule

Module	Target Completion
Detailed project plan in MS Project	2/4/22
GUI Layout in Visual Studio	2/9/22
Database Structure in Visual Studio Data Tools	2/14/22
Code for Materials tab in Visual Studio	2/19/22
Code for Prototype tab in Visual Studio	3/2/22
Code for Trial Batch tab in Visual Studio	3/7/22
Code for Submittal tab in Visual Studio	3/12/22
Code for Mix Design tab in Visual Studio	3/17/22
Project "polish"	3/22/22
Testing and debugging	4/12/22
User guide	5/3/22

Debugging and Testing

Prior to delivery the project will undergo rigorous debugging and testing to provide the best user experience. This testing will occur in two phases: Alpha and Beta. During the Alpha phase the program will undergo hypothetical use case testing and automated quality testing. In the Beta phase, the product will be deployed to at least one user for testing in the field. The user(s) will report bugs through Github and each will be addressed.

Anticipated Delivery

The final product will be an installation package that will install the software in the "Program Files" folder of a Windows machine by default. Because the software is a desktop application the software must be

downloaded and installed. This will allow for faster processing of data during use. The expected deployment of the solution is 5/3/22.