Final Report – Project 5: Automating Concrete Mix Design Using Python

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# Executive Summary

## Technical Summary

This project is the conversion of the Nebraska Department of Transportation’s (NDOT) Excel based concrete mix design calculator to a python program to enhance automation, reproducibility, and scenario analysis. A custom function named as ‘calculate\_mix\_design’ was developed which would enable users to enter in the Cement content, water- cement ratio, and the material percentages (for example, fly ash, GGBFS, aggregates, admixtures) and the total weight of each component required to produce one yard of concrete was computed. Four specific concrete mixing scenarios were investigated using this function: a Standard Mix, a High Strength Mix, an Eco-Friendly (Green) Mix, and a Workability Mix. The return of the function was aggregated to form a DataFrame; and bar charts used to contrast weights and percentage distributions. These visualizations resulted in useful insight regarding the effect of changes over design priorities on component selection and quantity. The project deliverables are the Python notebook, visualizations, annotated code, and documentation of engineering documents (Scope of Work, Gantt Chart, and team timesheet). How bias and ethics were handled were carefully documented, consistent units, and selective data visualization techniques.

# Non-Technical Summary

# The Nebraska Department of Transportation uses a spreadsheet to support engineers to determine the amount of cement, gravel, sand, water, and additives which are required to make concrete. Although this approach is perfect for individual designs, it is difficult to compare differing situations, or reuse the tool over and over again without returning to the calculations. In this project, our team developed a new tool, using Python (a computer programming language) to be able to make these same calculations automatically. This tool allows engineers to easily test out various types of concrete, strong and more sustainable or more accessible, and instantly find out how much of an ingredient is required. We designed and compared 4 concrete mixtures, then made graphs to demonstrate the difference. Our tool speeds it up, and makes it more flexible with easier adaptation for the future.

# 1. Introduction

# Currently Nebraska Department of Transportation (NDOT) uses an excel spreadsheet type of concrete mix design calculator to calculate the required weights of cement, aggregates, water and additives to be used for one cubic yard of concrete. Although it works well for single-case scenario, Excel strategy is not flexible for a comparative scenario analysis, automation or integration into a more complex workflow. The objective of this project was to reproduce NDOT’s analogy in Python, through a reusable function that accepts several inputs parameters and provides a comprehensive breakdown of concrete mix components.

# 2. Methodology

# A Python function was developed to mimic the logic of NDOT’s Excel tool ‘calculate\_mix\_design’. This function can take values like cement weight, water+cement ratio, the percentage of fly ash, GGBFS, fine and coarse aggregates as well as percentage of chemical admixtures. It determines total cementitious material but generates component weights in kg. The function employs comparable units and can be reintegrated to effectively analyze several concrete mix situations. Comparable results were generated when input values for all the four mix designs were pumped into the function.

# 3. Mix Scenario Descriptions

# Four concrete mix scenarios were developed to investigate varied performance priorities. The Standard Mix applies intermediate values, across the board, and is a baseline. The more cement the High Strength Mix has and the lesser the water-cement ratio the better the compressive strength. The Eco – friendly mix cuts down the cement and uses high concentrations of fly ash and GGBFS to make the material sustainable. The Workability Mix also raises fine aggregate and admixture amounts to enhance flowability and workability.

A screenshot of a graph

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# 4. Results and Visualizations

For each scenario, the results were obtained by the function and placed into a pandas DataFrame. Two plots were generated: the first presents a stacked bar chart depicting the absolute weights of the components by per mix in kilograms. The second plot shows the relative percentage of each material to point out changes in the mix composition. These visualizations show the effect that design variation has on the use of the components. For instance the High Strength Mix has much higher proportions of cement whereas the Eco-Friendly Mix has a greater percentage of supplementary material (fly ash and GGBFS).

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A graph of different colored squares

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# 5. Engineering Practice Components

This project provided professional engineering deliverables like a Scope of Work, a Gantt Chart to plan milestones, and a Team Timesheet to identify what each wall suffered. An Annotated Code Document (ACD) was also created that described each variable and each computation used in the Python function. These documents helped our team achieve their organization, communication, and documentation objectives in the course of this project.

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# 6. Bias and Ethics in Coding

# There were a number of biases thought throughout the project. These were rounding decisions, hardcoded constants such as (specific gravities) and inconsistencies in unit conversions. Wrong assumptions can result in erroneous outputs of misleading interpretations. Even visualization options are ethically questionable because some charts can overemphasize the differences. To mitigate these risks, we adopted a uniform unit system (SI), added explanatory comments to the code and chose plots that reflect proportion of components correctly.

# 7. Conclusion

# This project was successful in converting NDOT’s Excel based concrete mix design tool to a Python function that can analyze multiple scenarios. The new tool enables better repeatability, batch analysis, and the added visualization capabilities that were not possible in the initial spreadsheet. The possibility to contrast concrete mixes with respect to strength, sustainability, or workability in an open and repeatable form is one of the benefits of programming for civil engineering analysis. Future improvements may involve the incorporation of cost or emissions metrics or the development of a graphical user interface.

# 8. References

Nebraska Department of Transportation. Mix Design Submittal Sheet. https://dot.nebraska.gov/media/jp3paote/mix-design-submittal.xlsx

Nebraska Department of Transportation. Final Report on Optimized Aggregate Gradation. https://dot.nebraska.gov/media/3isfdv45/final-report-p336.pdf

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CIVE202\_Spring2025\_Project5\_GroupI\_SOW.docx

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CIVE202\_Spring2025\_Project5\_TimeSheet.docx