

Technical Report

Introduction:

This project is intended to be performed for NDOT. They have contracted our firm to make a concrete mix design model. We are expected to take an excel-based file and turn it into a python coding system. Switching from excel to python will give us several key advantages. The Python code will allow for less manual data entry and more clear formula use. The new Python code will allow for repeatability and limit user error. This project relies on modular functions, input prompts, and scenario testing to support engineering calculations.

The main objective of this project is to replicate and automate the logic provided in the “mix design” sheet provided by NDOT. This allows the user to enter materials and design parameters in an ordered manner. To complete the project, we will translate the excel logic into Python. We will implement sequential user inputs. The final output will produce an automatic generated weight chart for one cubic yard of concrete. We will prepare and evaluate four of these outputs.

Methods:

The NDOT design mix sheet is organized using letter-based references. Each Python variable has a corresponding letter (e.g., `water_weight_Q`). This allows for cross-reference between the Python code and the Excel sheet. Each Excel formula was written as a Python function using operators and parameters. One example is the water weight calculation: $Q = (A+B+C+D) * E$.

This equation accepts the cementitious material weights and the target- cement ratio as arguments. All constants used in the Excel sheet were defined in the notebook to ensure proper naming and referencing throughout the use of the work. The functions used were defined using “def”. All required inputs were entered, and the value was computed using Python arithmetic. These constants and variables were printed as f-strings to ensure they were set up correctly.

The notebook is organized into a structured format that mimics the NDOT design mix sheet. The notebook is started by defining the project name and client using Python variables. The key constants are defined using the correct naming and letter correlated to the NDOT’s design sheet. These values are printed and able to use for future parameters and calculations in the notebook. Each variable has a specific name and letter allowing Python outputs to be compared to the design sheet and allowing for transparent inputs and outputs as well as easy to follow logic.

The automated system uses a consistent set of inputs and outputs to allow for repeated usability. The following shows the inputs and outputs used for this project.

Inputs	Outputs
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Cement_A	water_weight_Q
fly_ash_B	volume_R
silica_fume_C	volume_S
other_SCM_D	volume_T
water_cement_ratio_E	volume_U
air_content_F	air_volume_V
percent_fine_G	water_volume_W
percent_coarse_H	total_aggregate_volume_X
percent_other_I	fine_aggregate_Y
sg_cement_J	coarse_aggregate_Z
sg_fly_ash_K	other_aggregate_AA
sg_silica_fume_L	
sg_other_SCM_M	
sg_fine_N	
sg_coarse_O	
sg_other_P	

Results and Discussions:

Four concrete mix design scenarios were executed using the automated Python code. Each is a realistic case able to be used by NDOT. The final product is for one cubic yard of concrete and accounts for various quantities of cementitious material and aggregate proportions.

Scenario 1: Baseline Highway Pavement (47B)

This scenario represents a traditional NDOT pavement mix with 540 lb/yd³ of cement and no supplementary cementitious materials (SCMs). The relatively low water–cement ratio (0.42) produced a water weight of 226.8 lb/yd³, consistent with a durable pavement mix. Aggregate proportions (35% fine, 65% coarse) resulted in:

- Fine aggregate: 1099.5 lb/yd³
- Coarse aggregate: 2080.5 lb/yd³
- Air volume: 1.6 lb/yd³

The total batch weight was 3946.9 lb/yd³, the highest among all scenarios due to the high cement content and relatively low SCM replacement.

Scenario 2 :Cost-Efficient, Sustainability-Focused Pavement (47BR)

Scenario 2 introduced 120 lb/yd³ of fly ash, reducing cement content to 420 lb/yd³. The water–cement ratio increased slightly to 0.44, producing a water weight of 216.0 lb/yd³. Aggregate proportions (36% fine, 64% coarse) yielded:

- Fine aggregate: 1127.8 lb/yd³
- Coarse aggregate: 2042.8 lb/yd³
- Air volume: 1.6 lb/yd³

The total batch weight decreased to 3806.7 lb/yd³, reflecting the lower cementitious mass. This mix balances durability with cost efficiency and reduced environmental impact.

Scenario 3 :High-Durability, Freeze–Thaw Resistant Mix (47BR-Modified)

Scenario 3 incorporated a blended SCM system: 80 lb/yd³ fly ash and 40 lb/yd³ silica fume, paired with 500 lb/yd³ cement. The water–cement ratio increased to 0.46, resulting in a water weight of 223.2 lb/yd³. With 38% fine and 62% coarse aggregate, the mix produced:

- Fine aggregate: 1165.3 lb/yd³
- Coarse aggregate: 1937.2 lb/yd³
- Air volume: 1.5 lb/yd³

The total batch weight was 3825.8 lb/yd³. The inclusion of silica fume increases paste density and improves freeze–thaw durability, making this mix suitable for heavy-traffic and harsh-climate applications.

Scenario 4: Economy Variant for Low-Traffic Pavement (47BR-Economy)

Scenario 4 used the lowest cement content (380 lb/yd³) with 100 lb/yd³ fly ash, targeting cost-effectiveness. The water–cement ratio (0.45) produced a water weight of 216.0 lb/yd³. Aggregate proportions (34% fine, 66% coarse) resulted in:

- Fine aggregate: 1076.9 lb/yd³
- Coarse aggregate: 2129.8 lb/yd³
- Air volume: 1.8 lb/yd³

The total batch weight was 3802.7 lb/yd³, the lowest among all scenarios. This mix is appropriate for low-traffic or non-structural pavement applications where cost savings are prioritized.

Comparative Discussion:

Scenario 1 had the highest cement content and highest batch weight. Scenarios 2, 3, and 4 progressively lowered their total weight and cement mass by adding more SCMs. Scenario 1 also had higher cement content and lower water weight, creating a lower water/cement ratio. As expected, since Scenarios 2, 3, and 4 had less cement, they had higher

water/cement ratios due to increased water content. The difference in aggregate proportioning between the scenarios will affect concrete density and durability. The air content remained the same throughout each scenario. However, air volume was changed depending on aggregate proportions.

The Python code produced four automated scenarios with accurate batch weights. It was able to adjust to changes in cementitious material and aggregate proportions. It produces accurate volumes and weights. It was accurate throughout the project and repeatable. This confirms the transition from Excel sheet to the Python code was successful and able to be used in future projects.

Mix Design Summary Senario 1

Source: NDOT

Use Case: Main Highway Pavement, Baseline pavement mix

Inputs:

Project Number: 1

Class of Concrete: 47B

cement content A (lb/yd³): 540.0

fly ash content B (lb/yd³): 0.0

silica fume content C (lb/yd³): 0.0

other scm content D (lb/yd³): 0.0

target water-cement ratio E: 0.42

target air content F (%): 5.0

percent fine aggregate G (%): 35.0

percent coarse aggregate H (%): 65.0

percent other aggregate I (%): 0.0

specific gravity of cement J: 3.15

specific gravity of fly ash K: 2.3

specific gravity of silica fume L: 2.2

specific gravity of other scm M: 2.6

specific gravity of fine aggregate N: 2.65

specific gravity of coarse aggregate O: 2.7

specific gravity of other aggregate P: 2.65

Component	Weight (lb/yd ³)	Notes
Cement	540.0	
Water	226.8	
Fine Aggregate	1099.5	
Coarse Aggregate	2080.5	
Air (volumetric)	1.6	percent / ft ³
Total (sanity check)3946.859		

The mix design for Project 1, Class 47B includes a cement weight of 540.0, water weight of 226.8, fine aggregate weight of 1099.5, coarse aggregate weight 2080.5 (all in lb/yd³), and air volume of 1.6 %/ft³. The total weight was 3946.9 lbs.

Mix Design Summary Senario 2

Source: NDOT

Use Case: Durable Highway Pavement, Cost-efficient, sustainability focused projects

Inputs:

Project Number: 2

Class of Concrete: 47BR

cement content A (lb/yd³): 420.0

fly ash content B (lb/yd³): 120.0

silica fume content C (lb/yd³): 0.0

other scm content D (lb/yd³): 0.0

target water-cement ratio E: 0.4

target air content F (%): 5.0

percent fine aggregate G (%): 36.0

percent coarse aggregate H (%): 64.0

percent other aggregate I (%): 0.0

specific gravity of cement J: 3.15

specific gravity of fly ash K: 2.3

specific gravity of silica fume L: 2.2

specific gravity of other scm M: 2.6

specific gravity of fine aggregate N: 2.65

specific gravity of coarse aggregate O: 2.7

specific gravity of other aggregate P: 2.65

Component	Weight (lb/yd ³)	Notes
Cement	420.0	
Water	216.0	
Fine Aggregate	1127.8	
Coarse Aggregate	2042.8	
Air (volumetric)	1.6	percent / ft ³
Total (sanity check)3806.673		

The mix design for Project 2, Class 47BR includes a cement weight of 420.0, water weight of 216.0, fine aggregate weight of 1127.8, coarse aggregate weight 2042.8 (all in lb/yd³), and air volume of 1.6 %/ft³. The total weight was 3806.7 lbs.

Mix Design Summary Senario 3

Source: NDOT

Use Case: Heavy traffic roads, freeze/thaw resistant structures

Inputs:

Project Number: 3

Class of Concrete: 47BR-Modified

cement content A (lb/yd³): 500.0

fly ash content B (lb/yd³): 80.0

silica fume content C (lb/yd³): 40.0

other scm content D (lb/yd³): 0.0

target water-cement ratio E: 0.36

target air content F (%): 5.0

percent fine aggregate G (%): 38.0

percent coarse aggregate H (%): 62.0

percent other aggregate I (%): 0.0

specific gravity of cement J: 3.15

specific gravity of fly ash K: 2.3

specific gravity of silica fume L: 2.2

specific gravity of other scm M: 2.6

specific gravity of fine aggregate N: 2.65

specific gravity of coarse aggregate O: 2.7

specific gravity of other aggregate P: 2.65

Component	Weight (lb/yd ³)	Notes
Cement	500.0	
Water	223.2	
Fine Aggregate	1165.3	
Coarse Aggregate	1937.2	
Air (volumetric)	1.5	percent / ft ³
Total (sanity check)3825.764		

The mix design Senario 3, Class 47BR-Modified has a cement weight of 500.0, water weight of 223.2, fine aggregate weight of 1165.3, coarse aggregate weight 1937.2 (all in lb/yd³), and air volume of 1.5 %/ft³. The total weight was 3825.8 lbs.

Mix Design Summary Senario 4

Source: NDOT

Use Case: Cost effective, non-structural pavement, low traffic areas

Inputs:

Project Number: 4

Class of Concrete: 47BR-Economy Variant

cement content A (lb/yd³): 380.0

fly ash content B (lb/yd³): 100.0

silica fume content C (lb/yd³): 0.0

other scm content D (lb/yd³): 0.0

target water-cement ratio E: 0.45

target air content F (%): 5.0

percent fine aggregate G (%): 34.0

percent coarse aggregate H (%): 66.0

percent other aggregate I (%): 0.0

specific gravity of cement J: 3.15

specific gravity of fly ash K: 2.3

specific gravity of silica fume L: 2.2

specific gravity of other scm M: 2.6

specific gravity of fine aggregate N: 2.65

specific gravity of coarse aggregate O: 2.7

specific gravity of other aggregate P: 2.65

Component	Weight (lb/yd ³)	Notes
Cement	380.0	
Water	216.0	
Fine Aggregate	1076.9	
Coarse Aggregate	2129.8	
Air (volumetric)	1.8	percent / ft ³
Total (sanity check)3802.654		

The mix design for Project 4, Class 47BR-Economy Variant includes a cement weight of 380.0, water weight of 216.0, fine aggregate weight of 1076.9, coarse aggregate weight 2129.8 (all in lb/yd³), and air volume of 1.8 %/ft³. The total weight was 3802.7 lbs.

References: *Proper in-text citations and a reference list for the NDOT and other references used.*

1. Primary Tool: NDOT Concrete Mix Excel. Link: <https://dot.nebraska.gov/media/jp3paote/mix-design-submittal.xlsx>
2. Research Base: NDOT Report on Optimized Aggregates Gradations for Portland Cement Concrete Mix Designs Evaluation. Link: <https://dot.nebraska.gov/media/3isfdv45/final-report-p336.pdf>
3. Standards: NDOT Standard Specifications for Highway Construction. Link: <https://dot.nebraska.gov/media/g4qp4y0d/2017-specbook.pdf>
4. Project 2 Client Prompt. Link: [Project 2 - Client Prompt.docx](#)
5. Project 2 Code. Link: [CIVE202_Spring 2025_Group14_Project2_PythonCode \(2\) \(1\)](#)
6. Scope of work. Link: [SOW_Project 2_Group-14.pdf](#)