Project 2

University of Nebraska–Lincoln
Department of Civil Engineering
Engineering Analysis II

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Section Number: 150

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Scope of Work

Project Title: Automation of Concrete Mix Design

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Submitted to: Nebraska Department of Transportation (NDOT)

Project Goals: The Nebraska Department of Transportation (NDOT) has engaged this project team to automate the Excel based concrete mix design model and convert it into a Python design model. The purpose of this project is to improve the calculation, reliability, transparency, and repeatability of the model. The model provides user inputs in sequential orders and automatically calculates a final concrete mix weight chart for one cubic yard of concrete.

Project Tasks:

Task 1: Review the NDOT concrete Mix Design workbook to understand calculation flow, dependencies, and required inputs

Task 2: Identify all formulas and their parameters and provide an input-output function

Task 3: Translate the Excel function into a reusable Python function with clear instructions and names and a step-by-step user input workflow

Task 4: Verify by testing with various realistic concrete mix design scenarios

Task 5: Provide all deliverables to the client

Gantt Chart

Table 1. Gantt Chart for Project 2

TASKS	Week 5			Week 6							Week 7							Week 8		Date Range		
	06 Feb Fri	07 Feb Sat	08 Feb Sun	09 Feb Mon	10 Feb Tues	11 Feb Wed	12 Feb Thur	13 Feb Fri	14 Feb Sat	15 Feb Sun	16 Feb Mon	17 Feb Tues	18 Feb Wed	19 Feb Thur	20 Feb Fri	21 Feb Sat	22 Feb Sun	23 Feb Mon	24 Feb Tues	Start Date	End Date	Duration
Data Processing																				06 Feb 2026	06 Feb 2026	1
Scope of Work																				07 Feb 2026	10 Feb 2026	4
Writing Code																				06 Feb 2026	20 Feb 2026	15
GitHub																				21 Feb 2026	24 Feb 2026	4
Annotated Code Document																				19 Feb 2026	24 Feb 2026	6
Final Report																				21 Feb 2026	24 Feb 2026	4
Flow Diagram																				19 Feb 2026	20 Feb 2026	2

PROJECT #2 - GANTT CHART

Table 2. Color coated legend to define project progress

Progress
25
50
75
Completed

Annotated Code:

Table 3. Annotation of each code used in project 2

Python Code	Annotation(s)
import pandas as pd import numpy as np	These import common Python libraries needed to run the code
project_name = "Project #2: Automation of NDOT Concrete Mix Design" client = "Nebraska Department of Transportation (NDOT)"	Stores project and client info as variables. They're printed later so outputs are clearly tied to the correct project
print(f'This project is designed for: {client}')	Prints the client name using an f-string. Demonstrates formatted output in Python
my_number = 7.341212 print(f"{my_number:8.2f}")	Demonstrates numeric formatting. Rounds a number to two decimal places. Used later for clean output formatting
cubic_yard_ft3 = 27 unit_weight_water = 62.4	Defines fixed constants for the entire code. One cubic yard is 27 cubic feet and the unit weight of water is 62.4 lb per cubic feet. Since its used repeatedly throughout code defining it once will make things simpler
print(f"defined constant: 1 cubic yard = {cubic_yard_ft3} cubic feet") print(f"Unit weight of water = {unit_weight_water} lb per cubic feet")	Prints the defined constants to confirm the values
def calculate_water_weight_Q(cement_A, fly_ash_B, silica_fume_C, other_SCM_D, wc_ratio_E): total_cementious = cement_A + fly_ash_B + silica_fume_C + other_SCM_D water_weight_Q = total_cementious * wc_ratio_E	Calculates the total water weight for the mix. First it lists all the materials needed. Then it defines total_cementious as the sum of A, B, C, and D. then it multiples itself by E to achieve Q.

return water_weight_Q	Returning Q sends the calculated value back to the main program
w_weight_1 = calculate_water_weight_Q(600, 100, 30, 70, 0.42) print(f"Water weight = {w_weight_1} lb/yd^3")	An example used for the function using random numeric values and printing the calculated water weight
cement_A = 600 fly_ash_B = 100 silica_fume_C = 30 other_SCM_D = 70 wc_ratio_E = 0.42	Demonstrates using variables as inputs.
w_weight_2 = calculate_water_weight_Q(cement_A, fly_ash_B, silica_fume_C, other_SCM_D, wc_ratio_E) print(f"water weight = {w_weight_2} lb/yd^3")	Both methods give the same output when ran

def calculate_volume_cement_R(cement_A, sg_cement_J):
    volume_R = cement_A / (sg_cement_J * unit_weight_water)
    return volume_R
# Example input values for demonstration 	
cement_A = 600
sg_cement_J = 3.5
# Use them in the function 	
R = calculate_volume_cement_R(cement_A, sg_cement_J)
# Print 	
print(f"cement volume (R): {R:.3f} ft^3")
	Calculates all the different material volumes using the same formula of volume = weight divided by (specific gravity * unit weight of water)

def calculate_volume_fly_ash_S(fly_ash_B, sg_fly_ash_k):
    return fly_ash_B / (sg_fly_ash_k * unit_weight_water)
 	
def calculate_volume_silica_fume_T(silica_fume_C, sg_silica_fume_L):
    return silica_fume_C / (sg_silica_fume_L * unit_weight_water)
 	
def calculate_volume_SCM_U(other_SCM_D, sg_other_SCM_M):
	Structurally the same as the previous volume function

| ```python
    return other_SCM_D / (sg_other_SCM_M *
unit_weight_water)
``` | |
| ```python
def calculate_air_volume_V(air_content_F):
    volume_V = (air_content_F /100) * cubic_yard_ft3
    return volume_V
def calculate_water_volume_W(weight_water_Q):
    volume_W = water_weight_Q / unit_weight_water
    return volume_W
``` | Calculates the air and water volumes. |
| ```python
def calculate_total_aggregate_volume_X(volume_R,
volume_S, volume_T, volume_U, volume_V, volume_W):
    volume_X = (cubic_yard_ft3 - volume_R - volume_S -
volume_T - volume_U - volume_V - volume_W)
    return volume_X
``` | Calculates the remaining volume available for aggregates. Subtracts all the cementitious, air, and water volumes from 27 cubic feet. Each function uses the aggregate percentage, specific gravity, and converts the volume to weight |
| ```python
def calculate_fine_aggregate_weight_Y(percent_fine_G,
sg_fine_N, volume_X):
    weight_Y = unit_weight_water * (percent_fine_G / 100) *
sg_fine_N * volume_X
    return weight_Y

def calculate_coarse_aggregate_Z(percent_coarse_H,
sg_coarse_O, volume_X):
    return unit_weight_water * (percent_coarse_H / 100) *
sg_coarse_O * volume_X

def calculate_other_aggregate_AA(percent_other_I,
sg_other_P, volume_X):
    return unit_weight_water * (percent_other_I / 100) *
sg_other_P * volume_X
``` | Structurally the same as the previous aggregate volume function |
| ```python
# Scenario 1 – Standard Pavement Mix
project_no = 101
concrete_class = "47B"

cement_A = 600
``` | User input example |

fly_ash_B = 100 silica_fume_C = 30 other_SCM_D = 70 water_cement_ratio_E = 0.42 air_content_F = 6 percent_fine_G = 45 percent_coarse_H = 50 percent_other_I = 5 sg_cement_J = 3.15 sg_fly_ash_K = 2.30 sg_silica_fume_L = 2.20 sg_other_SCM_M = 2.60 sg_fine_N = 2.65 sg_coarse_O = 2.70 sg_other_P = 2.60	

# Start with a general explanation 	
print("\n--")
print(" NDOT Concrete Mix Design – Weight Summary")
print("   (1 Cubic Yard of Concrete)")
print("--")
	print() outputs text to the console. \n inserts a blank line before the first divider. The dashed lines separate sections

# Project and mix details 	
print(f"Project Number: {project_no}")
print(f"Class of Concrete: {concrete_class}")
print("--")
	f"" is an f-string. {project_no} and {concrete_class} insert variable values. This identifies info for the mix.

# Cementitious material outputs 	
print(f"Cement (A):   {cement_A:8.1f} lb")
print(f"Fly Ash (B):   {fly_ash_B:8.1f} lb")
print(f"Silica Fume (C):   {silica_fume_C:8.1f} lb")
print(f"Other SCM (D):   {other_SCM_D:8.1f} lb")
print("--")
	These print cementious material weights. The :8.1f means that the total width is 8 characters with 1 decimal place and a fixed point format. This keeps the numbers in columns. Lb means in pounds

# Aggregate outputs 	
print(f"Fine Aggregate (Y):   {Y:8.0f} lb")
print(f"Coarse Aggregate (Z): {Z:8.0f} lb")
	Prints aggregate weights. :8.0f means its an 8 character width

print(f"Other Aggregate (AA): {AA:8.0f} lb") print("--")	with 0 decimal places and rounded to the whole number

# Water output 	
print(f"Water (Q):   {Q:8.0f} lb")
	Prints total batch water

# End it with a note 	
print("--")
print("End of Mix Design Summary")
	Final divider line

2nd block is the same so no need to repeat. When running every piece of code and inputting, you will get a final chart that displays everything	

Summary:

Introduction:

The project focused on making an automated concrete mix design program, which was created from an excel sheet provided by the Nebraska Department of Transportation. We took the provided excel sheet and used it to make a structured program using python to calculate the requested formulas to a mixed concrete design.

Methods:

To complete the requested proposal, the excel formulas were rewritten as python functions and by using a step-by-step user input prompt to help guide the user through the mix design process. The program itself generates a finalized weight chart for one cubic yard of concrete. At the end of the program, four realistic concrete mix scenarios were tested to showcase to the client that the code works as intended.

Results & Discussion:

The tested results showed that the program produced an expected output based on the variables imputed. The differences between the four tested mixed designs matched expectations, which are based on realistically used mix design scenarios. Overall, the automated concrete mix design program took the original spreadsheet and provides a proposed code that introduces efficiency through user imputed prompts.

Example Scenarios:

Scenario 1 NDOT Class 47B

Table 4. Scenario 1 NDOT Class 47B

Parameter	Value
project_no	101
concrete_class	"47B"
cement_A	580 lb
fly_ash_B	80 lb
silica_fume_C	0 lb
other_SCM_D	0 lb
water_cement_ratio_E	0.44
air_content_F	7
percent_fine_G	45
percent_coarse_H	50
percent_other_I	5
sg_cement_J	3.15
sg_fly_ash_K	2.30
sg_silica_fume_L	2.20
sg_other_SCM_M	2.60
sg_fine_N	2.65
sg_coarse_O	2.70
sg_other_P	2.60

Table 5. Created by using the proposed code and scenario 1

NDOT Concrete Mix Design – Weight Summary

(1 Cubic Yard of Concrete)

Project Number: 101

Class of Concrete: 47B

Cement (A):   580.0 lb

Fly Ash (B):   80.0 lb

Silica Fume (C):   0.0 lb

Other SCM (D):   0.0 lb

Fine Aggregate (Y):   1207 lb

Coarse Aggregate (Z):   1366 lb

Other Aggregate (AA):   132 lb

Water (Q):   290 lb

End of Mix Design Summary

Scenario 1 referenced from:
https://dot.nebraska.gov/media/jjwpyezr/pavdesignmanual.pdf (page 63 table)

Scenario 2: 4000 PSI Structural Concrete (Typical ACI Mix)

Table 6. Scenario 2 (Typical ACI Mix)

Parameter	Value
project_no	102
concrete_class	"4000psi Standard"
cement_A	650 lb
fly_ash_B	50 lb
silica_fume_C	0 lb
other_SCM_D	50 lb
water_cement_ratio_E	0.42
air_content_F	6
percent_fine_G	46
percent_coarse_H	49
percent_other_I	5
sg_cement_J	3.15
sg_fly_ash_K	2.30
sg_silica_fume_L	2.20
sg_other_SCM_M	2.60
sg_fine_N	2.65
sg_coarse_O	2.70
sg_other_P	2.60

Table 7. Created by using the proposed code and scenario 2

NDOT Concrete Mix Design – Weight Summary

(1 Cubic Yard of Concrete)

Project Number: 101

Class of Concrete: 47B

Cement (A):   650.0 lb

Fly Ash (B):   50.0 lb

Silica Fume (C):   0.0 lb

Other SCM (D):   0.0 lb

Fine Aggregate (Y):   1219 lb

Coarse Aggregate (Z):   1324 lb

Other Aggregate (AA):   130 lb

Water (Q):   315 lb

End of Mix Design Summary

Scenario 2 referenced from:
https://static1.squarespace.com/static/59c91fb8f7e0ab097112fbc4/t/5b5b22a81ae6cf14d8dcd716/1532699305261/Mix+Designs-COMBINED+072718.pdf

Scenario 3: 47BD Concrete Mix

Table 8. Scenario 3 – 47BD Concrete Mix

project_no = 103
concrete_class = "47BD"
cement_A = 658
fly_ash_B = 0
silica_fume_C = 0
other_SCM_D = 0
water_cement_ratio_E = 0.45
air_content_F = 7
percent_fine_G = 45
percent_coarse_H = 50
percent_other_I = 5
sg_cement_J = 3.15
sg_fly_ash_K = 2.30
sg_silica_fume_L = 2.20
sg_other_SCM_M = 2.60
sg_fine_N = 2.65
sg_coarse_O = 2.70
sg_other_P = 2.60

Table 9. Created by using the proposed code and scenario 3

NDOT Concrete Mix Design – Weight Summary

(1 Cubic Yard of Concrete)

Project Number: 101

Class of Concrete: 47BD

Cement (A):   658.0 lb

Fly Ash (B):   0.0 lb

Silica Fume (C):   0.0 lb

Other SCM (D):   0.0 lb

Fine Aggregate (Y):   1219 lb

Coarse Aggregate (Z):   1380 lb

Other Aggregate (AA):   133 lb

Water (Q):   296 lb

End of Mix Design Summary

Scenario 3 referenced from:

https://dot.nebraska.gov/media/jjwpyezr/pavdesignmanual.pdf (page 63 table)

Scenario 4: 10000 PSI Concrete Mix

Table 10. Scenario 4 – 10,000 PSI Concrete

project_no = 104
concrete_class = "NDOT Structural – Special Provision"
cement_A = 893
fly_ash_B = 0
silica_fume_C = 63
other_SCM_D = 50
water_cement_ratio_E = 0.27
air_content_F = 6.5
percent_fine_G = 45
percent_coarse_H = 50
percent_other_I = 5
sg_cement_J = 3.15
sg_fly_ash_K = 2.30
sg_silica_fume_L = 2.20
sg_other_SCM_M = 2.60
sg_fine_N = 2.65
sg_coarse_O = 2.70
sg_other_P = 2.60

Table 11. Created by using the proposed code and scenario 3

NDOT Concrete Mix Design – Weight Summary

(1 Cubic Yard of Concrete)

Project Number: 101

Class of Concrete: NDOT Structural

Cement (A):   893.0 lb

Fly Ash (B):   0.0 lb

Silica Fume (C):   63.0 lb

Other SCM (D):   0.0 lb

Fine Aggregate (Y):   1083 lb

Coarse Aggregate (Z):   1226 lb

Other Aggregate (AA):   118 lb

Water (Q):   272 lb

End of Mix Design Summary

Scenario 3 referenced from:

https://static1.squarespace.com/static/59c91fb8f7e0ab097112fbc4/t/5b5b22a81ae6cf14d8dcd716/1532699305261/Mix+Designs-COMBINED+072718.pdf

References:

Nebraska Department of Transportation. NDOT Concrete Mix Excel.
https://dot.nebraska.gov/media/jp3paote/mix-design-submittal.xlsx (accessed February 2026).

Nebraska Department of Transportation. Optimized Aggregate Gradations for Portland Cement Concrete Mix Designs Evaluation: Final Report (Report P-336). Lincoln, NE: Nebraska Department of Transportation.
https://dot.nebraska.gov/media/3isfdv45/final-report-p336.pdf (accessed February 2026).

Nebraska Department of Transportation. Standard Specifications for Highway Construction. Lincoln, NE: Nebraska Department of Transportation, 2017.
https://dot.nebraska.gov/media/g4qp4y0d/2017-specbook.pdf (accessed February 2026).

Reference material for our 4 tested scenarios:

Scenario 1 → Nebraska Department of Transportation. 2018. Pavement Design Manual. Lincoln, NE: Nebraska Department of Transportation.
https://dot.nebraska.gov/media/jjwpyezr/pavdesignmanual.pdf

Scenario 2 → Nebraska Department of Transportation. 2018. Mix Designs – Combined.
https://static1.squarespace.com/static/59c91fb8f7e0ab097112fbc4/t/5b5b22a81ae6cf14d8dcd716/1532699305261/Mix+Designs-COMBINED+072718.pdf

Scenario 3 → Nebraska Department of Transportation. 2018. Pavement Design Manual. Lincoln, NE: Nebraska Department of Transportation.
https://dot.nebraska.gov/media/jjwpyezr/pavdesignmanual.pdf

Scenario 4 → Nebraska Department of Transportation. 2018. Mix Designs – Combined.
https://static1.squarespace.com/static/59c91fb8f7e0ab097112fbc4/t/5b5b22a81ae6cf14d8dcd716/1532699305261/Mix+Designs-COMBINED+072718.pdf