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APPLICATION DEVELOPMENT IN PYTHON FOR CONCRETE MIX DESIGN ACCORDING TO *SNI 7656-2012*

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ABSTRACT

Concrete mix design is an important aspect in concrete construction process as it determines the quality of produced concrete. In practice, the process of getting a suitable concrete mix for a certain project is repetitive process. For repetitive work, it is an advantage to be carried out by using an application. This study focuses on the development of the application that can used to design the concrete mixes. Python programming language was employed in the development because it offers easiness and supports a rapid application development. The work is started by studying the procedure outlined SNI 7656-2012. The pseudocode of the application was then developed and implemented in Python. Tkinter, the Python package, was used in the development of Graphical User Interface for the application. The application was successfully developed and tested to carry out the concrete mix design.

Keywords: *concrete mixture, aggregate, cement, Python, TkInter.*

A. INTRODUCTON

Concrete is one of the widely used construction materials in Indonesia as it is economically competitive compared to the other alternatives and considerably durable. It is made primarily by mixing cement, aggregate and water. Additive and/or admixture may also be added to the concrete mixture to improve certain properties and characteristics of concrete. Since concrete is produced by mixing several ingredients, its quality depends on the proportion of its ingredients. Thus, it is important to carry out concrete mix design accurately and properly.

In a simple term, concrete mix design is the process of selecting proper amount of cement, aggregate, water and other ingredients to achieve certain desired properties of concrete. In practice, the design of a concrete mix is usually conducted by following a guidance given in the appropriate code. For this study, Indonesian code/standard called SNI 7656 (2012), which is adopted and modified from ACI 211.1 (2009) is used. Normally, the obtained concrete mixture must be first trialled in the laboratory to make sure that the resulted concrete mix design performs as expected. After the trial mix, some adjustment might be needed and the concrete mix must be reproportioned. The process of concrete mix design normally needs to be repeated several times before the final concrete mix is obtained. Since the process of concrete mix design is repetitive, it is better to use the computer application to help in the design process.

One of the advantages of the computer application or software is that it is very suitable to be used a repetitive task. With the help of computer application, the concrete mix design can be carried out efficiently without compromising the accuracy. Therefore, the purpose of this study is to develop application that can help in proportioning concrete mixture using Python programming language.

Python is employed because it is efficient to be used and supported by a large number of packages/modules that can bolster the rapid application development. One package that is heavily used in the development is Tkinter. Tkinter is the standard Python interface to Tk

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Graphical User Interface (GUI) toolkit that can be used to build GUI for an application.

B. LITERATURE REVIEW

Concrete

Concrete is a composite material made primarily of Portland cement, coarse aggregate, fine aggregate and water, with or without additive and/or admixture. It has been used since ancient times and has evolved significantly over the centuries. The versatility and durability of concrete have made it one of favorite construction materials in construction industry, with applications ranging from form roads, bridges, dams, residential building, industrial buildings and commercial buildings.

Concrete is basically formed by mixing cement, aggregate and water (Shetty, 2005). When mixed properly, water and cement become the paste that binds the aggregates together to produce concrete. Since the concrete made of several ingredients, the quality of concrete will depend on the proportion of its ingredients. The process of selecting the proper amount of each ingredient forming the concrete is called concrete mix design. Several methods are available for carrying out concrete mix design, with two popular ones are methods developed by American Concrete Institute (ACI 211.1, 2009) and Department of Environment (DOE). The American Concrete Institute method, developed in United States of America, focuses on water content per cubic meter of concrete. It specifies relative water contents for different workability and determines the bulk volume of coarse aggregate based on maximum aggregate size and fine aggregate grading. Meanwhile, DOE method is a standard approach for concrete mix design in the United Kingdom. The DOE method provides a systematic way to design concrete mixes, considering both strength and workability (Chandrakar and Mishra, 2012).

In Indonesia, for concrete mix design, the guidance that must be followed is SNI 7656 (2012). The guidance is basically used to obtain the initial proportion of concrete ingredients. To get the final concrete mix, one normally must carry out trial mixes several times. It is very important to design concrete mix properly in order to get concrete with the desired property.

Python Programming Language

Python is a high-level programming language that is versatile, easy to be learned and used, and free. In addition, Python has a large collection of libraries to support rapid application development. Moreover, Python is cross-platform and can run on various operating systems such as Windows, Linux, and macOS. As such, it is suitable for developers that want to build functional application efficiently that can run on any operating system.

Python has been developed so that it can be used by developers to easily and quickly built an application that be integrated easily to computer systems. Python was first developed by Guido van Rossum in 1991 (Trappenberg, 2022).

Python has been designed to have Python codes easy to read by the use of mandatory indentations to separate between among the blocks of Python codes. With object oriented support in Python, it empowers developers to write clear and logical codes for small and large scale projects (Dawson, 2010).

Beberapa *library* Python yang sering digunakan dalam bidang sain dan rekayasa adalah antara lain NumPy, math, Pandas, dan Matplotlib (Bayen et al., 2021). NumPy merupakan *library* Python yang umum digunakan untuk operasi matematika pada *arrays*/vektor dan matriks. Pandas adalah *library* Python yang dapat digunakan untuk manipulasi dan analisis data. Sedangkan math merupakan library yang menyediakan berbagai fungsi matematika seperti fungsi-fungsi untuk bilangan, trigonometri, dan pangkat dan logaritma. Sementara itu, Matplotlib adalah merupakan *library* Python yang sangat penting untuk keperluan pembatan grafik data. Data ditampilkan dalam berbagai bentuk grafik dengan kualitas yang siap untuk publikasi.

Tkinter

Tkinter is the de-facto standard GUI toolkit for Python. It is a thin object-oriented layer on top of Tcl/Tk, which is a robust and platform-independent windowing toolkit. Tkinter is included with Python as a standard library and is known for its simplicity and ease of use, making it an ideal choice for beginners in GUI programming (Hunt, 2023).

Tkinter simplifies the creation of graphical user interfaces. It offers a range of widgets, including buttons, labels, text boxes, and canvas for drawing shapes. With straightforward syntax, Tkinter allows developers to build native-looking applications on different operating systems. While debugging can be challenging, its simplicity and powerful feature make it an excellent choice for beginners.

C. METHODOLOGY

The step-by-step procedures for designing concrete mixes based SNI 7656-2012 can be stated as follows:

1. Prepare the required material information including specific gravity of cement, specific gravity of coarse aggregate, specific gravity of fine aggregate, absorption of coarse aggregate, absorption of fine aggregate
2. Determine the desired slump
3. Determine the nominal maximum aggregate size
4. Estimate of mixing water and air content using Table 1.

Table 1. Approximate mixing water and air content requirements for different slumps and nominal maximum sizes of aggregates

	Water, Kg/m^3 of concrete for indicated nominal maximum sizes of aggregate							
Slump, mm	9.5	12.5	19	25	37.5	50	75	150
Non-air-entrained concrete								
25 to 50	207	199	190	179	166	154	130	113
75 to 100	228	216	205	193	181	169	145	124
150 to 175	243	228	216	202	190	178	160	—
Approximate amount of entrapped air in non-air-entrained concrete, percent	3	2.5	2	1.5	1	0.5	0.3	0.2
Air-entrained concrete								
25 to 50	181	175	168	160	150	142	122	107
75 to 100	202	193	184	175	165	157	133	119
150 to 175	216	205	197	184	174	166	154	—
Recommended average total air content, percent for level of exposure:								
Mild exposure	4.5	4.0	3.5	3.0	2.5	2.0	1.5	1.0
Moderate exposure	6.0	5.5	5.0	4.5	4.5	4.0	3.5	3.0
Extreme exposure	7.5	7.0	6.0	6.0	5.5	5.0	4.5	4.0

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5. Determine water to cement ratio according to Table 2.

Table 2. Relationship between water-cement ratio and compressive strength of concrete

Compressive strength at 28 days, MPa*	Water-cement ratio, by mass	
	Non-air-entrained concrete	Air-entrained concrete
40	0.42	—
35	0.47	0.39
30	0.54	0.45
25	0.61	0.52
20	0.69	0.60
15	0.79	0.70

6. Calculation of cement content using the results from step 4 and step 5. Cement content is equal to water content divided by water to cement ratio.
7. Estimate of coarse aggregate content using Table 3.

Table 3. Volume of coarse aggregate per unit of volume of concrete

Nominal maximum size of aggregate, mm	Volume of dry-rodded coarse aggregate per unit volume of concrete for different fineness moduli† of fine aggregate			
	2.40	2.60	2.80	3.00
9.5	0.50	0.48	0.46	0.44
12.5	0.59	0.57	0.55	0.53
19	0.66	0.64	0.62	0.60
25	0.71	0.69	0.67	0.65
37.5	0.75	0.73	0.71	0.69
50	0.78	0.76	0.74	0.72
75	0.82	0.80	0.78	0.76
150	0.87	0.85	0.83	0.81

8. Estimate of fine aggregate content based on estimated concrete mass (with help of Table 4) or absolute volume of ingredients (with help of specific gravity of ingredients).

Table 4. First estimate of mass of fress concrete

Nominal maximum size of aggregate, mm	First estimate of concrete unit mass, kg/m³*	
	Non-air-entrained concrete	Air-entrained concrete
9.5	2280	2200
12.5	2310	2230
19	2345	2275
25	2380	2290
37.5	2410	2350
50	2445	2345
75	2490	2405
150	2530	2435

The result of concrete mix design from this procedure is the first estimate of a concrete mixture proportion. The trial mix must be conducted and the fresh concrete should be tested for slump, unit weight, yield, air content, and its tendencies to segregate, bleed and finishing characteristics. In addition, the hardened concrete samples should be tested for compressive and flexural strength.

As can be seen in this section, the calculation process uses a lot of tables. Python has a native feature called dictionary that is suitable to deal with table. Dictionaries are used to store data values in pairs of keys and their values. Thus, one can get a value based on a key. If the given key is in between two keys, then the interpolation must be conducted to obtain the appropriate value. Figure 1 shows the use of dictionary in the application in determining coarse aggregate content.

```
def volume_coarse_aggregate(max_CA, FM, CA_OD_density):
    # max_CA = maximum nominal size of coarse aggregate
    # FM = fineness modulus
    # CA_OD_density = dry rodded mass of coarse aggregate

    table3_1 = {2.4: 0.5, 2.6: 0.48, 2.8: 0.46, 3.0:0.44}
    table3_2 = {2.4: 0.59, 2.6: 0.57, 2.8: 0.55, 3.0:0.53}
    table3_3 = {2.4: 0.66, 2.6: 0.64, 2.8: 0.62, 3.0:0.6}
    table3_4 = {2.4: 0.71, 2.6: 0.69, 2.8: 0.67, 3.0:0.65}
    table3_5 = {2.4: 0.75, 2.6: 0.73, 2.8: 0.71, 3.0:0.69}
    table3_6 = {2.4: 0.78, 2.6: 0.76, 2.8: 0.74, 3.0:0.72}
    table3_7 = {2.4: 0.82, 2.6: 0.8, 2.8: 0.78, 3.0:0.76}
    table3_8 = {2.4: 0.87, 2.6: 0.88, 2.8: 0.83, 3.0:0.81}
    if max_CA == 9.5:
        if FM in list(table3_1.keys()):
            return table3_1[FM]*CA_OD_density
        else: # interpolated
            dfm = 0.2
            FM_0=mt.floor((FM-dfm/10)*10)/10
            vol_CA = ((table3_1[mt.floor((FM_0+dfm)*10)/10]-table3_1[FM_0])*((FM-FM_0)/(dfm)))+table3_1[FM_0]
            return vol_CA*CA_OD_density

    elif max_CA == 12.5:
        if FM in list(table3_2.keys()):
            return table3_2[FM]*CA_OD_density
        else: # interpolated
            dfm = 0.2
            FM_0=mt.floor((FM-dfm/10)*10)/10
            vol_CA = ((table3_2[mt.floor((FM_0+dfm)*10)/10]-table3_2[FM_0])*((FM-FM_0)/(dfm)))+table3_2[FM_0]
            return vol_CA*CA_OD_density
```

Figure 1. Implementation of Table 3 in Python with dictionary

D. RESULTS AND DISCUSSION

The application developed in this study was employed to solve the concrete mix design problem taken from SNI 7656-2012. The data for the problem are as follows:

- Required average strength will be 24 MPa

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- Slump is 75 to 100 mm
- The nominal maximum size of 37.5 mm
- The coarse aggregate has dry-rodded mass is 1600 kg/m^3
- The specific gravity of cement is 3.15
- Coarse aggregate bulk specific gravity is 2.68
- Coarse aggregate absorption is 0.5%
- Fine aggregate bulk specific gravity is 2.64
- Fine aggregate absorption is 0.7
- Fineness modulus is 2.8.

Figure 2 shows the application when it is run. One then needs to fill the required input data such as required slump, specific gravity of the cement and so on as shown in Figure 3. Once all required input data are filled, one just needs to press “Design concrete mix!” button to start the design process. The concrete mix design result is also shown in Figure 2. In calculating the amount of fine aggregate, there are two approaches that can be used, one is based on estimated concrete mass (mass basis) and the other based on absolute volume of ingredients (volume basis). Therefore, there are results for the amount of aggregate, one from mass basis method and the other from volume basis method.

The mix design result shown in Figure 2 will be validated with the manual calculation presented in Appendix 2 of ACI 211.1. Table 1 presents the concrete mix design from manual calculation. If the mix design result from application is compared with that of manual calculation, they are basically the same, except for rounding values in the calculation. Thus, the application is able to carry out the design properly and accurately.

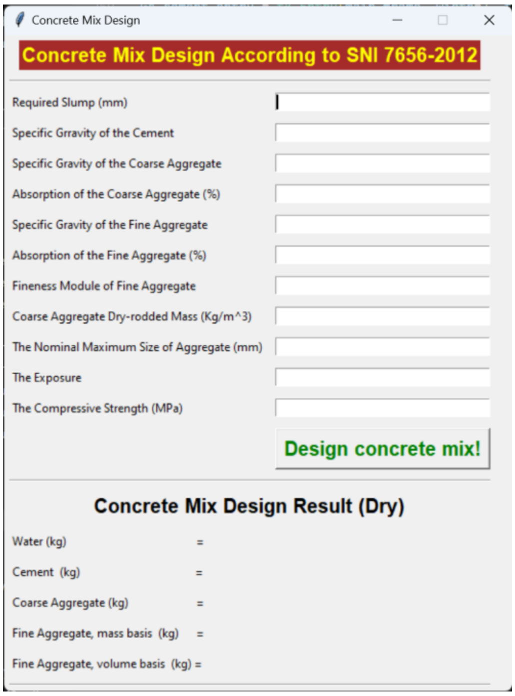

Figure 2. The appearance of application when run

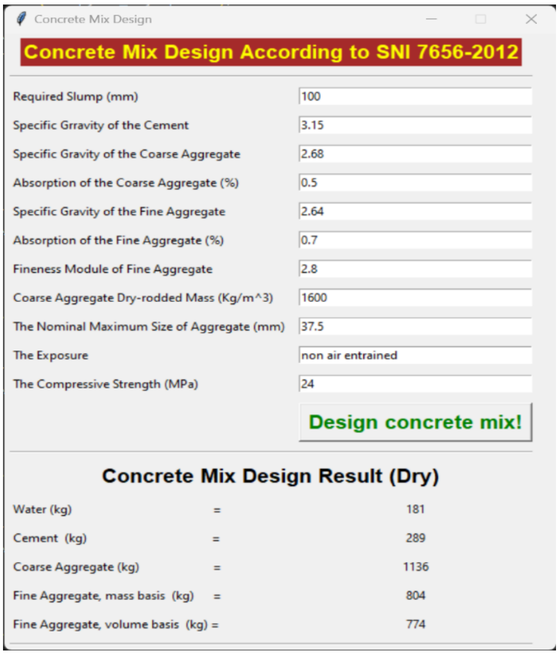

Figure 3. The appearance of application when the required data filled and the design result presented

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Table 5. Concrete mix design result: based on estimated concrete mass and absolute volume of ingredients

	Based on estimated concrete mass, kg	Based on absolute volume of ingredients, kg
Water (net mixing)	181	181
Cement	292	292
Coarse aggregate (dry)	1136	1136
Sand (dry)	801	771

E. CONCLUSIONS

In the present study, an attempt was made to develop a Python GUI application that can be used to design concrete mixes. The fully functional application for concrete mix design was successfully developed and validated with manual calculation. It is clearly demonstrated that the use of application in the design process of concrete mixes is practical and efficient.

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