

Computer Programming for Engineers

Assignment 1 (Concrete Beam Design)

a) Step 1: Problem Identification and Statement

The Objective is to write the program code for a software that designs a rectangular reinforced concrete beam. The concrete beam, to be designed, has to carry a distributed permanent load with a 60% margin of load and a variable load with a 20% margin of load. The beam will be supported on two masonry walls 200mm thick and of a given length (in metres). The reinforced concrete unit weight has a constant value of 25 kN/m³. Write a program code that takes input from the user for the length, permanent load, and the variable load and computes the size of the beam (depth and width), the total characteristic load, the Shear Force (V) and the Bending Moment (M), and outputs these on the screen.

b) Step 2: Gathering Information and I/O Description

In order to compute the size, total characteristic load, shear force and bending moment, we use the formulas and variables provided along with the input from the user and gather all missing information in one place.

- User Inputs and Constants:

- Length of the beam : L m
- Permanent load : gk kN/m
- Variable load : qk kN/m
- Reinforced Concrete Unit Weight : Cuw = 25 kN/m³
- Permanent Load Margin : PLM = 0.60
- Variable Load Margin : VLM = 0.20

- Size of the beam:

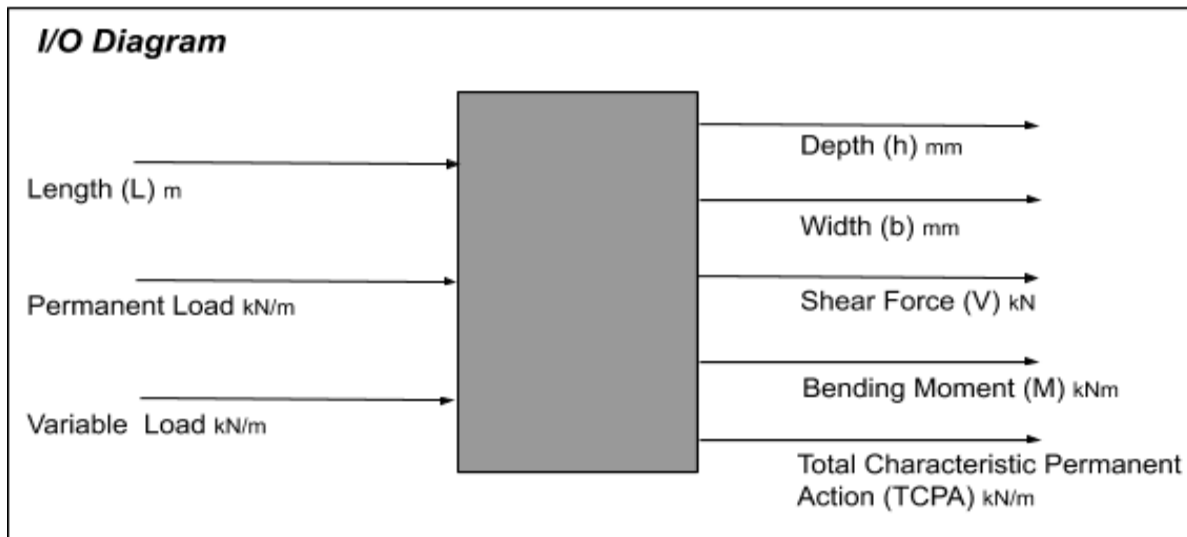
- Depth of the beam : h mm
- Width of the beam : b mm
- Length in mm : (L * 1000) mm
- $h = (L * 1000) / 14$
- $b = 0.4 * h$

- Total Characteristic Load:

- Beam Self Weight : Ws kN/m
- $Ws = (h / 1000) * (b / 1000) * Cuw$
- Total Characteristic Permanent Action : TCPA kN/m
- $TCPA = Ws + gk$

- Shear Force (V) and Bending Moment (M)
 - $W_d = (1 + PLM) \cdot g_k + (1 + VLM) \cdot q_k$
 - Shear Force : V kN
 - Bending Moment : M kNm
 - $V = W_d \cdot (L / 2)$
 - $M = W_d \cdot (L^3 / 8)$

The I/O diagram for this problem is illustrated below:



The Output message with the relevant Input and Output information will be shown in a similar pattern to this:

This software designs a rectangular beam. Enter the beam specifications:

Length: 6

Permanent load (gk, kN/m): 10

Variable load (qk, kN/m): 8

Here is a summary of the beam design:

The minimum values for the size of the beam are:

Depth = 429 mm, Width = 172 mm (Note the conversion to mm)

The total characteristic load = 11.8386 kN/m

Shear force (V) = 76.8 kN

Bending moment (M) = 115.2 kNm

Enter -1 to exit or any other number to repeat: -1

Program terminating ...

c) Step 3: Test Cases and algorithm

- Test Cases:

Test cases use sample input data that is used in manual calculations by the user to produce expected output data in order to verify the functionality of the program. For Test Cases, different ranges of data are used as follows;

L = 11, gk = 40, qk = 22 are input by the user

$$d = (11 \times 1000) / 14 = 785.7 = 786, b = 0.4 \times 786 = 314.4 = 314$$

$$Ws = (785.7/1000) \times (314.4/1000) \times 25 = 6.175714$$

$$TCPA = 6.175714 + 40 = 46.1757$$

$$Wd = (1 + 0.60) \times 40 + (1 + 0.20) \times 22 = 90.4$$

$$V = 90.4 \times (11/2) = 497.2$$

$$M = 90.4 \times (11^2 / 8) = 1367.3$$

L = 70, gk = 120, qk = 95 are input by the user

$$d = (70 \times 1000) / 14 = 5000, b = 0.4 \times 5000 = 2000$$

$$Ws = (5000/1000) \times (2000/1000) \times 25 = 250$$

$$TCPA = 250 + 120 = 370$$

$$Wd = (1 + 0.60) \times 120 + (1 + 0.20) \times 95 = 306$$

$$V = 306 \times (70 / 2) = 10710$$

$$M = 306 \times (70^2 / 8) = 187425$$

L = 800, gk = 1350, qk = 1050 are input by the user

$$d = (800 \times 1000) / 14 = 57142.9 = 57143, b = 0.4 \times 57143 = 22857.2 = 22857$$

$$Ws = (57142.9/1000) \times (22857/1000) \times 25 = 32653.14286$$

$$TCPA = 32653.14286 + 1350 = 34003.1$$

$$Wd = (1 + 0.60) \times 1350 + (1 + 0.20) \times 1050 = 3420$$

$$V = 3420 \times (800 / 2) = 1368000$$

$$M = 3420 \times (800^2 / 8) = 273600000$$

L = 1, gk = 1, qk = 1 are input by the user

$$d = (1 \times 1000) / 14 = 71.4 = 71, b = 0.4 \times 71 = 28.4 = 28$$

$$Ws = (71.4/1000) \times (28.4/1000) \times 25 = 0.050714$$

$$TCPA = 0.050714 + 1 = 1.050714$$

$$Wd = (1 + 0.60) \times 1 + (1 + 0.20) \times 1 = 2.8$$

$$V = 2.8 \times (11 / 2) = 1.4$$

$$M = 2.8 \times (11^3 / 8) = 0.35$$

Input				Output				
No.	L (m)	gk	qk	h (mm)	b (mm)	V	M	TCPA
1	6	10	8	429	172	76.8	115.2	11.8386
2	11	40	22	786	314	497.2	1367.3	46.1734
3	-20	-	-	Should prompt the user to input again				
4	30	-100	-	Should prompt the user to input again				
5	27	130	-78	Should prompt the user to input again				
6	70	120	95	5000	2000	10710	187425	370
7	800	1350	1050	57143	22857	1368000	273600000	34003.1
8	1	1	1	71	28	1.4	0.35	1.050714

- Algorithm:

Main() Function

Repeat

Assign 25 to Ws

Assign 0.60 to PERMANENT_LOAD_MARGIN

Assign 0.20 to VARIABLE_LOAD_MARGIN

Repeat

Print "Enter the Length of the Beam", newline

Read value into length

If length is less than or equal to zero

Print "You Must Enter a Positive Value for Length.", newline

While length is less than or equal to zero

Repeat

Print "Enter the Permanent Load of the Beam", newline

Read value into gk

If gk is less than or equal to zero

Print "You Must Enter a Positive Value for the Permanent Load.", newline

While gk is less than or equal to zero

Repeat

Print "Enter the Variable Load of the Beam", newline

Read value into qk

If qk is less than or equal to zero

Print "You Must Enter a Positive Value for the Variable Load.", newline

While qk is less than or equal to zero

Assign $(\text{length} * 1000) / 14$ to h

Assign $(0.4 * h)$ to b

Assign $((h / 1000) * (b / 1000) * C_{uw})$ to Ws

Assign $(W_s + g_k)$ to TCPA

Assign $((1 + \text{PERMANENT_LOAD_MARGIN}) * g_k) + (1 + \text{VARIABLE_LOAD_MARGIN}) * q_k$ to Wd

Assign $(W_d * \text{length} / 2)$ to V

Assign $(W_d * \text{length}^2 / 8)$ to M

Print "The depth of the beam is ", h, "mm", newline

Print "The width of the beam is ", b, "mm", newline

Print "The Total Characteristic Load is ", TCPA, "kN/m", newline

Print "The Shear Force is ", V, "kN", newline

Print "The Bending Moment is ", M, "kNm", newline

Print "Enter -1 to Exit or any other number to repeat", newline

Read value into counter1

Print "Program Terminating", newline

While counter1 is not equal to -1

d) Step 4: Code or implementation

```
#include <iostream> // Required for cout, cin, endl
#include <iomanip> // Required for setprecision
#include <cmath>
using namespace std; // The compiler will use all the library filenames in std
// The main function - the starting point of our program
int main() {
    // Declare and initialize objects
    double length = 0, gk = 0, qk = 0, h = 0, b = 0, Ws = 0, TCPA = 0, Wd = 0, V = 0, M = 0;
    int counter1;
    const int Cuw = 25;
    const double PERMANENT_LOAD_MARGIN = 0.60;
    const double VARIABLE_LOAD_MARGIN = 0.20;
    do{
        // Print values
        do
        {
            cout << "Enter the Length of the Beam (m)" << endl;
            cin >> length;
            if (length <= 0)
                cout << "You Must Enter a Positive Value for Length." << endl;
        }
        while (length <= 0);
        do
        {
            cout << "Enter the Permanent Load of the Beam (gk, kN/m):" << endl;
            cin >> gk;
            if (gk <= 0)
                cout << "You Must Enter a Positive Value for the Permanent Load." << endl;
        }
        while (gk <= 0);
        do
        {
            cout << "Enter the Variable Load of the Beam (qk, kN/m):" << endl;
            cin >> qk;
            if (qk <= 0)
                cout << "You Must Enter a Positive Value for the Variable Load." << endl;
        }
        while (qk <= 0);
        //Calculating the Size
        h = (length * 1000) / 14;
        b = 0.4 * round(h);
        //Calculating Total Characteristic Load
        Ws = (h/ 1000) * (b/1000) * Cuw;
        TCPA = Ws + gk;
        //Calculating Shear Force and Bending Moment
```

```

        Wd = (((1 + PERMANENT_LOAD_MARGIN)*gk) + ((1 + VARIABLE_LOAD_MARGIN)*qk));
        V = Wd * (length / 2);
        M = Wd * ((length*length) / 8);
//Printing the Values
cout << "The depth of the beam is " << round(h) << " mm" << endl;
cout << "The width of the beam is " << round(b) << " mm" << endl;
cout << "The Total Characteristic Load is " << setprecision (6) << TCPA << " kN/m" << endl;
cout << "The Shear Force is " << V << " kN" << endl;
cout << "The Bending Moment is " << M << " kNm" << endl;
//Prompting to repeat the program
cout << "Enter -1 to Exit or any other number to repeat"<<endl;
cin>> counter1;
}while(counter1 != -1);
    cout << "Program Terminating ..."<<endl;
system("pause");
// Exit program
return 0;
}

```

e) Step 5: Test and Verification

This step ensures if the final source code contains any errors or not. All the test cases in Step 3 are tried by running the program and the expected outcomes are compared with the actual outcomes.

Test Case 1:

```
Enter the Length of the Beam
6
Enter the Permanent Load of the Beam
10
Enter the Variable Load of the Beam
8
The depth of the beam is 429 mm
The width of the beam is 172 mm
The Total Characteristic Load is 11.8386 kN/m
The Shear Force is 76.8 kN
The Bending Moment is 115.2 kNm
Enter -1 to Exit or any other number to repeat
-1
sh: pause: command not found
Program ended with exit code: 0|
```

Test Case 2:

```
Enter the Length of the Beam
11
Enter the Permanent Load of the Beam
40
Enter the Variable Load of the Beam
22
The depth of the beam is 786 mm
The width of the beam is 314 mm
The Total Characteristic Load is 46.1757 kN/m
The Shear Force is 497.2 kN
The Bending Moment is 1367.3 kNm
Enter -1 to Exit or any other number to repeat
-1
sh: pause: command not found
Program ended with exit code: 0|
```


Test Case 3:

```
Enter the Length of the Beam
-20
You Must Enter a Positive Value for Length.
Enter the Length of the Beam
|
```

Test Case 4:

```
Enter the Length of the Beam
30
Enter the Permanent Load of the Beam
-100
You Must Enter a Positive Value for the Permanent Load.
Enter the Permanent Load of the Beam
|
```

Test Case 5:

```
Enter the Length of the Beam
27
Enter the Permanent Load of the Beam
130
Enter the Variable Load of the Beam
-78
You Must Enter a Positive Value for the Variable Load.
Enter the Variable Load of the Beam
|
```

Test Case 6:

```
Enter the Length of the Beam
70
Enter the Permanent Load of the Beam
120
Enter the Variable Load of the Beam
95
The depth of the beam is 5000 mm
The width of the beam is 2000 mm
The Total Characteristic Load is 370 kN/m
The Shear Force is 10710 kN
The Bending Moment is 187425 kNm
Enter -1 to Exit or any other number to repeat
-1
sh: pause: command not found
Program ended with exit code: 0|
```

Test Case 7:

```
Enter the Length of the Beam
800
Enter the Permanent Load of the Beam
1350
Enter the Variable Load of the Beam
1050
The depth of the beam is 57143 mm
The width of the beam is 22857 mm
The Total Characteristic Load is 34003.1 kN/m
The Shear Force is 1.368e+06 kN
The Bending Moment is 2.736e+08 kNm
Enter -1 to Exit or any other number to repeat
-1
sh: pause: command not found
Program ended with exit code: 0
```

Test Case 8:

```
Enter the Length of the Beam
1
Enter the Permanent Load of the Beam
1
Enter the Variable Load of the Beam
1
The depth of the beam is 71 mm
The width of the beam is 28 mm
The Total Characteristic Load is 1.05071 kN/m
The Shear Force is 1.4 kN
The Bending Moment is 0.35 kNm
Enter -1 to Exit or any other number to repeat
-1
sh: pause: command not found
Program ended with exit code: 0
```

User Guide

This software can be used by civil engineers in calculating the dimensions and dynamics of a concrete beam very efficiently. It would provide them with the depth and width of the beam and also with the Total Characteristic Load. Additionally the software will also provide the Shear Force and Bending Moment for the beam to assist them further. It only takes as input the length, permanent load and the variable load of the beam in order to provide with the relevant details for the beam. The software also ensures that the units for each measurement are converted adequately before used in any calculations.