**Proceedings of the
International Conference on Mechanical Engineering and Renewable Energy 2017
(ICMERE2017) 18 – 20 December, 2017, Chittagong, Bangladesh**

ICMERE2017-PI-131

ANALYSIS OF SIMPLE AND CANTILEVER BEAMS USING MATLAB GRAPHICAL USER INTERFACES

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***Abstract**-Shear force (SF) and bending moment (BM) diagrams carry great importance for the analysis of beams because these are the preliminaries for the study of developed stresses and deflections in beams. Software package MATLAB has sophisticated computational and graphic representational abilities which can be used as a convenient tool for the analysis of beams through the generation of SF and BM diagrams for any beams with given loading and supporting conditions. In the present work, a MATLAB Graphical User Interface (GUI) has been developed that can be used to produce and analyze the SF and BM diagrams for simply supported and cantilever beams loaded with any combination of concentrated, uniformly distributed and uniformly varying loads. This GUI can make the analysis of beams quick, simple and errorless. Moreover, the GUI can be used as an effective educational tool for the students of Mechanical, Civil or Structural Engineering.*

Keywords: SF, BM, MATLAB, GUI, Beam Analysis

1. INTRODUCTION

1.1 Introduction to MATLAB and GUI

The name MATLAB stands for *matrix laboratory.* MATLAB is a software package for high-performance numerical computation and visualization. It integrates computation, visualization, and programming in an easy-to-use environment where problems and solutions are expressed in familiar mathematical notation. Typical uses include

- Math and computation
- Algorithm development
- Data acquisition
- Modelling, simulation, and prototyping
- Data analysis, exploration, and visualization
- Scientific and engineering graphics
- Application development, including graphical user interface building

MATLAB is an interactive system whose basic data element is an array that does not require dimensioning. It has evolved over a period of years with input from many users. In university environments, it is the standard instructional tool for introductory and advanced courses in mathematics, engineering, and science. In industry, MATLAB is the tool of choice for high-productivity research, development, and analysis.

A graphical user interface (GUI) is a graphical display in one or more windows containing controls, called *components* that enable a user to perform interactive tasks.

GUI components can include menus, toolbars, push buttons, radio buttons, list boxes, and sliders—just to name a few. GUIs created using MATLAB tools can also perform any type of computation, read and write data files, communicate with other GUIs, and display data as tables or as plots.[1]

1.2 Why Use GUIs

GUIs are developed for utilizing the computational power of computers interactively. Using GUIs a user can communicate with the computer easily, give specific inputs and instructions, and visualize the results of the calculations or analysis in an easy to understand way.

The user of the GUI does not have to create a script or type commands at the command line to accomplish the tasks. Unlike coding programs to accomplish tasks, the user of a GUI need not understand the details of how the tasks are performed.[1]

In education sectors, MATLAB GUIs, with their very intuitive controls, provide an interactive learning environment and they allow the user to immediately see the impact of changes in various analysis parameters [2]. It has been observed by Kolb [3] that active experimentation leads to better than 90% retention of material compared to a 30% retention for reflective observations. GUIs offer a chance for active experimentations to the students. Efficient GUI design [4] will eliminate the direct use of lookup tables and graphs.

In engineering analysis, all the tedious calculations can be done by a GUI program so that the user only needs to check the validity of the input parameters and the corresponding results. The MATLAB GUI containing the entire input and output parameters can also be saved to a file or printed for documentation. Furthermore, any nonlinear and iterative calculations can be done in less than a second.[2]

1.3 Introduction to Beam Analysis

Beams are usually straight horizontal members used primarily to carry vertical loads. Quite often they are classified according to the way they are supported, as indicated in Figure 1.[5]

When a bar, i.e. a beam, carries lateral forces, two important types of loading action are set up at any section: these are a bending moment and a shearing force. Bending moment is defined as the summation of moments about the centroidal axis of any selected section of all loads acting either to the left or to the right side of the section, and is expressed mathematically as

$$M = (\sum M)_L = (\sum M)_R \qquad (1)$$

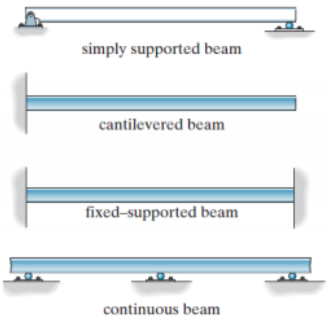


Fig. 1: Types of Beams

Shearing force at any selected section is defined as the net vertical unbalance determined from the summation of the vertical components of the external loads acting on the segment to the *left* of the section, and is expressed mathematically as

$$V = (\sum F_y)_L \qquad (2)$$

As a sign convention, positive effects (shear or moment) are produced by upward acting forces and negative effects by downward forces.[6]

1.4 Importance of SF and BM Diagrams in Beam Analysis

The basic problem in strength of materials is to determine the relations between the stresses and deformations caused by loads applied to any structure. In the case of beams, where bending loads are involved, these loading effects take the form of *Shear* and *Moment*. Two kinds of stresses act over the transverse section of a beam:

i) A **bending stress**, which varies directly with the bending moment, and

ii) A **shearing stress**, which varies directly with the shear.

So, as a preliminary to the study of stresses in beams, the variation or distribution of shear and moment in beams subjected to various combinations of loadings under different conditions of support has to be known.[6]

Shear Force (SF) and Bending Moment (BM) diagrams are the plots *V-x* and *M-x* respectively and they give a graphical representation of the distribution of the shear and moment along the span of a beam. So, in the analysis and design of beams, SFD and BMD carry a great importance.

2. OBJECTIVES

2.1 Beam Analysis Using MATLAB GUI

In the analysis of beams, use of MATLAB or GUI is not a new or unique approach. In the References section, some of the previous works in this field have been cited. See, ref.[2],[3],[5],[7],[8] and [9]. But none of them is general for any kind of beams loaded with any kind of loadings.

In present work, a MATLAB GUI has been developed which can be used to produce and analyze SF and BM diagrams for Simply Supported and Cantilever beams loaded with any number of Concentrated, Uniformly Distributed and/or Uniformly Varying loads. The scope and principal for further development has also been illustrated.

2.2 Developing a General Algorithm for Beam Analysis

For developing a GUI software that can produce SF and/or BM diagrams of beams loaded with any kind of loads, a general algorithm must be developed and implemented in ‘code’ using some programming language. In this work, the algorithm and MATLAB Script necessary for the analysis of Simple and Cantilever beams has been developed. The script is used along with a MATLAB GUI to analyze and produce SF and BM Diagrams of Simple and/or Cantilever beams.

3. PRINCIPLES OF BEAM ANALYSIS GUI DEVELOPMENT

3.1 Flowchart of a GUI Designing Procedure

Figure 2 illustrates the main aspects of GUI designing process[1]—

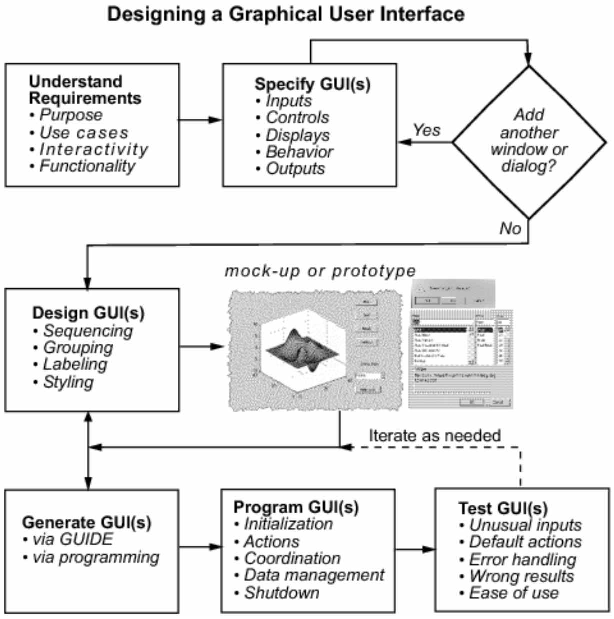


Fig. 2: GUI designing principle

3.2 Ways of Creating a MATLAB GUI

MATLAB GUIs can be created in two ways:

1) Using GUIDE (GUI Development Environment), an interactive GUI construction kit that provides a set of tools for creating graphical user interfaces (GUIs). These tools simplify the process of laying out and programming GUIs.

2) Creating M-files that generate GUIs as functions or scripts (programmatic GUI construction)

The two approaches can be combined to some degree. A GUI may be created with GUIDE and then modified programmatically. However, a GUI created programmatically cannot be modified with GUIDE later.[1]

3.3 General Algorithm for Constructing SF and BM Diagrams

The general algorithm for constructing SF and BM diagrams is as follows [6]—

1) Compute the reactions.

2) Compute values of shear at the change of load points, using Eq. (1) or $\Delta V = (area)_{load}$.

3) Sketch the shear diagram, determining the shape using the equation:

$$w = \frac{dV}{dx} = slope\ of\ shear\ diagram \qquad (3)$$

That is, the intensity of the load ordinate equals the slope at the corresponding ordinate of shear diagram.

4) Locate the points of zero shear.

5) Compute values of bending moment at the change of load points and at the points of zero shear, using either Eq. (2) or $\Delta M = (area)_{shear}$, whichever is more convenient.

6) Sketch the moment diagram through the ordinates of the bending moments computed in step 5. The shape of the diagram is determined from the equation:

$$V = \frac{dM}{dx} = slope\ of\ moment\ diagram \qquad (4)$$

4. RESULTS, DISCUSSIONS AND FUTURE AIM

4.1 Features and Layout of the Beam Analysis Toolbox GUI

The developed GUI contains following features—

1) It can produce SF and BM diagrams of Simple and Cantilever beams loaded with any number of Concentrated, Uniformly Distributed and/or Uniformly Varying loads.

2) In case of Simple beams, reactions at both ends and in case of Cantilever beams, moment and reactions at the fixed end is displayed.

3) Point of zero shear and zero moment is displayed. Maximum value of shear force and its position and maximum value of moment and its position is displayed.

4) An option for refreshing the entire interface for performing a new analysis is included.

5) Option for indicating wrong inputs is available.

Figure 3 shows the layout of the 'Beam Analysis Toolbox' GUI when opened in GUIDE.

Figure 4 shows the error dialog for the input of load position greater than the span of beam.

Figure 5 shows the pop-up dialog for the confirmation to close the GUI on pressing the 'Exit' key.

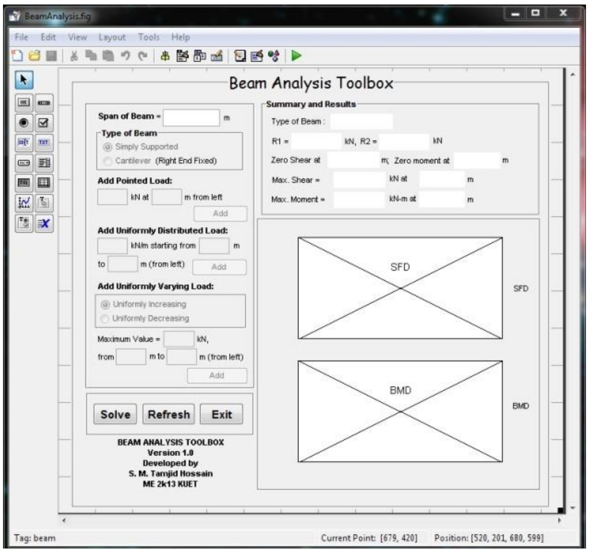
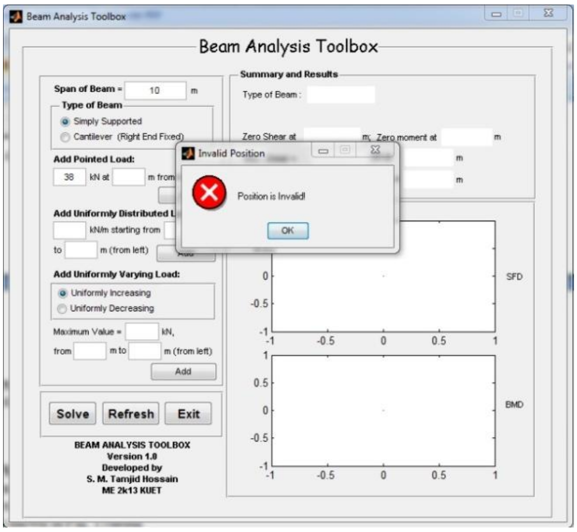


Fig. 3: Layout of the developed GUI in GUIDE


Span of Beam = 10 m

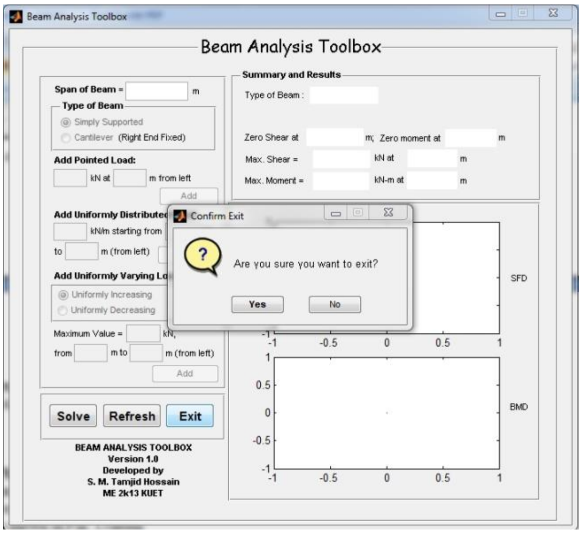
Add Pointed Load: 38 kN at

Invalid Position

Position is Invalid!

OK

Fig. 4: Error message for incorrect input of load position


Confirm Exit

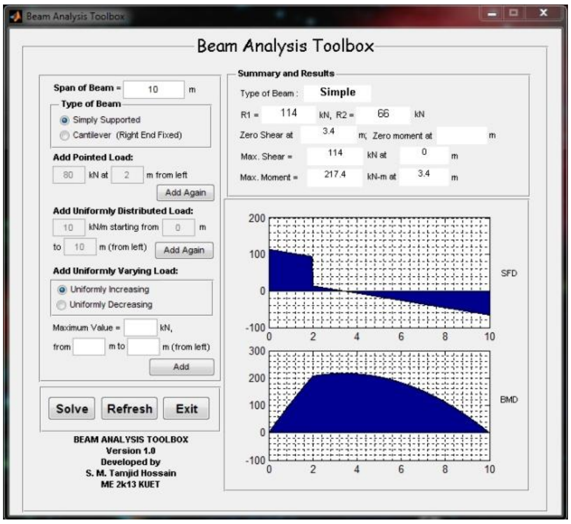
Are you sure you want to exit?

Yes No

Fig. 5: Popup dialog on pressing the Exit key

4.2 Solved Problems Using the GUI

In figures 6 to 17 example of some solved problems along with their traditional solution is presented. The problems are taken from ref.[6].



Beam Analysis Toolbox

Span of Beam = 10 m

Type of Beam
● Simply Supported
○ Cantilever (Right End Fixed)

Add Pointed Load:
80 kN at 2 m from left
Add Again

Add Uniformly Distributed Load:
10 kN/m starting from 0 m
to 10 m (from left) Add Again

Add Uniformly Varying Load:
● Uniformly Increasing
○ Uniformly Decreasing

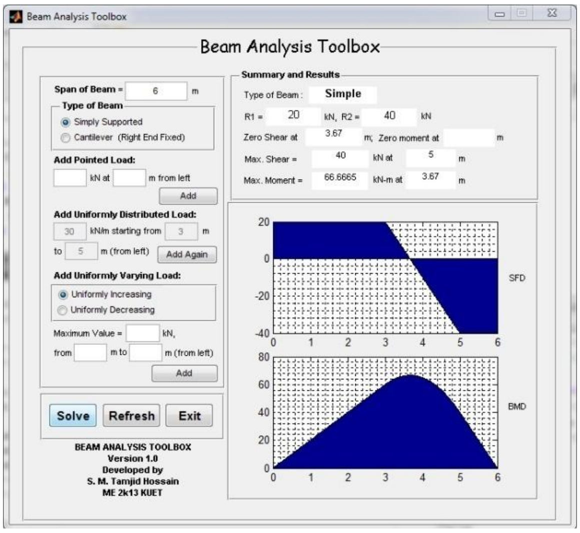
Maximum Value = kN,
from m to m (from left)
Add

Solve Refresh Exit

BEAM ANALYSIS TOOLBOX
Version 1.0
Developed by
S. M. Tamjid Hossain
ME 2k13 KUET

Summary and Results
Type of Beam : Simple
R1 = 114 kN, R2 = 66 kN
Zero Shear at 3.4 m; Zero moment at m
Max. Shear = 114 kN at 0 m
Max. Moment = 217.4 kN-m at 3.4 m

Fig. 6: GUI solution of Prob. 405



Beam Analysis Toolbox

Span of Beam = 6 m

Type of Beam
● Simply Supported
○ Cantilever (Right End Fixed)

Add Pointed Load:
kN at m from left
Add

Add Uniformly Distributed Load:
30 kN/m starting from 3 m
to 5 m (from left) Add Again

Add Uniformly Varying Load:
● Uniformly Increasing
○ Uniformly Decreasing

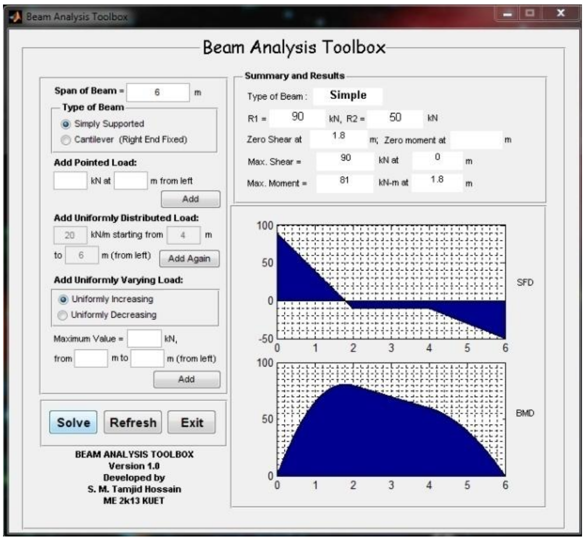
Maximum Value = kN,
from m to m (from left)
Add

Solve Refresh Exit

BEAM ANALYSIS TOOLBOX
Version 1.0
Developed by
S. M. Tamjid Hossain
ME 2k13 KUET

Summary and Results
Type of Beam : Simple
R1 = 20 kN, R2 = 40 kN
Zero Shear at 3.67 m; Zero moment at m
Max. Shear = 40 kN at 5 m
Max. Moment = 66.6665 kN-m at 3.67 m

Fig. 7: GUI solution of Prob. 407



Beam Analysis Toolbox

Span of Beam = 6 m

Type of Beam
● Simply Supported
○ Cantilever (Right End Fixed)

Add Pointed Load:
kN at m from left
Add

Add Uniformly Distributed Load:
20 kN/m starting from 4 m
to 6 m (from left) Add Again

Add Uniformly Varying Load:
● Uniformly Increasing
○ Uniformly Decreasing

Maximum Value = kN,
from m to m (from left)
Add

Solve Refresh Exit

BEAM ANALYSIS TOOLBOX
Version 1.0
Developed by
S. M. Tamjid Hossain
ME 2k13 KUET

Summary and Results
Type of Beam : Simple
R1 = 90 kN, R2 = 50 kN
Zero Shear at 1.8 m; Zero moment at m
Max. Shear = 90 kN at 0 m
Max. Moment = 81 kN-m at 1.8 m

Fig. 8: GUI solution of Prob. 408

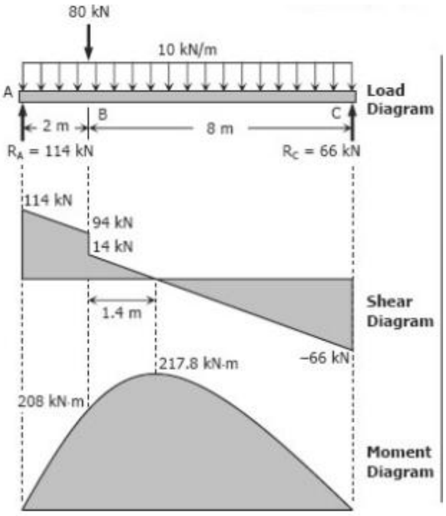


Fig. 9: Traditional solution of Prob. 405

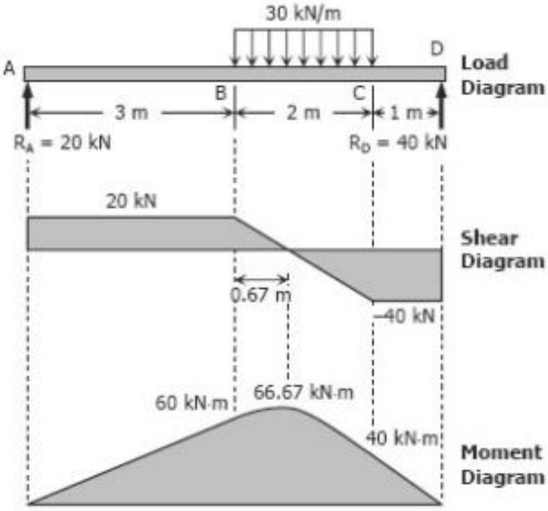


Fig. 10: Traditional solution of Prob. 407

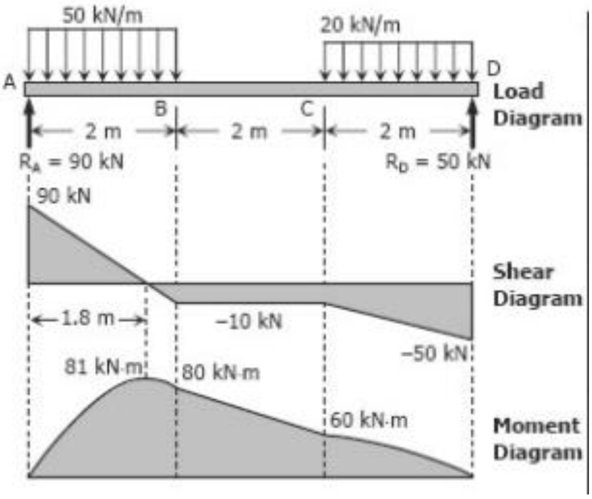
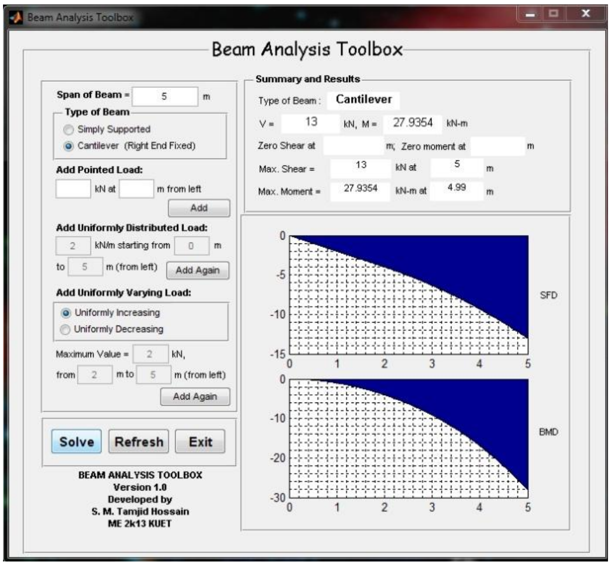


Fig. 11: Traditional solution of Prob. 408



Beam Analysis Toolbox

Span of Beam = 5 m

Type of Beam

○ Simply Supported

● Cantilever (Right End Fixed)

Add Pointed Load:

kN at m from left

Add Uniformly Distributed Load:

2 kN/m starting from 0 m

to 5 m (from left)

Add Uniformly Varying Load:

● Uniformly Increasing

○ Uniformly Decreasing

Maximum Value = 2 kN,

from 2 m to 5 m (from left)

BEAM ANALYSIS TOOLBOX
Version 1.0
Developed by
S. M. Tamjid Hossain
ME 2k13 KUET

Summary and Results

Type of Beam : Cantilever

V = 13 kN, M = 27.9354 kN-m

Zero Shear at m; Zero moment at m

Max. Shear = 13 kN at 5 m

Max. Moment = 27.9354 kN-m at 4.99 m

Fig. 12: GUI solution of Prob. 414

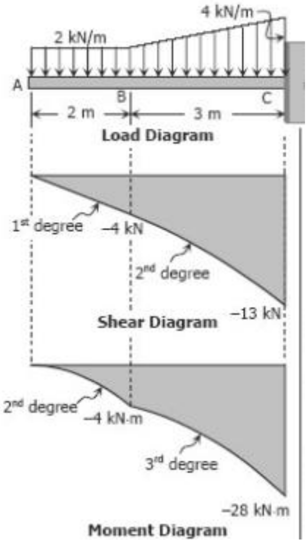
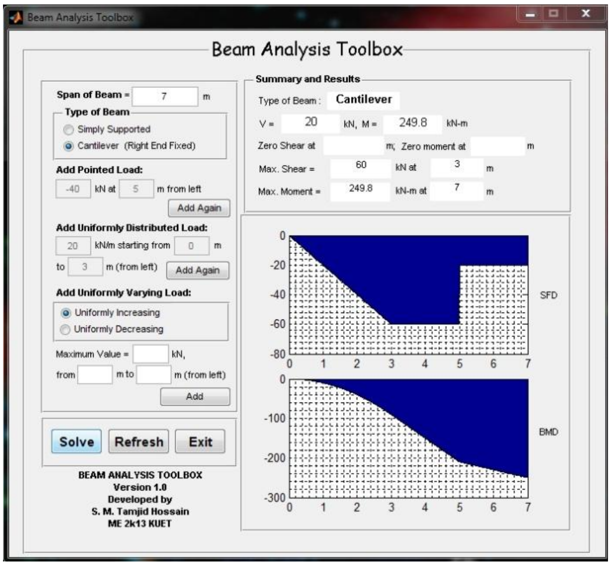


Fig. 15: Traditional solution of Prob. 414



Beam Analysis Toolbox

Span of Beam = 7 m

Type of Beam

○ Simply Supported

● Cantilever (Right End Fixed)

Add Pointed Load:

-40 kN at 5 m from left

Add Uniformly Distributed Load:

20 kN/m starting from 0 m

to 3 m (from left)

Add Uniformly Varying Load:

● Uniformly Increasing

○ Uniformly Decreasing

Maximum Value = kN,

from m to m (from left)

BEAM ANALYSIS TOOLBOX
Version 1.0
Developed by
S. M. Tamjid Hossain
ME 2k13 KUET

Summary and Results

Type of Beam : Cantilever

V = 20 kN, M = 249.8 kN-m

Zero Shear at m; Zero moment at m

Max. Shear = 60 kN at 3 m

Max. Moment = 249.8 kN-m at 7 m

Fig. 13: GUI solution of Prob. 415

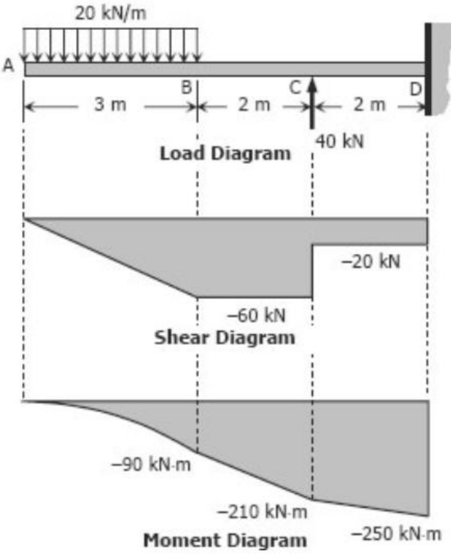
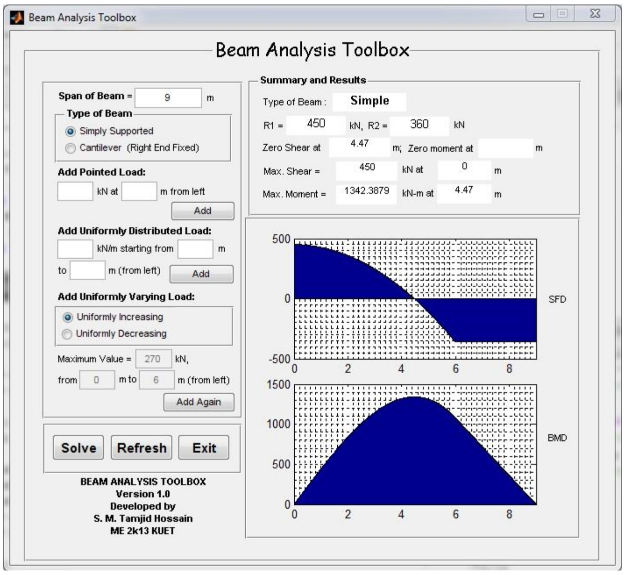


Fig. 16: Traditional solution of Prob. 415



Beam Analysis Toolbox

Span of Beam = 9 m

Type of Beam

● Simply Supported

○ Cantilever (Right End Fixed)

Add Pointed Load:

kN at m from left

Add Uniformly Distributed Load:

kN/m starting from m

to m (from left)

Add Uniformly Varying Load:

● Uniformly Increasing

○ Uniformly Decreasing

Maximum Value = 270 kN,

from 0 m to 6 m (from left)

BEAM ANALYSIS TOOLBOX
Version 1.0
Developed by
S. M. Tamjid Hossain
ME 2k13 KUET

Summary and Results

Type of Beam : Simple

R1 = 450 kN, R2 = 360 kN

Zero Shear at 4.47 m; Zero moment at m

Max. Shear = 450 kN at 0 m

Max. Moment = 1342.3879 kN-m at 4.47 m

Fig. 14: GUI solution of Prob. 419

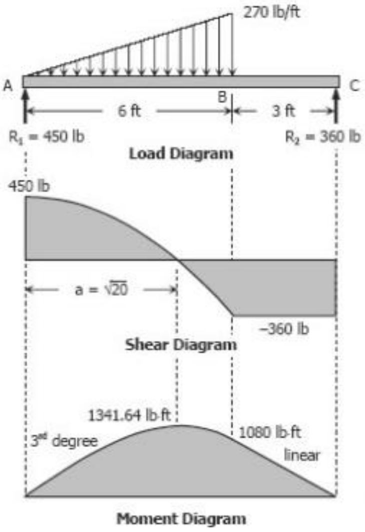
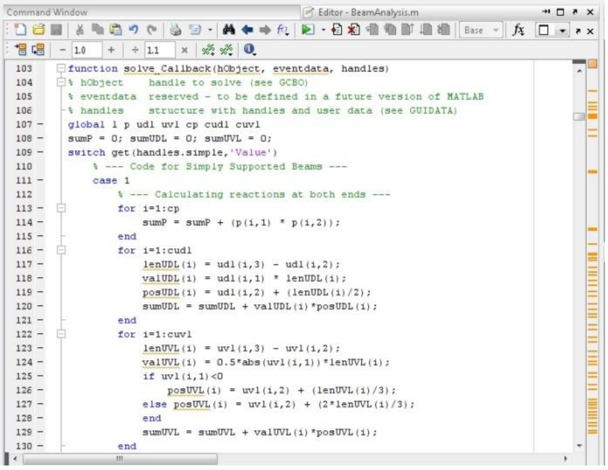


Fig. 17: Traditional solution of Prob. 419

4.4 The MATLAB Script for Operating the Developed GUI

The MATLAB M-file associated with the FIG-file is a 1060 line code containing a total of 43 functions. However, most of the code is automatically generated when the layout of the GUI or the ‘FIG-file’ is created using GUIDE. The main solution algorithm is written under the ‘solve_Callback’ function.

Figure 18 shows a snapshot of a fragment of the MATLAB M-file opened in M-file Editor.



```
function solve_Callback(hObject, eventdata, handles)
% hObject    handle to solve (see GCBO)
% eventdata  reserved - to be defined in a future version of MATLAB
% handles    structure with handles and user data (see GUIDATA)
global l p udl uvl cp cudl cuvl
sumP = 0; sumUDL = 0; sumUVL = 0;
switch get(handles.simple,'Value')
    % --- Code for Simply Supported Beams ---
    case 1
        % --- Calculating reactions at both ends ---
        for i=1:cp
            sumP = sumP + (p(i,1) * p(i,2));
        end
        for i=1:cudl
            lenUDL(i) = udl(i,3) - udl(i,2);
            valUDL(i) = udl(i,1) * lenUDL(i);
            posUDL(i) = udl(i,2) + (lenUDL(i)/2);
            sumUDL = sumUDL + valUDL(i)*posUDL(i);
        end
        for i=1:cuvl
            lenUVL(i) = uvl(i,3) - uvl(i,2);
            valUVL(i) = 0.5*abs(uvl(i,1))*lenUVL(i);
            if uvl(i,1)<0
                posUVL(i) = uvl(i,2) + (lenUVL(i)/3);
            else posUVL(i) = uvl(i,2) + (2*lenUVL(i)/3);
            end
            sumUVL = sumUVL + valUVL(i)*posUVL(i);
        end
```

Fig. 18: Part of the M-file for running the GUI

4.5 Limitations and Sectors of Development

1) The developed GUI can only produce SF and BM diagrams for Simple and Cantilever beams, not for any other types of beams.

2) The feature of adding applied moment as a kind of loading is not yet available.

3) In the diagrams produced, the feature of pointing out the values of SF and BM at desired and/or specific points is not yet included.

4.6 Future Aim

1) Work is going on to develop a GUI in recent future that can produce and analyze any kind of beams loaded with any number of and any type of loadings.

2) The developed GUI is not yet capable of running outside the MATLAB environment. So, in future it will be made standalone and cross-platform compatible.

3) There is a plan for developing an android application also.

5. CONCLUSIONS

From this work following conclusions can be made—

1) Beam analysis can be made easy, fast and errorless using the computational power of MATLAB.

2) The developed ‘Beam Analysis Toolbox’ GUI will help the students and engineers to analyze beams in practical field.

3) It can be used as a convenient educational tool in introductory solid mechanics courses.

4) In future versions, the cross-platform compatibility will offer a mobile and versatile use of the GUI application.

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8. NOMENCLATURE

Symbol	Meaning	Unit
V	Shear force (SF)	(N)
M	Bending moment(BM)	(N.m)
w	External loadings	(N)
F_y	Vertical components of the external loadings	(N)