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Development of a GUI Based Program for Design of various Steel Connections

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Abstract: *Steel frame buildings consist of a number of different types of structural elements. Every element must be attached properly to its neighbouring part of structure. This will involve use of various types of connections. Connections account for more than half the cost of structural steel work. Connection failure is not a ductile failure and hence it should be avoided before member failure. Large uncertainty is there in the design of connections. Connections are usually the most vulnerable part of the structure, failure of which may lead to the failure of whole structure. Thus, design of connection is an important and integral part of design of the steel structure. This MATLAB GUI program developed will be a very useful and user-friendly tool for the design of connections.*

Keywords: *GUI, MATLAB, shear connection, Web Angle, fillet weld, eccentric connection, seat connection*

I. INTRODUCTION

Unlike concrete, connections in steel structures need special design. Mainly three major connections are there: - bolted, welded, riveted but rivets are now seldom used. Steel connection calculations are the most complex and time-consuming phases of the steel structural design. This long and complex process requires precision and efficiency and can become a source of errors with unwanted consequences. This MATLAB GUI program can help reducing time in these complex calculations and also human calculation errors. This can increase precision and accuracy in design process. GUI is a very user-friendly tool and it can be easily used by people. In industry it can of great benefit as it will reduce the long-time consuming process. Connections should satisfy the requirements of structural behaviour. They should be strong enough to transmit the design loads and at the same time have the intended degree of flexibility and rigidity.

There are various types of steel connections based on following: -

- 1) On the basis of connecting medium: -
 - a) Bolted
 - b) Welded
 - c) Riveted
- 2) According to nature and location of load: -
 - a) Direct shear connections
 - b) Pure moment connections
 - c) Eccentric connections
 - d) Moment shear connections
- 3) According to the type of structural elements: -
 - a) Single plate angle connections
 - b) Double web angle connections
 - c) Top and seated angle connections
 - d) Seated beam connections
- 4) According to type of members joining:
 - a) Beam to beam connection
 - b) Beam to column connection
 - c) Column base plate connection
 - d) Column to column connection

Various types of steel connections are analysed and GUI program is developed for design of connections. Classification of connections is show in the figure below: -

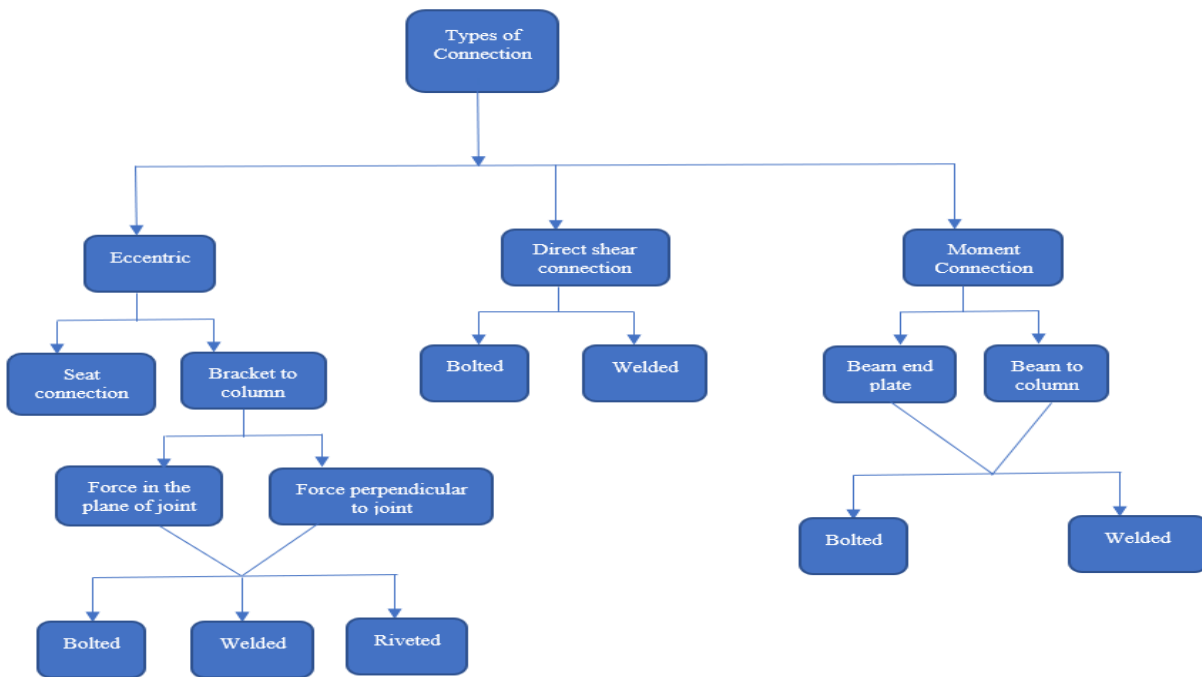


Fig. 1 Division of connections

II. DESIGN METHODOLOGY

1) Eccentric Connections

1) Load lying in the Plane of Joint

a) Riveted Connection

- First number of rivets is found out using the direct axial shear

$$\text{No of rivets} = 1.25 \cdot P/R;$$

R=rivet value.

P= shear force

- Then from bending stress the number of rivets is found out

$$\text{Number of rivets in a line} = \frac{\sqrt{6M}}{mpR}$$

Where, M=moment

m= no. of rivets line

p=pitch

R=rivet value

Thus, total rivets=m*n

- Check if force in extreme rivet is under limit of rivet value.

b) Welded Connection

- Force from direct shear and bending is found out in terms of throat thickness of weld
- Resultant force is found out
- Equating the resultant force with limit of weld(108Mpa) throat thickness is found
- Size of weld=t/0.707

2) *Load Perpendicular to Joint*

a) *Welded Connection*

- Same process as for load lying in the plane of joint except that for forces are perpendicular to each other.

Force due to bending = $M \cdot y / I$;

i.e.

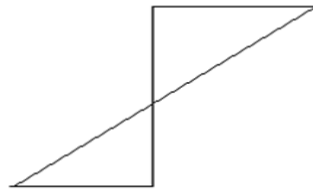


Fig. 2 Stress diagram of weld

Thus, maximum force due to bending develops in the top portion of the joint. The resultant force for that part is found.

F_a (stress due to direct shear) = factor load/area of weld

The resultant of the stresses should be less than the maximum stress limit of weld (108 MPa). Equating the force with this value we can find out the size of weld.

III. DIRECT SHEAR CONNECTIONS

1) *Bolted Connection*

1) *Between Plates:*

- First bolt value is found out considering whether bolt is in single shear or double shear
- Then number of bolts is found out by dividing factored load by bolt value
- End distance and pitch is calculated considering the codal provision of IS800:2007

2) *Welded Connection:*

1) *Fillet weld:*

- Design strength of fillet weld is calculated on its throat area using the formula

$$P_{dw} = \frac{f_u L_w t_e}{\sqrt{3} \gamma_{mw}}$$

Where, P_{dw} = design strength of weld

L_w =

- End returns of length equal to twice the size of weld are provided at each end of longitudinal fillet weld

2) *Butt Weld:*

- When plates to be joined are in the same plane then butt weld is used as shown below: -

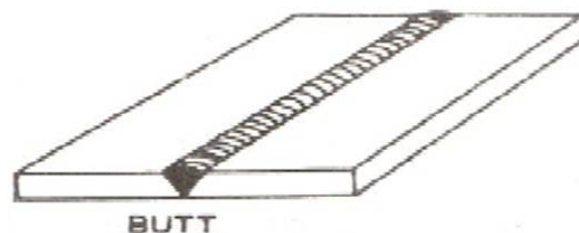


Fig. 3 A typical butt weld

IV. RESULTS AND DISCUSSION

GUI codes for different types of connection are made and shown below.

A. Types of connections

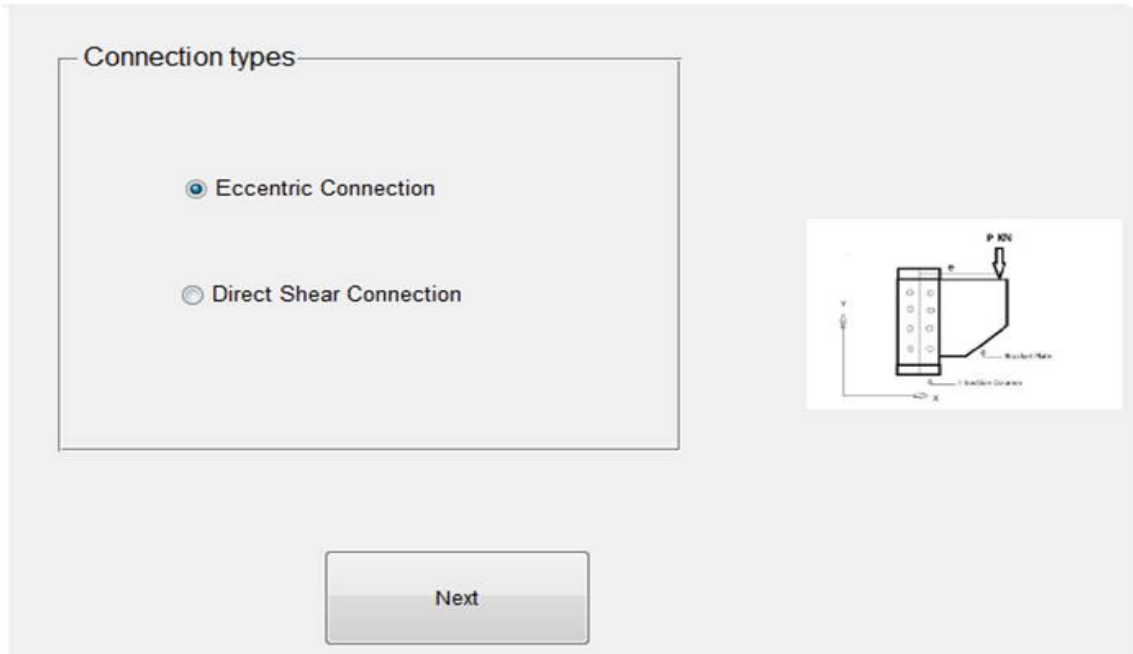


Fig. 4. Types of connections GUI

1) Eccentric Connection

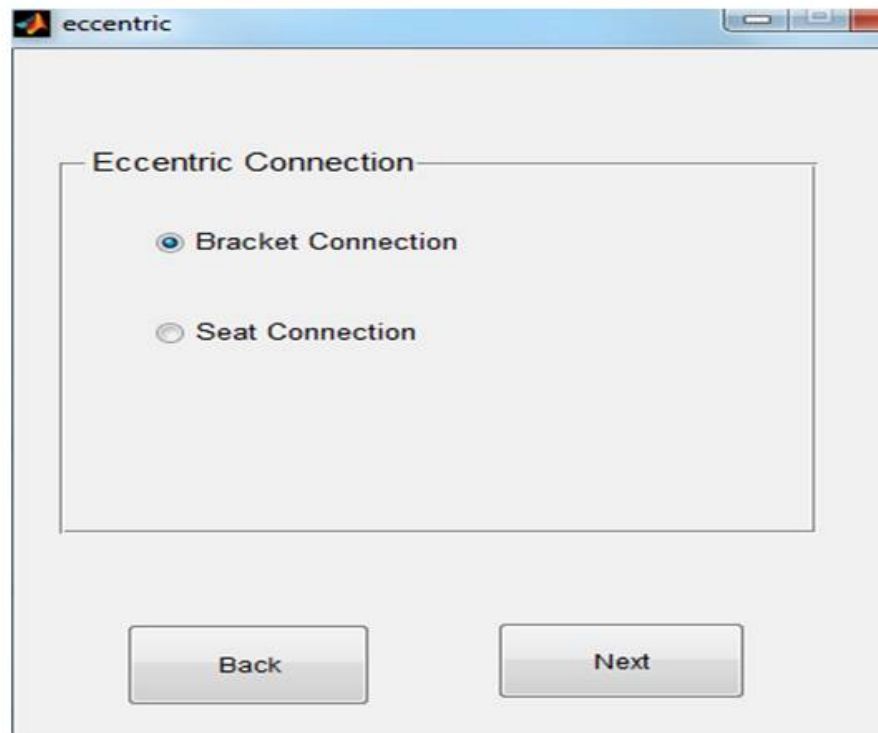


Fig. 5. Eccentric connection types GUI

a) *Bracket Connection*: Different types of bracket connections design are made in GUI as shown in the figures below: First, we have interface for choosing types of bracket connections.

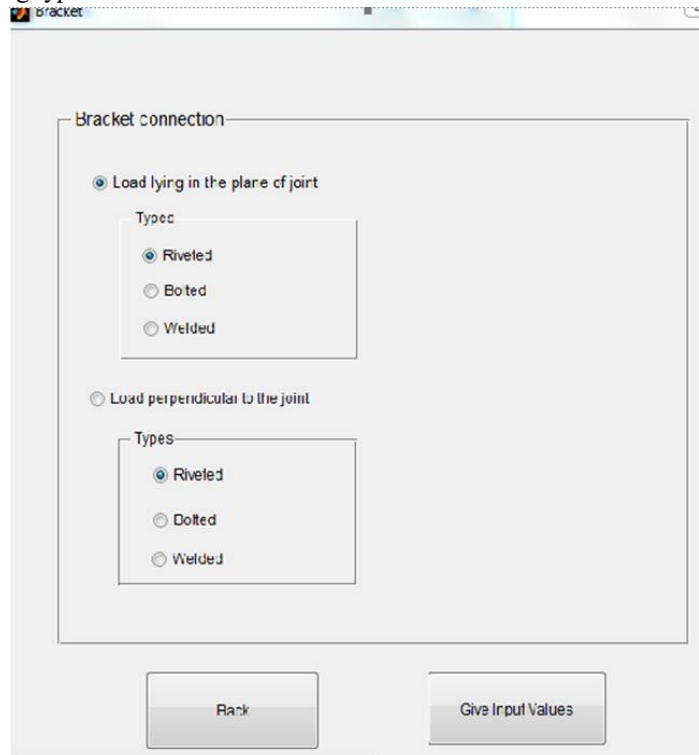


Fig. 6. Types of Bracket connections GUI

We have two cases for bracket connection: - a) load lying in the plane of joint and b) load perpendicular to the joint

b) *Load Lying In The Plane Of Joint*

- Riveted connection

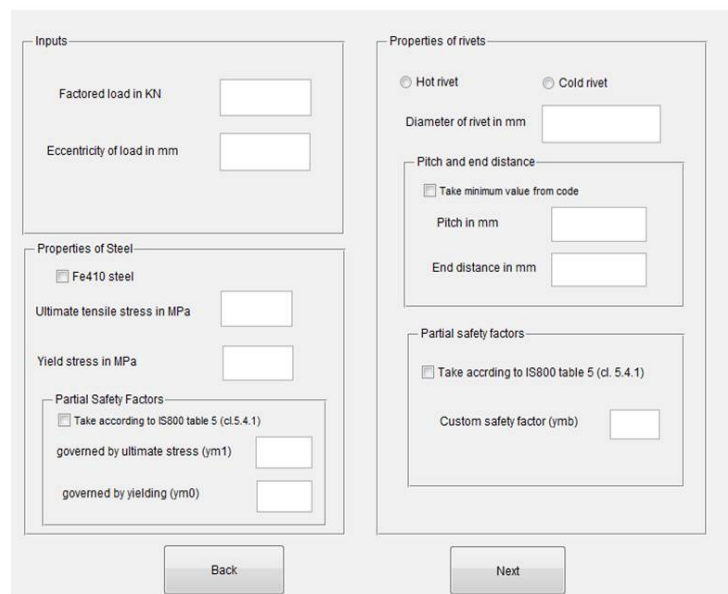


Fig. 7 rivet connections for load in plane of joint GUI

Given the below sample inputs, we can find the number of rivets and check it for extreme force developed in the extreme of rivet.

Sample input: -

Eccentricity = 160mm

Factor load = 225KN

Hot rivets and cold rivet show whether rivets are in pretension or not.

Results: - 2*8 no of rivets. 8 in each line.

And it is safe to carry to above load

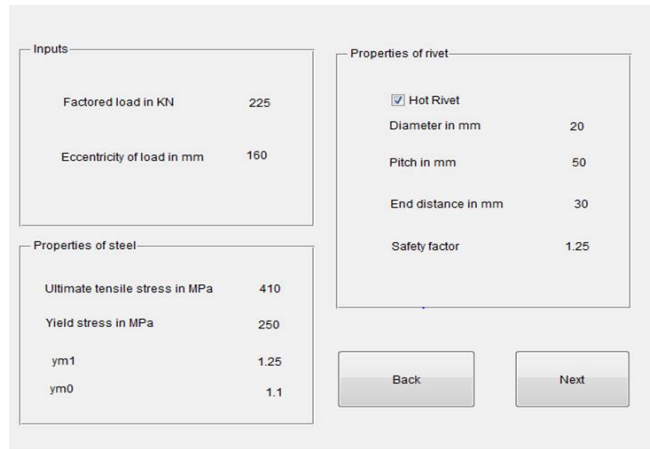


Fig. 8 Value check for above GUI



Fig. 9 Result for the above case

- Welded connection

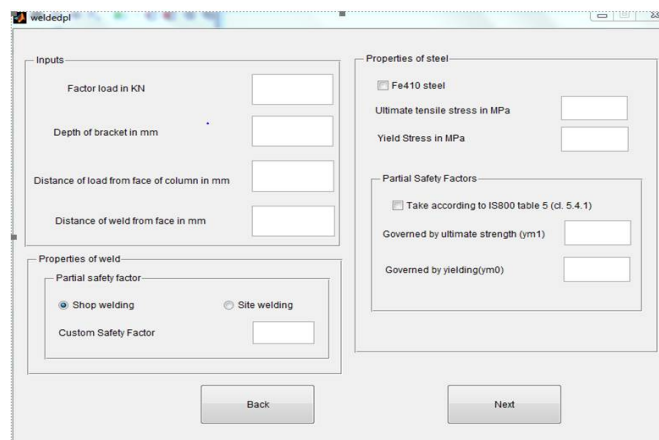
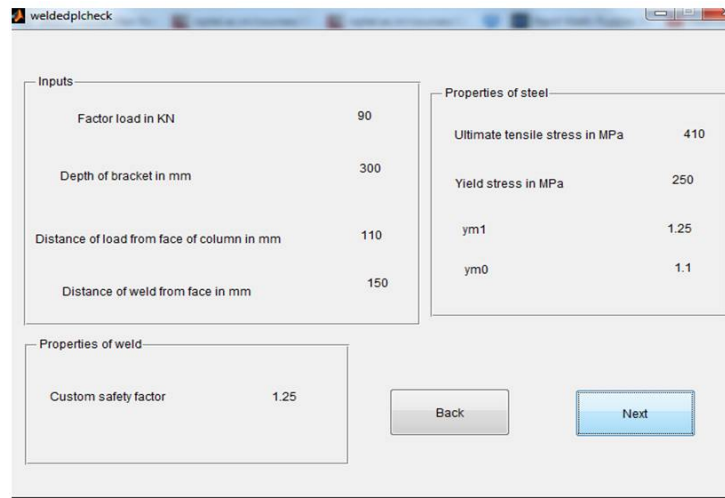


Fig. 10 Welded connections for load in plane of joint GUI

Giving the input value and finding the weld size. First the value is checked and then result is then found out.

Direct shear stress and maximum shear stress due to bending is calculated and resultant stress is calculated and from where thickness of weld is calculated.

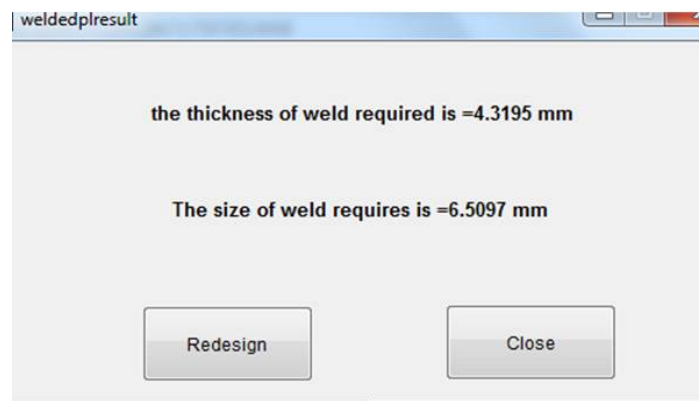


Inputs		Properties of steel	
Factor load in KN	90	Ultimate tensile stress in MPa	410
Depth of bracket in mm	300	Yield stress in MPa	250
Distance of load from face of column in mm	110	ym1	1.25
Distance of weld from face in mm	150	ym0	1.1

Properties of weld	
Custom safety factor	1.25

Buttons: Back, Next

Fig. 11 Values check for above case



the thickness of weld required is =4.3195 mm

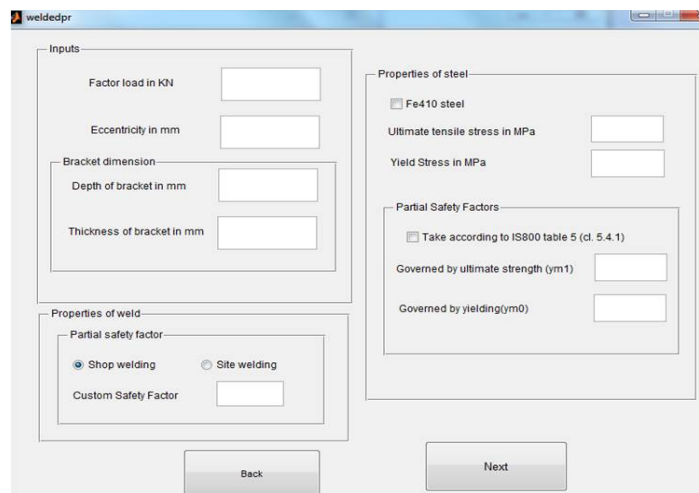
The size of weld requires is =6.5097 mm

Buttons: Redesign, Close

Fig. 12 Result for above case

c) *Load Perpendicular To Plane Of Joint*

- *Welded Joint*



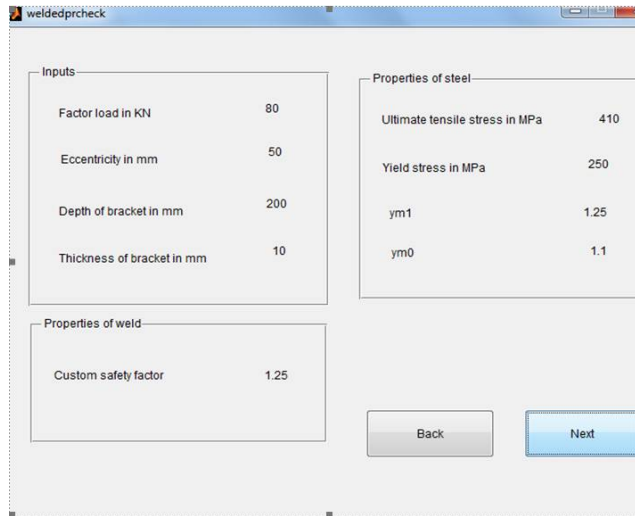
Inputs		Properties of steel	
Factor load in KN	<input type="text"/>	<input checked="" type="checkbox"/> Fe410 steel	Ultimate tensile stress in MPa <input type="text"/>
Eccentricity in mm	<input type="text"/>	Yield Stress in MPa	<input type="text"/>
Bracket dimension		Partial Safety Factors	
Depth of bracket in mm	<input type="text"/>	<input type="checkbox"/> Take according to IS800 table 5 (cl. 5.4.1)	Governed by ultimate strength (ym1) <input type="text"/>
Thickness of bracket in mm	<input type="text"/>	Governed by yielding(ym0)	<input type="text"/>

Properties of weld	
Partial safety factor	<input checked="" type="radio"/> Shop welding <input type="radio"/> Site welding
Custom Safety Factor	<input type="text"/>

Buttons: Back, Next

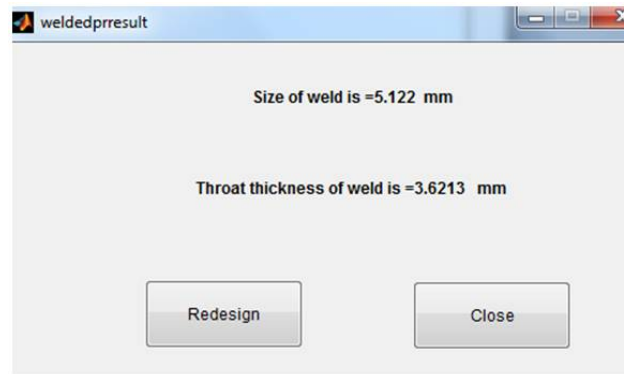
Fig. 13 Weld joint for eccentric load perpendicular to the plane of joint GUI

Check for value for some input case and then get the result



The screenshot shows a software window titled 'weldedprcheck'. It contains three main sections: 'Inputs', 'Properties of steel', and 'Properties of weld'.
Inputs:
 Factor load in KN: 80
 Eccentricity in mm: 50
 Depth of bracket in mm: 200
 Thickness of bracket in mm: 10
Properties of steel:
 Ultimate tensile stress in MPa: 410
 Yield stress in MPa: 250
 ym1: 1.25
 ym0: 1.1
Properties of weld:
 Custom safety factor: 1.25
 At the bottom right, there are 'Back' and 'Next' buttons.

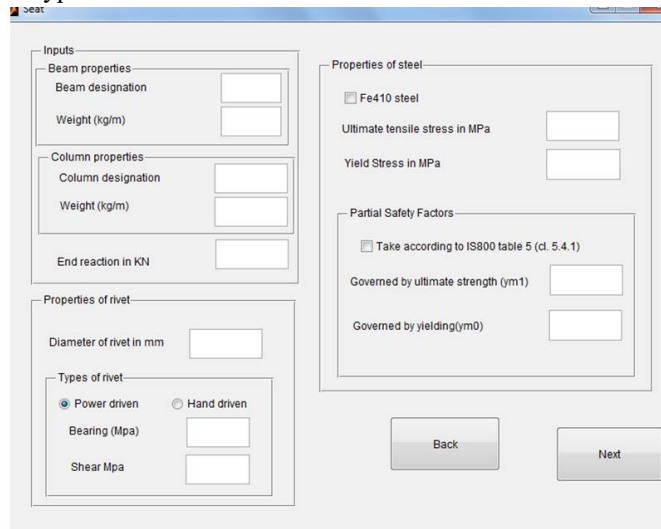
Fig. 14 check for value of above case



The screenshot shows a software window titled 'weldedprresult'. It displays the results of the calculation:
 Size of weld is =5.122 mm
 Throat thickness of weld is =3.6213 mm
 At the bottom, there are 'Redesign' and 'Close' buttons.

Fig. 15 Result for above case

d) *Seat Connection:* This is another type of eccentric connection.



The screenshot shows a software window titled 'seat'. It contains several sections for inputting design parameters:
Inputs:
 Beam properties: Beam designation, Weight (kg/m)
 Column properties: Column designation, Weight (kg/m)
 End reaction in KN
Properties of rivet:
 Diameter of rivet in mm
 Types of rivet: Power driven (selected), Hand driven
 Bearing (Mpa), Shear Mpa
Properties of steel:
 Fe410 steel
 Ultimate tensile stress in MPa
 Yield Stress in MPa
Partial Safety Factors:
 Take according to IS800 table 5 (cl. 5.4.1)
 Governed by ultimate strength (ym1)
 Governed by yielding (ym0)
 At the bottom, there are 'Back' and 'Next' buttons.

Fig. 16 Seat connection design GUI

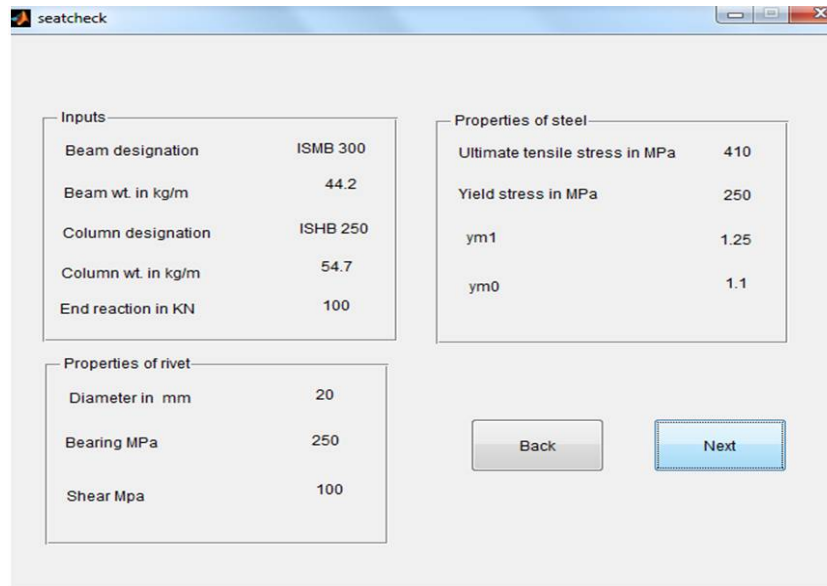


Fig. 17 Value check for above case



Fig. 18 Angle choice GUI for above case

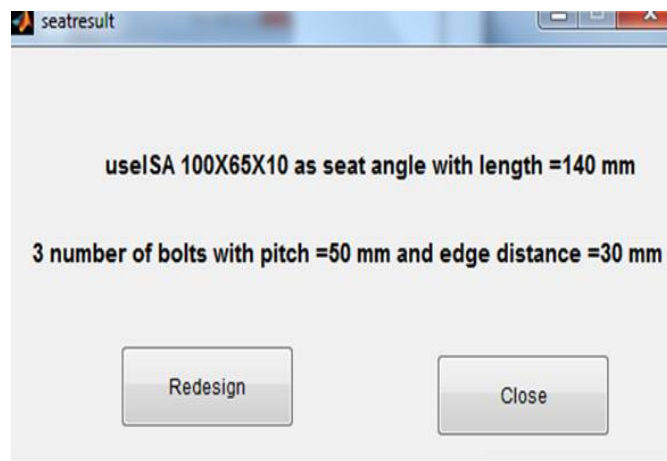


Fig. 19 Result for above case

2) Direct Shear Connection

a) Bolted Connection: we will consider two cases for this connection one will be between plates and another will be between plate and angle.

- Between Plates

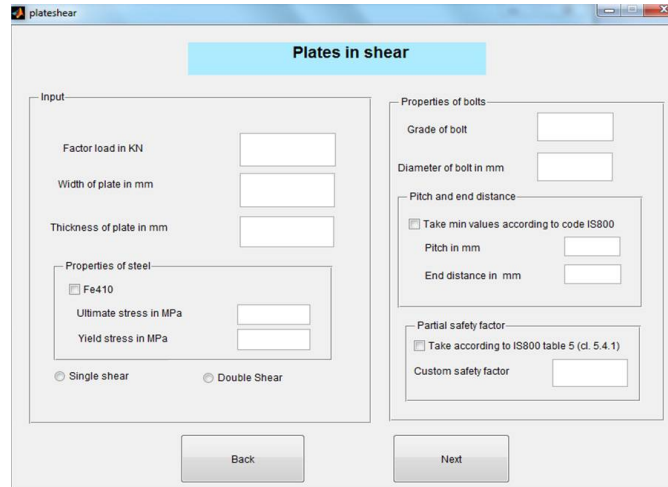


Fig. 20 Shear bolted connection for plates GUI

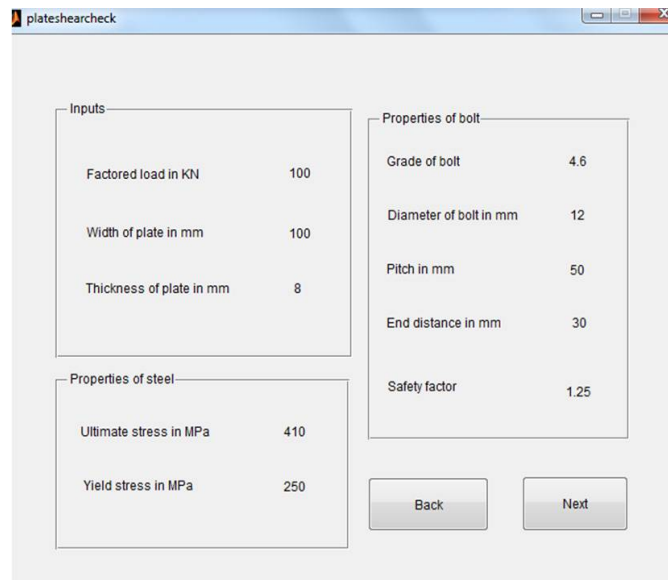


Fig. 21 Value check for above case

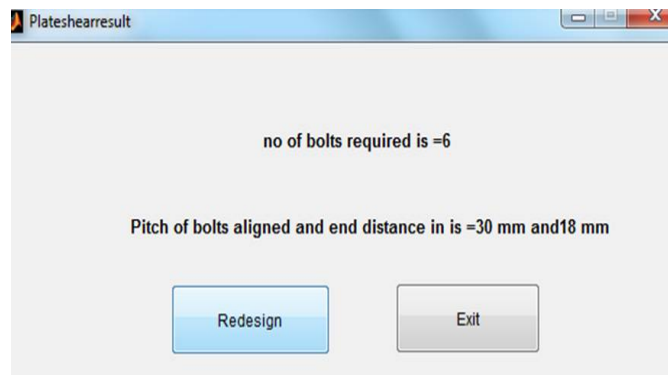
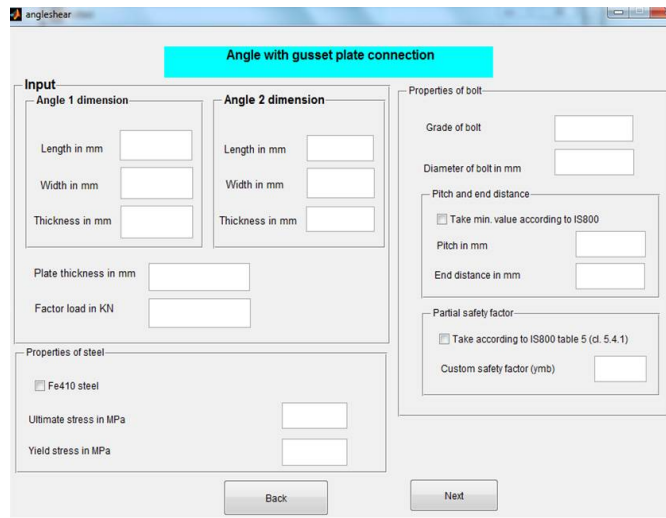


Fig. 22 Result for above case

- *Between Angle and Plates*



Angle with gusset plate connection

Input

Angle 1 dimension

Length in mm:

Width in mm:

Thickness in mm:

Angle 2 dimension

Length in mm:

Width in mm:

Thickness in mm:

Plate thickness in mm:

Factor load in KN:

Properties of steel

Fe410 steel

Ultimate stress in MPa:

Yield stress in MPa:

Properties of bolt

Grade of bolt:

Diameter of bolt in mm:

Pitch and end distance

Take min. value according to IS800

Pitch in mm:

End distance in mm:

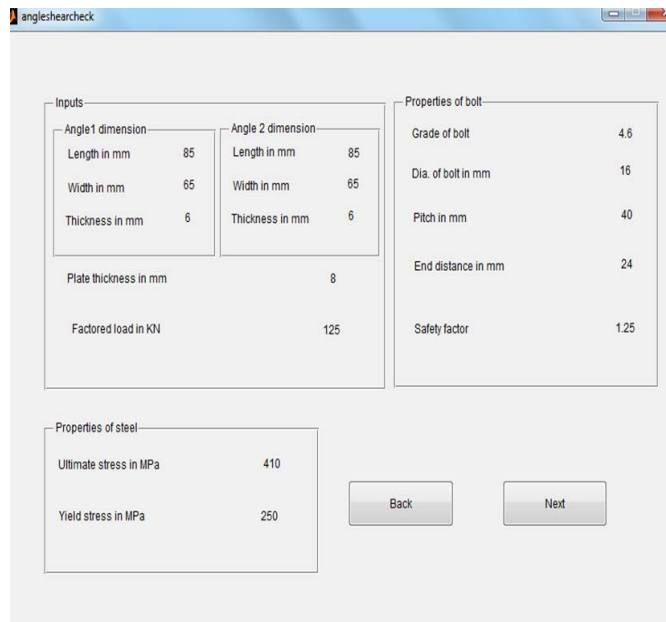
Partial safety factor

Take according to IS800 table 5 (cl. 5.4.1)

Custom safety factor (γ_{mb}):

Buttons: Back, Next

Fig. 23 Result for above case



angleshearcheck

Inputs

Angle1 dimension		Angle 2 dimension	
Length in mm	85	Length in mm	85
Width in mm	65	Width in mm	65
Thickness in mm	6	Thickness in mm	6
Plate thickness in mm	8		
Factored load in KN	125		

Properties of bolt

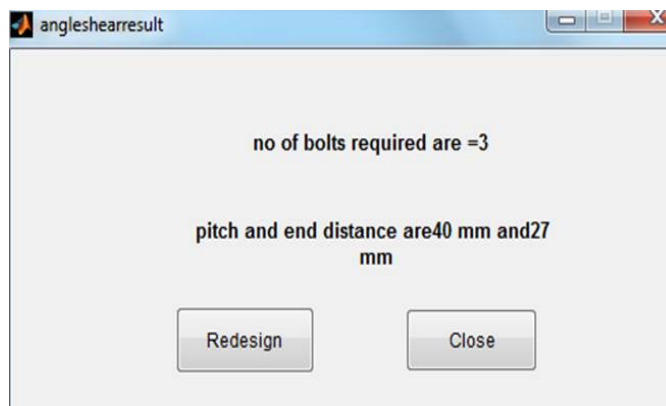
Grade of bolt	4.6
Dia. of bolt in mm	16
Pitch in mm	40
End distance in mm	24
Safety factor	1.25

Properties of steel

Ultimate stress in MPa	410
Yield stress in MPa	250

Buttons: Back, Next

Fig. 24 Shear bolted connection between angle and plate



angleshearresult

no of bolts required are =3

pitch and end distance are 40 mm and 27 mm

Buttons: Redesign, Close

Fig. 25 Result for above case

- b) *Welded Connection*: Two types of welded connection are designed.
- *Fillet weld design*: - fillet weld is used for lap joint and tee joint. A typical fillet weld is shown below:

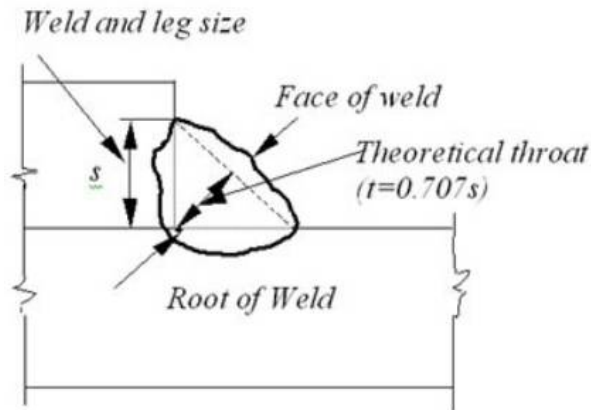


Fig. 26 A typical fillet weld

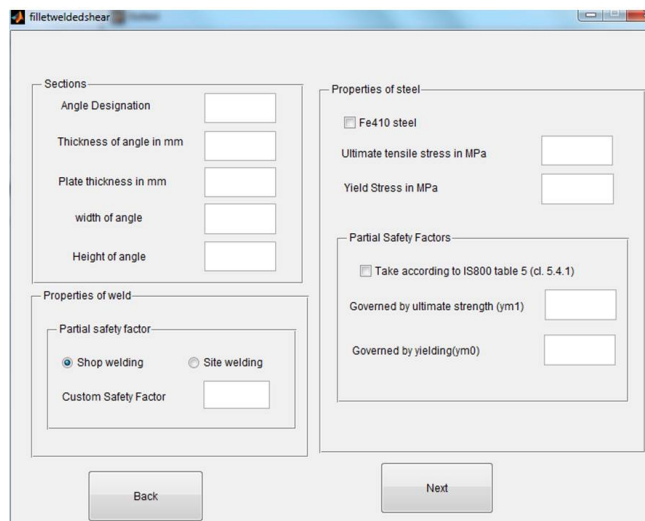


Fig. 27 Fillet weld design for shear connection GUI

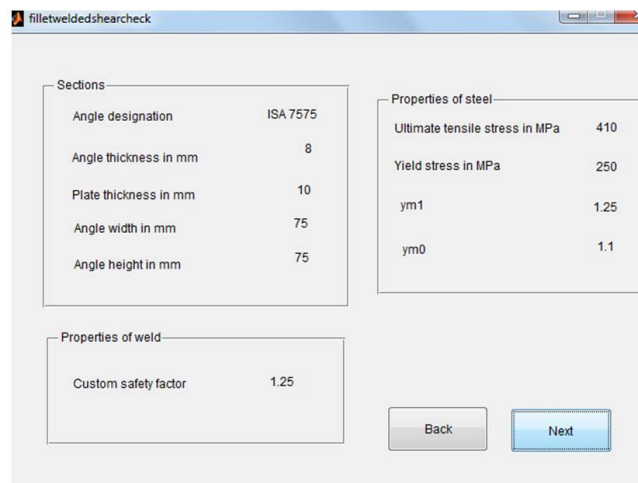


Fig. 28 Value check for above case

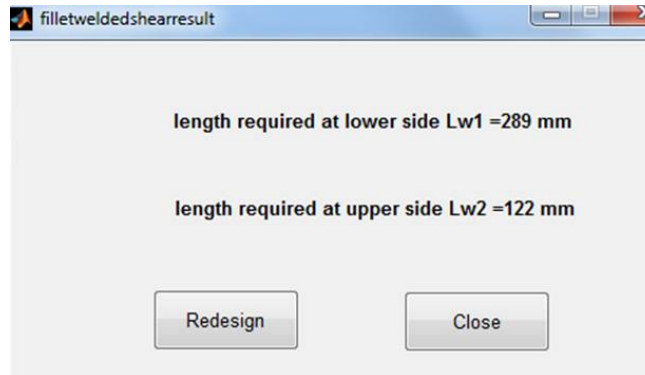


Fig. 29 Result for above case

- *Butt weld design:* - Butt weld is mainly used to connect members which are in the same plane. A typical butt weld is shown below:

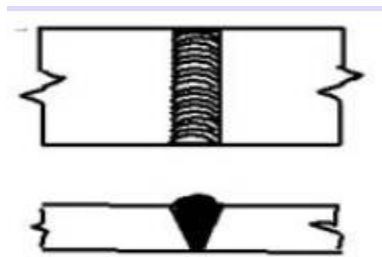


Fig. 30 A typical butt weld

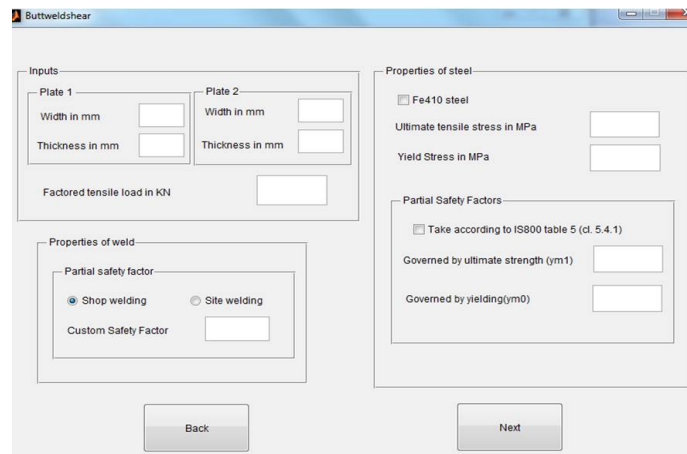


Fig. 31 Butt weld design for shear connections GUI

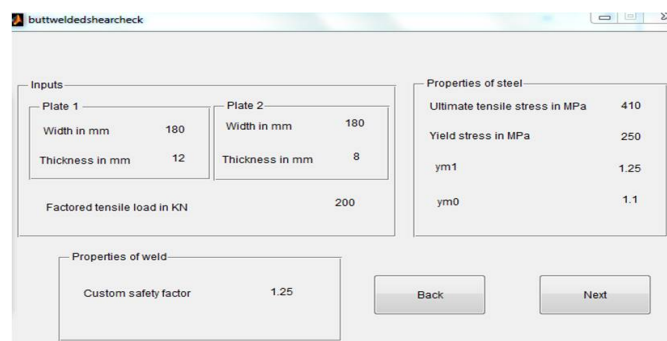


Fig. 32 Value check for above case

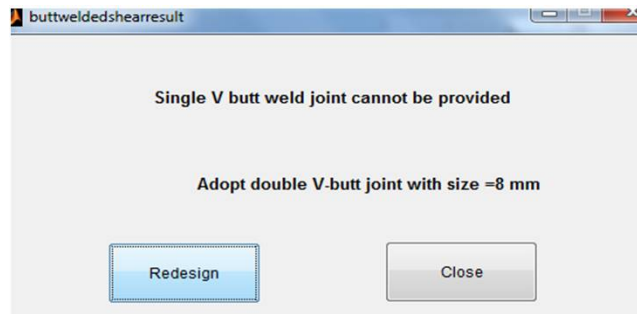


Fig. 33 Result for above case

IV. CONCLUSION

This GUI program made can be very helpful in industrial sector. Connections account for more than half of structural steel work. This program is very user friendly and easy to handle. It finds out the number of bolts and size of welds for various types of connections.

V. ACKNOWLEDGEMENT

I am highly indebted to my Guide Professor Dr. Damodar Maity Sir for his guidance throughout the project. Again, author wishes to thank Math works and MATLAB for providing platform for developing this software.

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