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# Evaluation of Strength of Structural Steel Angle Sections, under IS Code: 800 - 1984 – A Case Study with Equal vis-a-vis Unequal Angles

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## Introduction

Structural steel is an alloy of iron, carbon and small amounts of manganese, chromium, nickel, phosphorus, copper, silicon, and sulfur. It is used to form its rolled steel sections like angles, tees, channels, girders, plates, beams, truss frames, columns, plate-girders etc to bear loads in the structure under compression stresses to safe the structure under bending. Structural steel is weather resistant and more stress bearing than normal steel. Mild steel is used in utensils, toys, machine frames, furniture-watches etc., where loads of varying stresses are not of structural nature. While designing the steel structure two codes are usually followed viz. IS-Code: 800-1984 and IS-Code: 800-2000 which are known as elastic method and limit state method respectively. Elastic method is simple-n-easy to design the structure, wherein stress-strain relation is considered till yield stress. The permissible stress is kept by dividing it by factor of safety. Factor of safety is failure load divided by working load. But it is not

true for the material. As the material can resist load after the yield appear on the fiber of steel. Hence the section becomes uneconomical.

In limit state working load is taken into account by multiplying the factor 1.5 to strengthen the serviceability of structure. The limitable strength is desired to avoid the collapse of the structure in safe life. The permissible stresses are taken much higher than working stresses. In working stress, stresses are taken like  $f_t = 150 \text{ N/mm}^2$ , while  $f_c = 227 \text{ N/mm}^2$ ,  $f_t = 295 \text{ N/mm}^2$ , are taken in limit state. Though the paper theme has no concern with design differentiation, however it is seem necessary to go to narrow analogous to the stresses in respective methods of design.

## 2. General Concept

So far the title of the paper is concern wherein the study has been made for angles of equal and unequal in size but having same cross sectional area, have been used as tension and compression members and their ends have either single riveted or double riveted.

The strength has been calculated by using various conditional formulas and higher strength bearing condition under IS Code 800-1984, is recommended to use at construction sites where steel structures are being erected.

To make it lucid and easy & to make understandable the title to the readers it becomes necessary to illustrate by setting an example for choosing angle ISA-200\*100\*15 mm and ISA-150\*150\*15 mm having cross sectional area 4278 mm<sup>2</sup> are attached with 20mm thick gusset plate for its long leg /short leg jointed by 20mm diameter rivet shank. The permissible stress in tension has been taken 150 N/mm<sup>2</sup> for Fe-250 grade steel and corresponding stresses in compression have been taken from standard table by interpolation. It has been assumed that compression member is of discontinuous type.

### 3. Methodology as Tension Member

The angle members of truss are either single or double, used as tension member either side to gusset plate or one side to gusset plate. Which connection will give higher strength, either long leg connected or short leg connected to gusset plate of angle, will be treated as best in economical design for valuation.

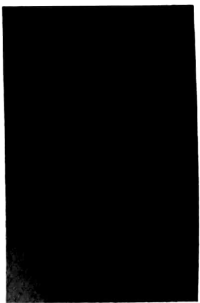
Table 1. Comparative Study Table as tension single member

S/No	Angle	Leg connected	Connection	Tensile strength	Preference
1	Equal ISA-150 150 15	Any leg	single riveted	503100 N	2 <sup>nd</sup>
2	Unequal ISA 200 100 15	long leg	single riveted	561656 N	1 <sup>st</sup>
3	Unequal ISA 200 100 15	short leg	single riveted	387260.79 N	3 <sup>rd</sup>

### 3.1 Case Study 1: Single Angle with Gusset Plate as Tension Member Riveted with 20mm Rivet Diameter

#### 3.1.1 Connected Leg Area=(150-21.5-7.5) 15=1815 mm<sup>2</sup>

outstanding area=(150-7.5) 15 =2137.5 mm<sup>2</sup>  
 $K=0.72$   
 $A_{NET} = 3354 \text{ mm}^2$   
 $F_t=503100N$

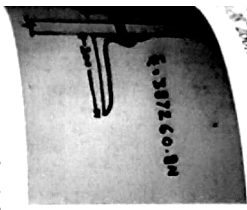


#### 3.1.2 Unequal Angle

200\*100\*15mm whose long leg connected to 20mm thick gusset plate.  
 connected area=(200-21.5-7.5) 15=2565 mm<sup>2</sup>  
 outstanding area=(100-7.5) 15=1387.5 mm<sup>2</sup>  
 $K=0.85$   
 $A_{net}=3744.375 \text{ mm}^2$   
 $F_t=561656N$



**Unequal Angle**  
 whose short leg is connected with  
 gusset plate:  
 $A_{net} = (100 - 21.5 - 7.5) 15 = 1065 \text{ mm}^2$   
 $F_t = 1065 \times 150 = 159750 \text{ N}$   
 outstanding area =  $(200 - 7.5) 15 = 2887.5 \text{ mm}^2$



**Comparative Study Table as Tension Member**

unequal angles long leg connected  
 gusset plate is showing higher strength than  
 angle whose tensile strength  $F_t = 561656 \text{ N}$

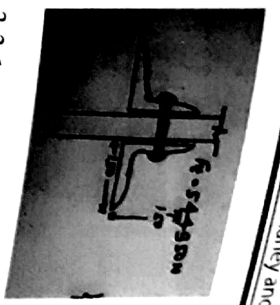
**Two Angle as Tension Member**

where when load is more then to restrict the  
 in the tension member two members of same  
 sizes are used. The two angle members are  
 not either side or only one side to the gusset

**Case Study 2: ISA 150\*150\*15mm and**  
 ISA 200\*100\*15mm

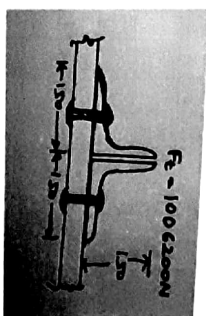
**Equal Angles Either Side Connected**  
 with 20mm Thick Gusset Plate Means  
 the Plate is Sandwiched Between Two  
 Angles

$A_{net} = (150 - 43) 15 = 3633 \text{ mm}^2$   
 $F_t = 3633 \times 150 = 544950 \text{ N}$



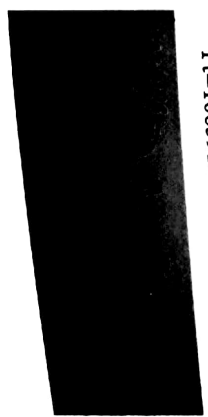
**3.3.1.2 Equal Angles are One Side to the 20 mm Thick Gusset Plate without Tacking Rivet**

connected area =  $2(150 - 21.5 - 7.5) 15 = 3630 \text{ mm}^2$   
 outstanding area =  $2(150 - 7.5) 15 = 4275 \text{ mm}^2$   
 $K = 0.72$   
 $A_{net} = 3630 + 0.72(4275) = 6708 \text{ mm}^2$   
 $F_t = 6708(150) = 1006200 \text{ N}$   
 $F_t = 1006200 \text{ N}$



**3.3.1.3 Equal Angles are One Side to 20mm Thick Gusset Plate with Tacking Rivet**

Connected area =  $3630 \text{ mm}^2$   
 outstanding area =  $4275 \text{ mm}^2$   
 $A_{net} = 3630 + 0.81(4275) = 7092.75 \text{ mm}^2$   
 $F_t = 7092.75(150) = 1063912.5 \text{ N}$   
 $F_t = 1063912.5 \text{ N}$



3.3.1.4 Unequal Angles Short Leg is Connected with 20mm Thick Gusset Plate on its Either Side

$$A_{net} = 3633 \text{ mm}^2$$

$$F_t = (3633) 150 = 544950 \text{ N}$$

$$F_c = 544950 \text{ N}$$



3.3.1.5 Unequal Angles Short Leg is Connected with 20mm Thick Gusset Plate on its One Side without Tacking Rivet

$$\text{Connected area} = 2(100-21.5-7.5) 15 = 2130 \text{ mm}^2$$

$$\text{outstanding area} = 2(200-7.5) 15 = 5775 \text{ mm}^2$$

$$K = 0.52$$

$$A_{net} = 2130 + 0.52(5775) = 5133 \text{ mm}^2$$

$$F_t = 5133 (150) = 769950 \text{ N}$$

$$F_c = 769950 \text{ N}$$



3.3.1.6 Unequal Angles Short Leg is Connected with 20mm Thick Gusset Plate on its One Side with Tacking Rivet

$$\text{Connected area} = 2130 \text{ mm}^2$$

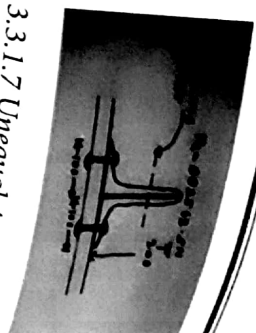
$$\text{outstanding area} = 5775 \text{ mm}^2$$

$$K = 0.65$$

$$A_{net} = 2130 + 0.65(5775) = 5883.75 \text{ mm}^2$$

$$F_t = 5883.75 (150) = 882562.5 \text{ mm}^2$$

$$F_c = 882562.5 \text{ N}$$

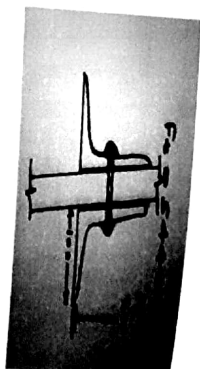


3.3.1.7 Unequal Angles Long Leg is Connected with 20mm Thick Gusset Plate on its Either Side

$$A_{net} = 3633 \text{ mm}^2$$

$$F_t = 3633 (150) = 544950$$

$$F_c = 544950 \text{ N}$$



3.3.1.8 Unequal Angles Long Leg is Connected with 20mm Thick Gusset Plate on its One Side without Tacking Rivet

$$\text{Connected area} = 2(200-21.5-7.5) 15 = 5130 \text{ mm}^2$$

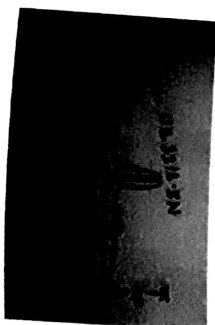
$$\text{Outstanding area} = 2(100-7.5) 15 = 2775 \text{ mm}^2$$

$$K = 0.85$$

$$A_{net} = 5130 + 0.85 (2775) = 7488.75 \text{ mm}^2$$

$$F_t = 7488.75 (150) = 1123312.5 \text{ N}$$

$$F_c = 1123312.5 \text{ N}$$



**Equal Angles Long Leg is Connected with 20mm Thick Gusset Plate on its Side with Tacking Rivet**

one side  $= 2(200 - 21.5 - 7.5)15 = 5130 \text{ mm}^2$   
 other side  $= 2(100 - 7.5)15 = 2775 \text{ mm}^2$

total area  $= 2(100 - 7.5)15 = 2775 \text{ mm}^2$

$= 5130 + 0.90(2775) = 7627.5 \text{ mm}^2$

$= 5(150) = 1144125 \text{ N}$

rivet is giving higher strength in tension whose  $F_t = 1144125 \text{ N}$  (Table 2).

### 3.5 Discontinuous Compression Member

The members are either single equal or un-equal and double equal single or unequal and their legs are connected with 20mm thick gusset plate on various conditions with ends rivet either single riveted or double riveted with a length of 2000mm have been assumed and illustrated to get the result, for the theme of the paper.

#### 3.5.1 Equal Single Member Connected to the Gusset Plate with Ends Single Riveted

$r_v = 29.2, l = 2000 \text{ mm}, l/r_v = 2000/29.2 = 68.5$   
 stress at  $l/r_v = 68.5 = 113.5 \text{ N/mm}^2$   
 $F_c = 4278(113.5)(0.8) = 388442.4 \text{ N}$   
 $F_t = 388442.4 \text{ N}$

**Comparative Table for Tensile Strength of Two Angles Connected with 20mm Thick Gusset Plate on its Various Positions**

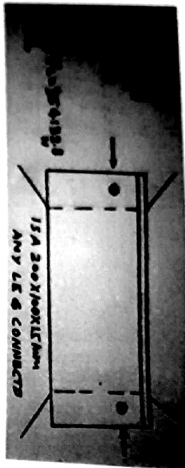
• Double unequal angles long leg connected one side of gusset plate without tacking

Table 2 Comparative table for tensile strength of two angles connected with 20mm thick gusset plate in various positions

Double Angle	Condition to gusset plate	Connection	Tensile Strength	Preference
ISA 150 150 15	Either side	Any Leg	544950N	Same
ISA 200 100 15	Either side	Long Leg	544950N	Same
ISA 200 100 15	Either side	Short Leg	544950N	Same
150 150 15	one side without tacking	Any Leg	1006200 N	2 <sup>nd</sup>
200 100 15	one side without tacking	Long Leg	1123312 N	1 <sup>st</sup>
200 100 15	one side without tacking	Short Leg	769950 N	3 <sup>rd</sup>
150 150 15	one side without tacking	Any Leg	1063912.5 N	2 <sup>nd</sup>
200 100 15	one side without tacking	Long Leg	1144125 N	1 <sup>st</sup>
200 100 15	one side without tacking	Short Leg	882562 N	3 <sup>rd</sup>

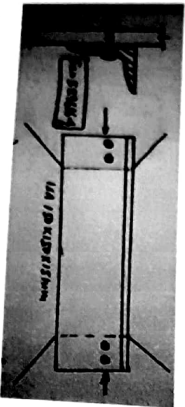
**3.5.2 Unequal Single Angle Any Leg is Connected with Gussel Plate with Ends Single Riveted**

$r_y = 26.4, l = 2000\text{mm}, l/r_y = 2000/26.4 = 75.75$   
 stress at  $l/r_y = 75.75 = 103.475 \text{ N/mm}^2$   
 $F_c = 4278(103.475)(0.8) = 354132.8 \text{ N/mm}^2$   
 $F_c = 354132.8 \text{ N}$



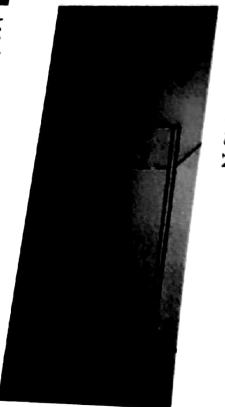
**3.5.3 Equal Angle Single with Ends Double Riveted**

$r_y = 29.2, l = 0.85(2000) = 1700\text{mm}, l/r_y = 1700/29.2 = 58.2$   
 stress at  $l/r_y = 58.2 = 123.8 \text{ N/mm}^2$   
 $F_c = 4278(123.8) = 529616.4 \text{ N/mm}^2$   
 $F_c = 529616.4 \text{ N}$



**3.5.4 Unequal Single Angle any Leg Connected with Ends Double Riveted**

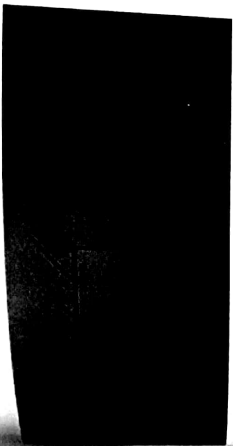
$r_y = 26.4, l = 1700\text{mm}, l/r_y = 1700/26.4 = 64.4$   
 stress at  $l/r_y = 64.4 = 117.6 \text{ N/mm}^2$   
 $F_c = 117.6(4278) = 503092.8 \text{ N}$   
 $F_c = 503092.8 \text{ N}$



**3.6 Discontinuous Compression Members Double Equal and Double Unequal Angle**  
 Result = Equal angle single with ends double riveted is more strength full compression member unequal angle, whose  $F_c = 529616.4 \text{ N}$ , connected gusset plate under various positions then the resulting strength will show the good strength steel angle section.

**3.6.1 Equal Angles either Side of Gusset Plate with Single Riveted**

$l = 2000\text{mm}, I_{xx} = 2(8968000) = 17936000\text{mm}^4$   
 $I_{yy} = 2(8968000) + 2(4278)(52.6)^2 = 41608398.56 \text{ mm}^4$   
 $I_{min} = 17936000\text{mm}^4$   
 $r_{xx} = 45.8, l/r_{xx} = 2000/45.8 = 43.7$   
 stress at  $l/r_{xx} = 43.7 = 136.4 \text{ N/mm}^2$   
 $F_c = 4278(136.4)(0.8) = 466849.584 \text{ N}$   
 $F_c = 466849.584 \text{ N}$



**3.6.2 Equal Angles are One Side of Gusset Plate with Single Riveted**

Things will be same as in 3.6-1  
 $F_c = 466849.584 \text{ N}$

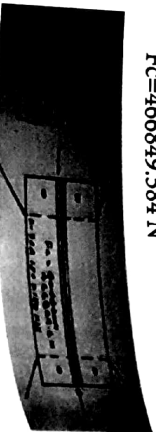
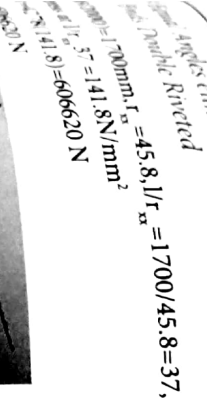




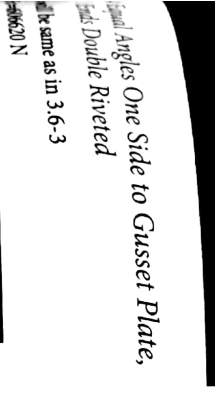
Table for single compression member

End Condition	Compressive Strength	Preference
Leg Connected	388442.4 N	3 <sup>rd</sup>
Any Leg	354132.8 N	4 <sup>th</sup>
Any Leg	529616.4 N	1 <sup>st</sup>
Any Leg	503092.8 N	2 <sup>nd</sup>

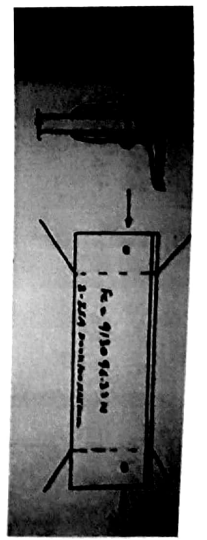
Angles either Side to Gusset Plate,  
 Double Riveted  
 $F_c = 2(4278)(133.4) = 913096.32 \text{ N}$   
 $F_c = 913096.32 \text{ N}$



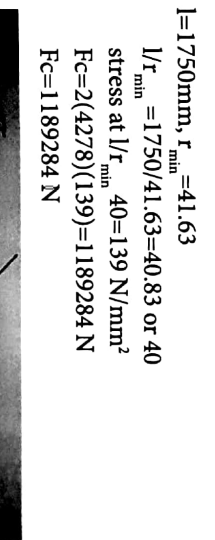
Equal Angles One Side to Gusset Plate,  
 Double Riveted  
 will be same as in 3.6-3  
 $F_c = 913096.32 \text{ N}$



Unequal Angle Long Leg Connected  
 either Side to the Gusset Plate, Ends  
 Single Riveted  
 $I_{xx} = 2(2981000) = 5962000 \text{ mm}^4$   
 $I_{yy} = 2(17500000) + 2(4278)(81.8)^2 = 92250249.44 \text{ mm}^4$   
 $r_{xx} = 3000/41.63 = 48$   
 $r_{yy} = 133.4 \text{ N/mm}^2$



3.6.6 Unequal Angle Long Leg Connected  
 either Side to the Gusset Plate, Ends -  
 Double Riveted  
 $I = 1750 \text{ mm}, r_{\min} = 41.63$   
 $I/r_{\min} = 1750/41.63 = 40.83$  or 40  
 stress at  $I/r_{\min} = 40 = 139 \text{ N/mm}^2$   
 $F_c = 2(4278)(139) = 1189284 \text{ N}$   
 $F_c = 1189284 \text{ N}$



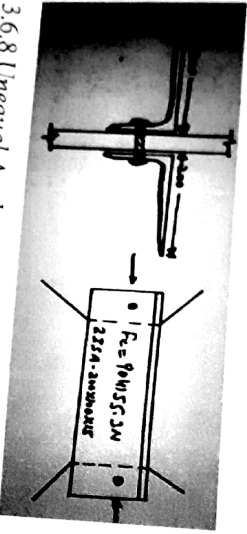
3.6.7 Unequal Angles Short Leg Connected  
 either Side to Gusset Plate Ends Single  
 Riveted  
 $I_{xx} = 2(2981000) = 5962000 \text{ mm}^4$   
 $I_{yy} = 2(17500000) + 2(4278)(81.8)^2 = 92250249.44 \text{ mm}^4$   
 $I_{\min} = 5962000 \text{ mm}^4$   
 $r_{\min} = 26.4$   
 $I/r_{\min} = 2000/26.4 = 75.75$

Table 4. Comparative table for double angles as compression member under various positions

Sl.no.	Double Angle	Leg Connected	End Condition	Gusset plate Condition	Various Positions	Compressive strength	Reduction
1	150 150 15	Any Leg	single riveted	Angle either side of plate	Angle either side of plate	466849.6 N	0%
2	150 150 15	Any Leg	single riveted	Angle one side of plate	Angle one side of plate	466849.6 N	0%
3	150 150 15	Any Leg	Double riveted	Angle one side of plate	Angle either side of plate	597208.8 N	0%
4	150 150 15	Any Leg	Double riveted	Angle either side of plate	Angle either side of plate	597208.8 N	0%
5	200 100 15	Long Leg	single riveted	Angle either side of plate	Angle either side of plate	913096.3 N	0%
6	200 100 15	Long Leg	Double riveted	Angle either side of plate	Angle either side of plate	1189284 N	0%
7	200 100 15	Short Leg	single riveted	Angle either side of plate	Angle one side of plate	904555.3 N	1%
8	200 100 15	Long Leg	single riveted	Angle one side of plate	Angle one side of plate	904555.3 N	1%
9	200 100 15	Long Leg	Double riveted	Angle one side of plate	Angle one side of plate	999600 N	0%
10	200 100 15	Short Leg	Double riveted	Angle either side of plate	Angle either side of plate	999600 N	0%
11	200 100 15	Short Leg	single riveted	Angle one side of plate	Angle one side of plate	848160 N	3%
12	200 100 15	Short Leg	Double riveted	Angle either side of plate	Angle either side of plate	1132875 N	6%

stress for  $l/r_{min} = 75.75 = 105.675 \text{ N/mm}^2$   
 $F_c = 2(4278)(105.675) = 904155.3 \text{ N}$   
 $F_c = 904155.3 \text{ N}$

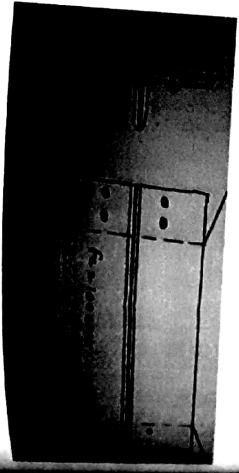
3.6.9 Unequal Angles Long Leg Connected  
 Side to the Gusset Plate Ends Double Riveted



$l = 1700 \text{ mm}$ ,  $r_{min} = 26.4$ ,  $l/r_{min} = 1700/26.4 = 64.4$   
 stress at  $l/r_{min} = 64.4 = 117.6 \text{ N/mm}^2$   
 $F_c = 2(4278)(117.6) = 1006185 \text{ N}$   
 $F_c = 1006185 \text{ N}$

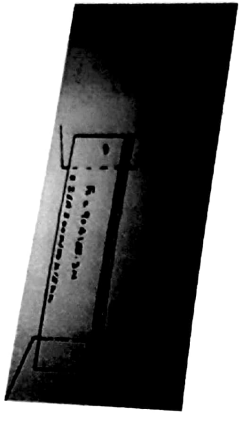
3.6.8 Unequal Angles Long Leg Connected  
 One Side to the Gusset Plate, Ends Single Riveted

The strength will be same as in 3.6-7  
 $F_c = 904155.3 \text{ N}$



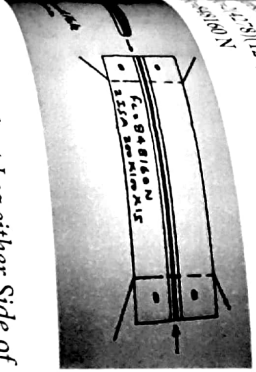
3.6.10 Unequal Angles Short Leg Connected  
 either Side to the Gusset Plate Ends Double Riveted

$F_c = 999600 \text{ N}$



*Unequal Angles Short Leg one Side to Gusset Plate Ends Single Riveted*

$$\begin{aligned}
 & \times 2000/34.5 = 58 \\
 & \times 124 = 124 \text{ N/mm}^2 \\
 & \times 8 = 848160
 \end{aligned}$$



*Unequal Angles Short Leg either Side of Gusset Plate, Ends Double Riveted*



**built and Discussions**

It reveals that the angles bearing same cross-sectional area of either equal or unequal angles, they are single or double, while using as member, unequal angles-long leg connected member will show higher strength. Long leg side to gusset plate with tacking rivet member has shown highest strength than sections while using double angles

So far the compression member is concerned, single equal angle has shown good strength with ends double riveted, than unequal angle. If double angles are used then unequal angles long leg connection, either side to gusset plate, with ends double riveting has been showing the highest compressive strength than only side connection to gusset plate even equal angles.

Hence it is finally discussed with this paper and recommended to use single unequal angle with its long leg connected to gusset plate and using it as tension member is preferable rather than equal angle rather than unequal short leg connected as constrain. Also if double angles are being used as tension member then unequal angles long leg connected to gusset plate to its one side with tacking rivet will be showing highest tensile strength than without tacking rivet. If constrain then equal angles one side to gusset plate plus tacking rivet and then without tacking rivet may be used. Short leg connection is not recommended to use in structures.

As compression member single equal angle with ends double riveted is recommended to use in place of unequal angle. It is too recommended that if double angles are being used as compression member than long leg connected either side to gusset plate is having highest strength rather than one side to gusset plate of long leg connected. Equal angles are not recommended to use as compression member.

**5. Reference**

1. Varshaney MK. Book design of steel and masonry structures.