RESEARCH ARTICLE OPEN ACCESS

Valuation 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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I. Introduction

Basically the structural steel is an alloy of iron, carbon-n-little parts of manganese, chrome nickel, sulfur, phosphorous-n-copper to form its rolled steel sections like angles, tees, channels, girders-n-plates which are used as beams, truss frames, column-bases, plate-girders etc to bear loads in the module of tensile-n-compressive stresses to safe the structure in deflection-n- bending. Structural steel is weather resistant and more stress bearing than normal steel. As normal specified steel is used in utensils, toys, vehicle-frames, furniture -n-watches etc. , where loads and incoming varying stresses are not of structural type. While designing the steel structure two codes are usually followed viz. IS-Code: 800-1984 and 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 linear till yield stress. The permissible stress is kept by dividing it by factor of safety. Factor of safety is the 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 n serviceability of structure. The limitable strength is desired to avoid the collapse of the structure n safe the life. The permissible stresses are taken much higher than working stresses. In working stress, stresses are taken like ft=150N/mm^2, while ft=227 N/mm^2-n-rupture stress 295N/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.

II. GENERAL CONCEPT

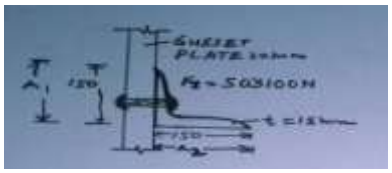
So far the title of the paper is concern wherein the study has been made for angles of equal and unequal in size but having same cross sectional area, have been used as tension and compression members and their ends have either single riveted or double riveted. The strength has been calculated by using 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^2 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^2 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.

III. 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.

3.1-Case Study :-1-Single angle with gusset plate as tension member riveted with 20mm rivet diameter.

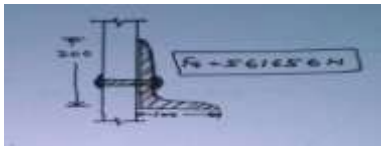


3.1-1-connected leg area=(150-21.5-7.5) 15=1815 mm^2

outstanding area=(150-7.5) 15 =2137.5 mm^2

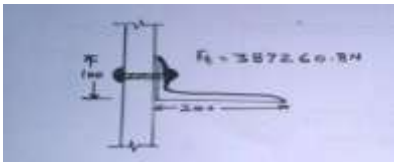
K=0.72
A_{NET} = 3354 mm^2
F_t=503100N

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^2
outstanding area=(100-7.5) 15=1387.5 mm^2
K=0.85
A_{net}=3744.375 mm^2
Ft=561656N

3.1-3-Unequal Angle 200*100*15mm whose short leg is connected with 20mm thick gusset plate.
connected area=(100-21.5-7.5) 15=1065 mm^2
outstanding area=(200-7.5) 15= 2887.5 mm^2
K=0.52
A_{net}= 2581.74 mm^2
F_t=387260.79 N



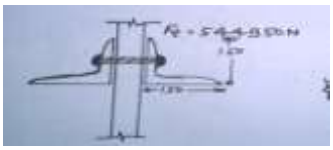
3.2-Comparative Study Table as tension single member Result-single unequal angle's long leg connected to the gusset plate is showing higher strength than

equal angle, whose tensile strength Ft=561656 N

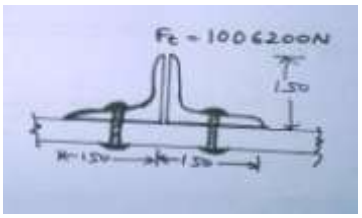
Sl.No	Angle	Leg cunnected	Connection	Tensile strenth	Preference
1	Equal ISA-150 150 15	Any leg	single riveted	503100 N	2nd
2	Unequal ISA 200 100 15	long leg	single riveted	561656 N	1st
3	Unequal ISA 200 100 15	short leg	single riveted	387260.79 N	3rd

3.3-Two Angle as tension member:-Somewhere when load is more then to restrict the stress in the tension member two members of same dimensions are used. The two angle members are connected either side or only one side to the gusset plate.

3.3-1-Case Study 2:-ISA 150*150*15mm and ISA 200*100*15mm.
3.3-1.1-Equal angles either side connected with 20mm thick gusset plate means the plate is sandwiched between two angles.
A_{net}=(4278-43) 15= 3633 mm^2
Ft= (3633)150 N
F_t=544950 N



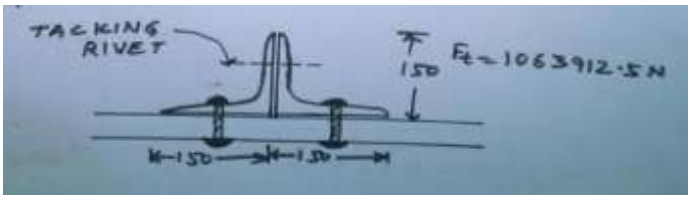
3.3-1.2-Equal angles are one side to the 20 mm thick gusset plate without tacking rivet.
connected area=2(150-21.5-7.5) 15= 3630 mm^2
outstanding area=2(150-7.5) 15=4275 mm^2
K=0.72
A_{net}= 3630 +0.72(4275)=6708 mm^2
Ft=6708(150)= 1006200 N
F_t=1006200 N



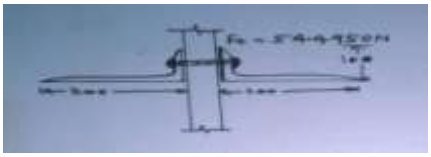
3.3-1.3-Equal angles are one side to 20mm thick gusset plate with tacking rivet.
Connected area= 3630 mm^2
outstanding area=4275 mm^2
K=0.81
Anet= 3630 +0.81(4275)=7092.75 mm^2

Ft= 7092.75(150)=1063912.5 N

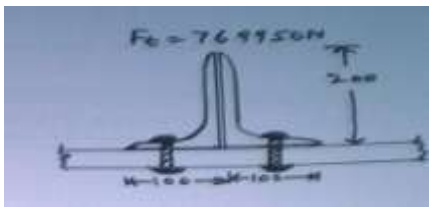
F_t=1063912.5 N



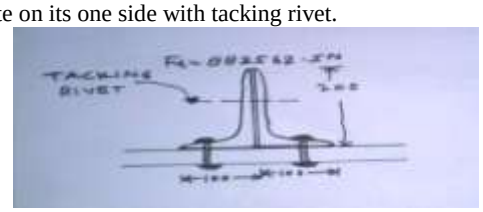
3.3-2.1-Unequal angles short leg is connected with 20mm thick gusset plate on its either side
A_{net}=3633mm^2
Ft= (3633) 150= 544950 N
F_t=544950N



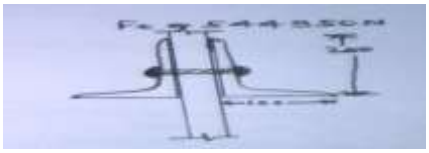
3.3-2.2-Unequal angles short leg is connected with 20mm thick gusset plate on its one side without tacking rivet
Connected area= 2(100-21.5-7.5) 15= 2130 mm^2
outstanding area= 2(200-7.5) 15= 5775 mm^2
K=0.52
A_{net}= 2130 + 0.52(5775) =5133 mm^2
Ft= 5133 (150)= 769950 N
F_t=769950 N



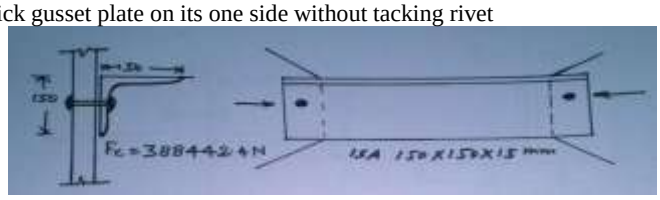
3.3-2.3-Unequal angles short leg is connected with 20mm thick gusset plate on its one side with tacking rivet.
Connected area= 2130 mm^2
outstanding area= 5775 mm^2
K=0.65
A_{net}= 2130+0.65(5775)= 5883.75 mm^2
Ft= 5883.75 (150) =882562.5 mm^2
F_t=882562.5 N



3.3-3.1-Unequal angles long leg is connected with 20mm thick gusset plate on its either side
A_{net}= 3633 mm^2
Ft= 3633 (150)= 544950
F_t=544950 N

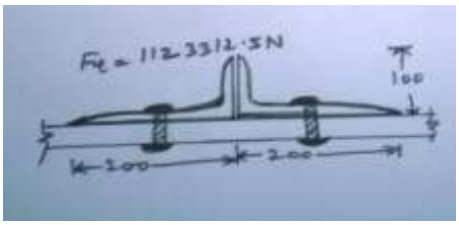


3.3-3.2-Unequal angles long leg is connected with 20mm thick gusset plate on its one side without tacking rivet
Connected area=2(200-21.5-7.5) 15= 5130 mm^2
Outstanding area= 2(100-7.5) 15=2775 mm^2
K=0.85
A_{net}= 5130 +0.85 (2775)= 7488.75 mm^2
F_t= 7448.75 (150)= 1123312.5 N
F_t=1123312.5 N



3.3-3.3-Unequal angles long leg is connected with 20mm thick gusset plate on its one side with tacking rivet

Connected area=2(200-21.5-7.5)15=5130 mm^2
outstanding area=2(100-7.5)15=2775mm^2
K=0.90
A_{net}= 5130+0.90(2775)=7627.5 mm^2
F_t=7627.5 (150)=1144125 N
F_t=1144125N



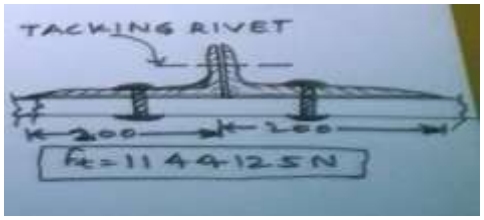
3.4- Comparative table for tensile strength of two angles connected with 20mm thick gusset plate on its various positions
Result- Double unequal angles long leg connected with one side of gusset plate without tacking rivet is giving higher strength in tension whose F_t=1144125N

Sl.No.	Double Angle	Condition to gusset plate	connection	Tensile Strength	Preference
1	ISA 150 150 15	Either side	Any Leg	544950N	Same
2	ISA 200 100 15	Either side	Long Leg	544950N	Same
3	ISA 200 100 15	Either side	Short Leg	544950N	Same
1	150 150 15	one side without tacking	Any Leg	1006200 N	2nd
2	200 100 15	one side without tacking	Long Leg	1123312 N	1st
3	200 100 15	one side without tacking	Short Leg	769950 N	3rd
1	150 150 15	one side without tacking	Any Leg	1063912.5 N	2nd
2	200 100 15	one side without tacking	Long Leg	1144125 N	1st
3	200 100 15	one side without tacking	Short Leg	882562 N	3rd

3.5-DiscontinuousComression 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_{vv}=29.2, l=2000mm, l/r_{vv} =2000/29.2 =68.5
stress at l/r_{vv} 68.5=113.5 N/mm^2

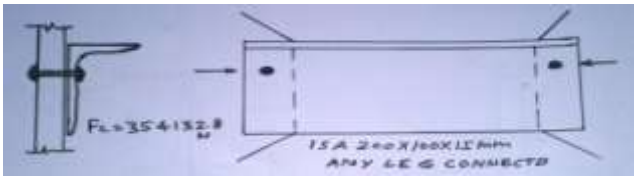
Fc=4278(113.5)(0.8) =388442.4 N
F_c=388442.4 N



3.5-2-Unqual single angle any leg is connected with gusset plate with ends single riveted

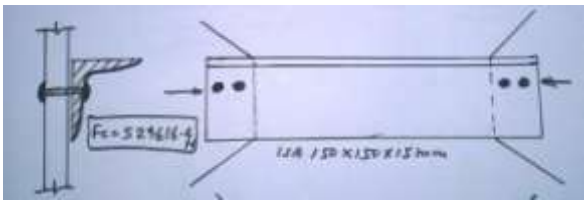
r_{yy}=26.4, l=2000mm , l/r_{yy}=2000/26.4 =75.75

stress at l/r_{yy}75.75 =103.475 N/mm^2
Fc= 4278(103.475)(0.8) =354132.8 N/mm^2
F_c=354132.8 N



3.5-3:-Equal angle single with ends double riveted

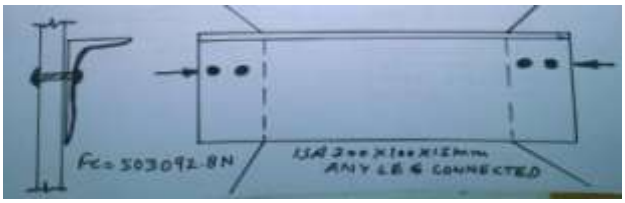
r_{vv}=29.2, l=0.85(2000)=1700mm, l/r_{vv} =1700/29.2 =58.2
stress at l/r_{vv} 58.2 =123.8 N/mm^2
Fc= 4278(123.8)= 529616.4 N/mm^2
F_C=529616.4 N



3.5-4:-Unequal single angle any leg connected with ends double riveted

r_{yy}=26.4, l=1700mm, l/r_{yy} =1700/26.4 =64.4
stress at l/r_{yy} 64.4 = 117.6N /mm^2
Fc=117.6(4278)=503092 .8 N

F_c=503092.8 N



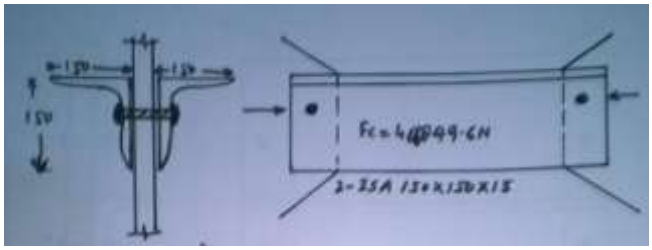
Comparative table for single compression member

Sl.No.	Angle Single	Leg Connected	End Condition	Compressive Strength	Preferance
1	150 150 15	Any Leg	single riveted	388442.4 N	3rd
2	200 100 15	Any Leg	single riveted	354132.8 N	4th
3	150 150 15	Any Leg	single riveted	529616.4 N	1st
4	200 100 15	Any Leg	single riveted	503092.8 N	2nd

Result=Equal angle single with ends double riveted is more strength full compression member than unequal angle, whose F_c=529616.4N

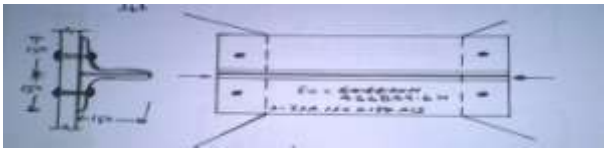
3.6-Discontinuous Compression member double equal and double unequal connected with gusset plate under various positions may be there and they are having different strength. The higher resulting strength will show the good valuated strength steel angle section.

3.6-1-Equal angles either side of gusset plate with single riveted
l=2000mm, I_{xx}=2(8968000)=17936000mm^4
I_{yy}=2(8968000) +2(4278)(52.6)^2
=41608398.56 mm^4
I_{min}=17936000mm^4
r_{xx}=45.8, l/r_{xx}= 2000/45.8 =43.7
stress at l/r_{xx} 43.7= 136.4 N/mm^2
Fc=4278(136.4)(0.8)=466849.584N
Fc=466849.584 N



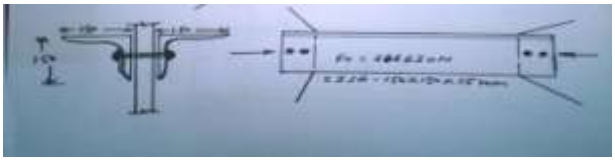
3.6-2-Equal angles are one side of gusset plate with single riveted

Things will be same as in 3.6-1
Fc=466849.584 N



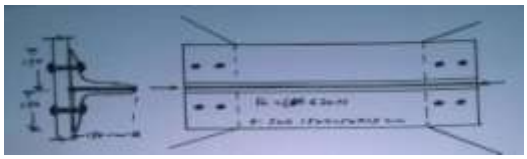
3.6-3-Equal angles either side to gusset plate, ends double riveted
l=0.85(2000)=1700mm, r_{xx}=45.8, l/r_{xx}=1700/45.8=37,
stress at l/r_{xx}37 =141.8N/mm^2

Fc=4278(141.8)=606620 N
Fc=606620 N

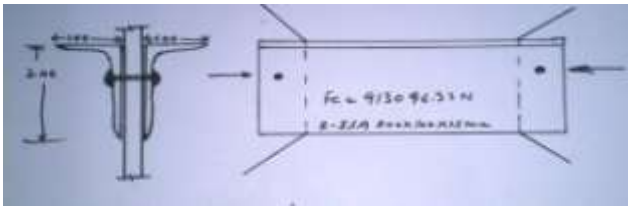


3.6-4-Equal angles one side to gusset plate, ends double riveted
This will be same as in 3.6-3

Fc=606620 N

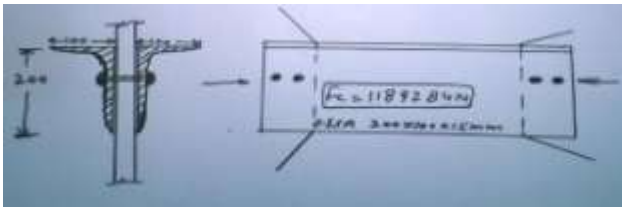


3.6-5-Unequal angle long leg, connected either side to the gusset plate, ends single riveted
I_{xx}=2(17500000)=35000000 mm^4
I_{yy}=2(2981000) +2(4278)(32.2)^2 =14833203 mm^4
$I_{min.}$=14833203 mm^4
r_{min}=41.63
l/r_{min}=2000/41.63 =48
stress al l/r_{min}48=133.4 N/mm^2
Fc=2(4278)(133.4)=913096.32 N
Fc=913096.32N

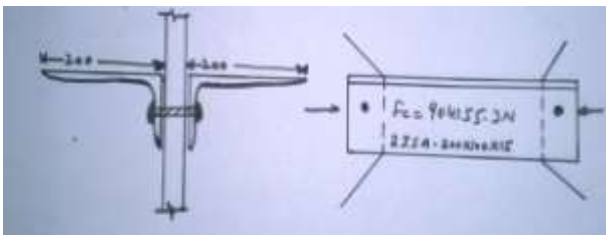


3.6-6-Unequal angle long leg, connected either side to the gusset plate, ends -DOUBLE RIVETED
l=1750mm, r_{min}=41.63
l/r_{min} =1750/41.63=40.83 or 40
stress at l/r_{min} 40=139 N/mm^2
Fc=2(4278)(139)=1189284 N

Fc=1189284 N



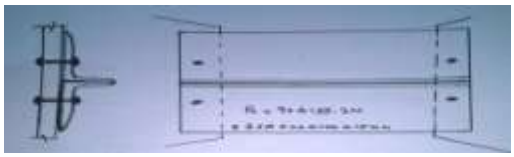
3.6-7-Unequal angles short leg connected either side to gusset plate ends single riveted
l_{xx}=2(2981000)=5962000 mm^4
I_{yy}=2(17500000)+2(4278)(81.8)^2=92250249.44 mm^4
I_{min}=5962000mm^4
r_{min}=26.4
l/r_{min}=2000/26.4=75.75
stressfor l/r_{min} 75.75=105.675 N/mm^2
Fc=2(4278)(105.675)=904155.3N
Fc=904155.3 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

Fc=904155.3 N

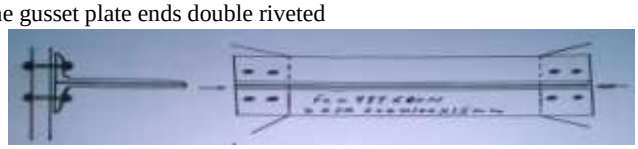


3.6-9--Unequal angles long leg connected one side to the gusset plate Ends double riveted

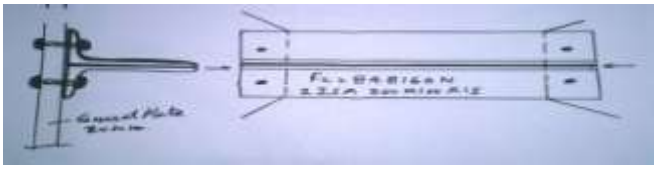
l=1700 mm, r_{min}=26.4, l/r_{min}=1700/26.4=64.4
stress at l/r_{min}64.4=117.6N/mm^2
Fc=2(4278)(117.6)=1006185 N
Fc=1006185N

3.6-10-Unequal angles short leg connected either side to the gusset plate ends double riveted

Fc=999600N

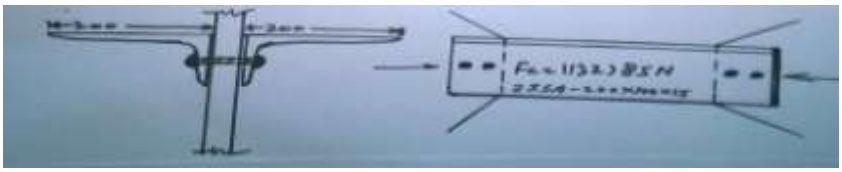


3.6-11 - Unequal angles short leg one side to gusset plate ends single riveted
I_{xx}=35000000mm^4
I_{yy}=1017782mm^4
r_{min}=34.5, l/r_{min}=2000/34.5=58
stress at l/r_{min} 58=124N/mm^2
Fc=2(4278)(124)=848160
Fc=848160 N



3.6-12-Unequal angles short leg either side of gusset plate, ends Double riveted

Fc=1132875 N



Comparative table for double angles as compression member under various positions

sl.no.	Double Angle	Leg Connected	End Condition	Gusset plate Condition	Compressive-strength	Preference
1	150 150 15	Any Leg	single riveted	Angle either side of plate	466849.6 N	8th
2	150 150 15	Any Leg	single riveted	Angle one side of plate	466849.6 N	8th
3	150 150 15	Any Leg	Double riveted	Angle one side of plate	597208.8 N	7th
4	150 150 15	Any Leg	Double riveted	Angle either side of plate	597208.8 N	7th
5	200 100 15	Long Leg	single riveted	Angle either side of plate	913096.3 N	4th
6	200 100 15	Long Leg	Double riveted	Angle either side of plate	1189284 N	1st
7	200 100 15	Short Leg	single riveted	Angle either side of plate	904555.3 N	5th
8	200 100 15	Long Leg	single riveted	Angle one side of plate	904555.3 N	5th
9	200 100 15	Long Leg	Double riveted	Angle one side of plate	999600 N	3rd
10	200 100 15	Short Leg	Double riveted	Angle either side of plate	999600 N	3rd
11	200 100 15	Short Leg	single riveted	Angle one side of plate	848160 N	6th
12	200 100 15	Short Leg	Double riveted	Angle either side of plate	1132875 N	2nd

IV. Result and discussions

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

Reference

[1.] M. K. Varshaney's book design of steel & masonry structures.