Design of Connections in Tubular Structure

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Abstract – *Due to advancements in the construction industry a slow shift from RCC structures to steel structures can be seen. Steel tube structures have started dominating construction industry due to its various advantages like they perform better in twisting and minor direction bending capacity, are better in buckling due to less slenderness ratio, provide better earthquake performance, no shuttering is required in composite columns, Less Construction Time is required.*

All these members and components are joined by connections, so it becomes important to design the steel junction connections precisely and with utmost care. These connections are responsible for the transference of forces or loads from one member to another. In this project various connection details have been designed manually.

Key Words: Steel connections, Steel tubes, Shear connections, Bolted connection, Fixed welded connection.

1. INTRODUCTION

Connection design is One of the most important components of steel detailing. It is the essential part of the process which makes sure that the components hold together as they probably should. Dy by day Engineers are developing new ideas and coming up with new and improved challenging designs. Without proper connection designs, the completion of new steel tubes building buildings is not possible. The steel framework, which is concealed under a sleek facade, is put to extreme pressures by the building's tall heights and unusual geometries. There is a great demand for precise steel details and connection design.

Producing steel detailing and connecting designs is a difficulty for all buildings, of course. It is also important for less complex construction projects, such as factory structures, apartment complexes with distinctive balconies, and bridges. To ensure that lives aren't put in danger, they all need precise, dependable steel details and connection design

Fundamentally , the connectivity element of steel detailing is what is used to calculate the transference of forces between sections of steel. Basically, these forces can be categoriesed into : Beam to beam, bracing connections, column to beam, and splice.

A connection must be designed for connectivity in order to assure that it won't fail due to the applied load detail. It must also take into account the requirements of fabricators and erectors while creating and putting in place the various components. The method of verifying steel connections must include demonstrating the quality of welds and confirming that the stresses placed on the steel plates, sections, and bolts holding them together are all well within the tolerances of the materials that are specified.

1.1 TYPES OF CONNECTIONS

On the basis of different loads broadly steel connections can be categorized into following types.

1.Tension Connections

2.Compression Connections

3.Shear Connections

4.Moment Connections

Steel connections can further be classified on the basis of the restraint they provide. These classifications (in decreasing restraint level are as follows:

1.Fully restrained moment connections

2.Partially restrained moment connections

3.Simple shear connections

The fully restrained connections can resist the maximum end moments and it allows minimum amount of end rotation while as simple shear connections supports lower end moments and allows maximum end rotation. Partially restrained connections lie in the middle of fully restrained and the simple shear connections

2. AXIAL CONNECTON FOR BRACINGS

Grade of Steel, fy	= 345 N/mm2
Details of Section (D x B x t)	= 250x250x10mm3
Area of Section, Ag	= 9600 mm2
Diameter of Bolt	= 24 mm
Grade of Bolt	= 8.8
No. of Bolts Provided	= 18 Minimum 31 Bolts
No. of Bolts Provided along Width of Plate	=3
Provided Thickness of Plate	= 32 mm

2.1 Welded connection for bracing

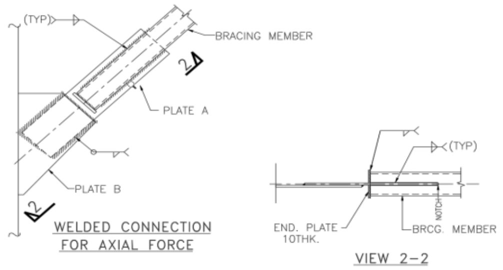

Fig -1: Typical detail for welded bracing connection

As per is 800 2007 connection should be designed for tension force of 1.2 x Ag x Fy

Tensile force for connection = 1.2 x Ag x Fy
= 1.2 x 9600 x 345
= 3974.4 kN

Taking Plate Strength T_{dg} = Tensile force for connection
0.9 x (Width of plate) x (345/1.25)x 32 = 3974.4 kN
So, Required Width of plate A adjacent to plate B = 500mm

Plate to Gusset Plate Connection (Wielding Required)

Provided Weld Thickness = 32 x 0.7 =22 mm

Length of Weld = $\frac{\text{Area of Weld}}{\text{Weld Thickness}}$

Area Of weld between plate A and B
= 3974.4 x 10^3 x √3x 1.5/345 = 29929.8 mm2
Length of Weld = 29929.84/22
= 1426 mm

Length of Weld except on width of plate
= 1426-500 = 926 mm
Length of Weld on one side
= 926/2 = 463mm

2.2 Bolt connection

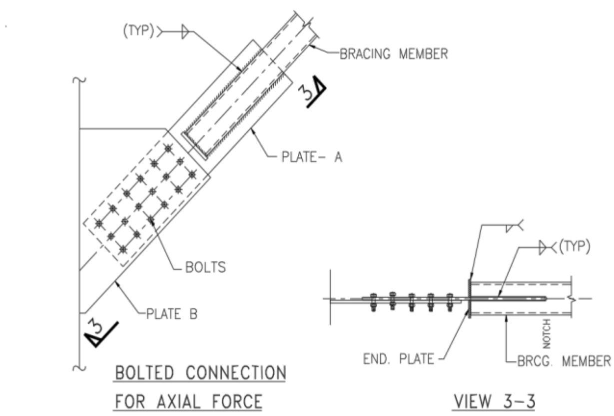

Fig -2: Typical detail for bolted bracing connection

Tensile force for connection = 3974 KN
Shear Capacity of Bolt

$$= \frac{f_u \times A_{nb}}{\gamma_{m1} \times \sqrt{3}}$$

Anb = Net area of bolt = 0.78 x area of shank
= 800/125 x 352.86/√3
= 130.38 KN

No. of Bolts required = = 3974.4/130.38
= 30.48 » 31

Area of weld between member and plate A
= 3974.4 x 10^3 x √ 3 x 1.5/345
= 29929.8 mm2

Allowable weld on member = 0.7x10 = 7mm
Length of weld = 29929/(7x2) = 2137 mm
Length of weld on both side of member = 2137 /2
= 1068 mm.

2.3 Shear connection for secondary beams

Section Details (DxBxt) = ISMB350
Grade of Steel = 250 N/mm2
Diameter of Bolt = 16 m
Grade of Bolt = 8.8
No. of Bolts Provided = 4
Pitch Distance of Bolts,p = 75 mm
Edge Distance of Bolts,e = 50 mm
Thickness of Plate = 25 mm
Thickness of Weld = 8.5 mm

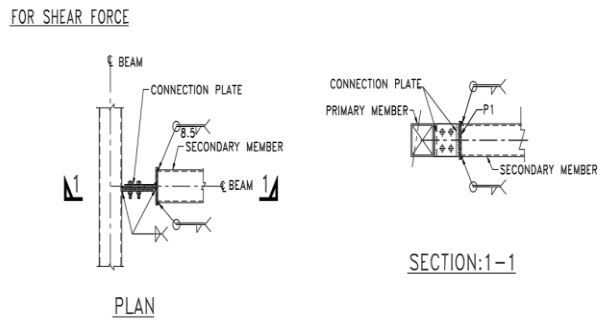

Fig -3: Typical detail for bolted shear connection

Loads on floor

Self-weight of deck slab
= (0.080+0.0375) x 25 + 0.001 x 78.5 = 3.016 kN/m2
Floor fininsh = 0.05x25
= 1.25 kN/m2

Service load = 1 kN/m2
Partition wall load = 1 kN/m2
Live load = 3 kN/m2
Total load = 9.266 kN/m2

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Contributory width of deck slab = 2m
UDL on secondary beam = 18.532 kN/m2
Total factored shear at support = 1.5x 7.5 x 18.532 /2
= 105 KN

Bolted Connection

Shear Capacity of Bolt, Vnsb
= (fu x (nn x Anb)) / √3Ymb =(800 x 1 x 157) / √3/1.25
= 58 kN
No. of Bolts Required = 105 / 58
= 1.8
Provided No. of Bolts = 4
Check plate strength –
Distance of 1st row of bolt from member = 75 mm
Diatance of 2nd row of bolt from member = 150mm
Moment at main member face
= 0.075x105x0.5 + 0.15x 105x0.5 = 11.82 knm
Assume 12mm thk. Plate
Moment capacity of plate = ZeFy / γmo
= $bd^2/6$ x 350/1.1
= 11.82 KNm

d (depth of plate) = √((11.82 x10^6 x 1.1 x 6)/(12x350))
d = 136 mm
Provide 350 mm deep plate
Bending capacity of 350 mm deep plate = ZeFy / γ_{mo}
= (12 x 350^2 x350) / (6 x1.1) = 78 KNm
Shear strength of plate = AgFy / γ_{mo}
= 12 x 400 x 350/1.1
= 1336 KN

Now combined ratio in axial and bending

N/Nd + M/Md ≤ 1
Here N = 1.5 KN M = 11.82
Nd = 1336 KN Md = 78
= 1.5/1336 + 11.82/ 78 = 0.23 ≤ 1
Safe

Check welding of connection plate to primary member

Provide thickness of weld = 6mm on each side
Shear stress in weld = (105x1000)/(6x350x2)
= 25 N/mm²
Section modulus of weld = $bd^2/6$
= (6 x 350^2 x 2)/ 6
= 245000 mm³
Bending stress in weld = (11.82 x 10^6) / 245000
= 49 N/mm²
Equivalent stress, Fe = $\sqrt{fa^2 + 3q^2} \leq fy/(\sqrt{3}\,\gamma_{mw})$
fa = 49 N/m2 = $\sqrt{49^2+25^2 x3} \leq 490/(\sqrt{3}x\,1.25)$
q= 25 N/mm = 66 N/mm² ≤ 226 N/mm²
Safe

2.4 Fixed Bolted Connection Detail for main beam to main beam (on view 5-5 in figure)

Moment,M (From Etab) = 292 kNm
Shear, V (From Etab) = 242 kN
Diameter of Bolt = 20 mm
Grade of Bolt = 10.9
Grade of Steel Plate = 350 N/mm2
Plate Details (DxB) = 400 X 600 mm2
Depth of Stiffener above or below member = 100 mm
Distance Between Stiffner plates = 100 mm

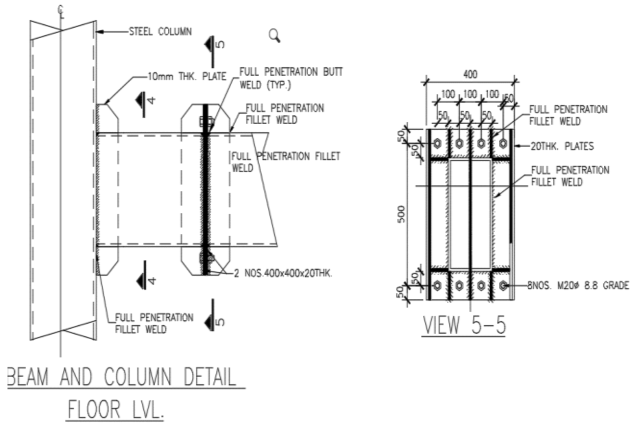

Fig -4: Typical detail for bolted tube splice connection

Distance between upper bolt row and lower bolt row
= 500 mm
Tension in Extreme Bolt, T = 292 /(0.5 x 0.4)
= 146 kN
Shear in each bolt = 242/8
= 30.25 kN
Tension Capacity of Bolt = 0.9 x 0.78 x 314.16 x1000/1.25
= 176.43 kN
Shear Capacity of Bolt =1000x0.78x314.16)/(√3) x 1.25)
= 113.18 kN
Combined Shear and Tension
= $(146/176.43)^2+(30.25/113.1)^2$ = $(0.83)^2+(0.27)^2$
= 0.76 < 1
Connection is SAFE

Design of Plate at View 5-5

Moment due to Tension in bolt = w x l /8
=146 x 0.1 /8
= 1.83kNm
Thickness of Plate =1.2x(100-22)x d^2/6 x 350/1.1
Now, Thickness of plate Calculated from = 1.83 kNm
= 1.83 x 106
= 1.2x(100-22)xd2/6x350/1.1
d2 = 368.6813187 d
= 20 mm

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2.5 Fixed Welded Connection Detail

On view 4-4 in figure -

Grade of Steel , fy = 350
Ultimate Strength of Steel, fu = 490 N/mm^2
Section Details (DxBxt) = 400x 200 x 10
Area of Cross Section, A = 116 cm^2
Elastic Section Modulus, Ze = 1217.9 cm^3
Plastic Section Modulus, Zp = 1502 cm^3
Shear from Etabs, V = 252 kN
No. of Stiffeners on one side of member = 3
Depth of Stiffener above and below member = 100 mm

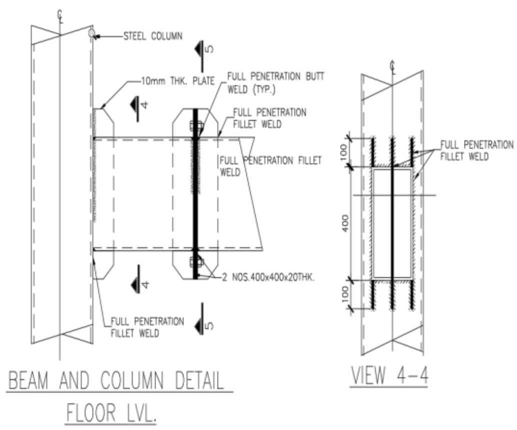

Fig -4: Typical detail for welded tube column beam junction connection

As per IS 800 -2007 all column beam junction should be designed for 1.2 times plastic moment capacity
Design Bending Strength of Steel Beam, Md
= β_b x Zp x fy/γ_{mo}x1.2
= 1.2x1x1502000x350/1.1 = 573.49 kNm
Shear force at face of column = 252 kN
Assumed Height of Stiffener (View 4-4)= 100 mm
Area of weld for shear = (400+(200x3)) x 2 x te
= 2000te
Moment of Inertia of weld
=(tex400^3)/12x2+(600xte)x250^2x2+(tex100^3)/12x12+(200x te)x200^2x2
= 10666666.66 te +75000000 te+999999.96te+ 16000000te
= 102666666.6 te
MOI of Weld = 102.67 x te x 10^6 mm^4
Section Modulus of weld, Z = 102.67/300 xte
=34xtex 10^4 mm3
Moment/ Section Modulus, M/Z
=(292x10^{6}Nmm)/ 34x10^{4}mm3 te
= 858.8235294 / te N/mm^2
Shear Stress = 252x 10^3/ 2000 te
= 126/ te N/mm^2
Equivalent Stress, fe = $\sqrt{fa^2 + 3q^2}$
Now, fa = 858.8235294 / te
q = 126/ te
fe= √858.8235294^2+(3x126^2) / te
Equivalent Stress, fe = 886.1184202 / te
Equivalent Stress, fe = 490/((√3)x1.5)
= 188.6
So, = 886.1184202 / te
= 188.6
te = 4.7 mm
Provide throat thickness = 5mm
Required Thickness of weld = 5 /0.7
= 7.1 mm

3. CONCLUSIONS

Design of steel connection requires vigorous calculations but provides much more control than connection by other building materials.

Upon experience we have understood that steel connection is much more safer than RCC connection.

Any two steel members can be joined by many numbers of connection possibilities as can be seen by the literature above.

The need to calculate modular ratio (m) becomes nil when two members of same material like steel are connected.

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