Design of Metal Deck Sheet and Composite I-Section as secondary member

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Abstract - *In recent times steel structures are being adopted for construction of structures conforming to their advantages over conventional RCC structures. India is the world's second-largest cement producer, so before the year 2000 most of the constructions were done in RCC and there were other numerous reasons for this some of them being, in RCC construction lesser skilled labours were required, the deadline of the project did not matter ,there was a lack of higher grade steel and large steel sections were not readily available but after the year 2000 steel structures were gaining popularity and their execution was started ,the chief reason for this was the shift in market from cost oriented to time oriented construction. During this time there was unavailability of higher section sizes in steel tubes so built-up composite structures were preferred. The production of higher cross section tube sizes was started in 2019 by some vendors like TATA ,APL Apollo, this has revolutionized the construction market and a some of new constructions are being done in steel structures now.*

Key Words: Steel structure, Earthquake, Seismic, Metal deck sheet, I-Section, Composite tube.

1. INTRODUCTION

A steel structure may be defined as a metal construction made mostly of structural steel components and sections that are joined to one another in various ways like welding, bolting, or riveting to carry loads from the structure *(also known as dead loads)* and from people inside the structure *(also known as Live Loads)* & provides rigidity. Due to steels high strength to counter tensile and compressive stresses, these structures are reliable and require less raw material in comparison to some other types of structural materials such as concrete.

To meet the requirements of a project, structural steel is manufactured with a certain shape and chemical composition. In present day construction practices, structures made of steel are employed almost for every other type of structure which includes high-rise buildings, towers, bridges, infrastructure, support systems for equipment and machinery, heavy industrial building, heavy industrial plant, etc.

Adhering to every structural specification, the dimensions for steel members formed by hot and cold rolled procedures are connected by welding or bolting flat and bent plates together. Frequently adopted shapes are the I shaped beams, Hollow sections, angle, channel, and plates.

1.1 ADVANTAGES OF STEEL STRUCTURES

Structures made from steel sections are quickly built at the project site because majority of building components could be prefabricated at the workshop or Steel manufacturing facility. The Expansion of any steel Structure can comparatively be very easy and fast. As steel can be molded into different shapes as a result repair & rehabilitation and/or retrofitting is conveniently possible. As the steel building components are prepared in the workshop, the erection of the structure at site is fast in comparison to other building materials.

Because of their flexibility, they are excellent at resisting dynamic (changing) forces like wind or seismic forces. In earthquake zones, the fact that steel may bend without cracking serves as a warning. There is a large selection of pre-made structural sections, including I, C, and angle sections. They can be fashioned into any shape and covered with any kind of shape. Bolting, welding, and riveting are just a few of the connecting techniques that are accessible. we can also recycle steel. About one-third of the energy required to produce new steel from scrap steel is used in this process.

1.2 DISADVANTAGES OF STEEL STRUCTURES

Before forming a structural system, analytical approaches and assumptions must be fairly clear and final. The time consumed to design a connection is longer than that of an RCC structure connection. The cost of structural steel (especially India) is higher than RCC. Skilled workforce is required. Steel has a property of becoming soft and melting when exposed to very high temperatures.

Additional fire protection, such as spray on fireproofing, structural steel buildings can withstand high temperatures, which in turn enhances security. They tend to corrode in damp or marine environments. Hence, consistent care is needed.

2. PROJECT STRUCTURAL SCHEME

All structural design and analysis must adhere to the latest Provisions of the Indian Standard codes for Steel and RCC construction primarily IS 800:2007 and IS 456:2000.

Special quality weld joints allowing 100% tension strength shall be required. Non-destructive testing techniques should be used for weld quality inspection and control. For slip-critical joints a slip factor of 0.5 shall be used in accordance with IS 4000 with specified surface treatment and preparation.

2.1. LOADS ON STRUCTURE

Dead load

Self-weight

The unit weight of materials shall conform to IS 875 – Part 1. The self-weight of structure is automatically calculated by the analysis software depending upon the cross-sectional area and density of each member.

Density of R.C.C members = 25.0 kN/m^3

Density of P.C.C members = 24.0 kN/m^3

Density of structural steel = 78.5 kN/m^3

Density of brick masonry walls (230/115 mm thick) = 20.0 kN/m^3

Dry density of soil = 18.0 kN/m^3

Density of saturated soil = 20.0 kN/m^3

Density of water = 10.0 kN/m^3

Density of floor finish = 24.0 kN/m^3

Density of plaster = 24 kN/m^3

Dead load on all floors

Screed and Finishes (50mm) on typical floors = 0.05 m × 25 = 1.2 kN/m^2

Service Loads = 1 kN/m^2

Partition Walls = 1 kN/m^2

Dead load on Terrace

Screed and Finishes (150mm) = 0.150 m × 25 = 3 kN/m^2
Service Loads = 1 kN/m^2
Parapet Walls (1.5 meters) = 0.45 kN/m

Live load

Live load on all floors = 3 kN/m^2
Live load on Terrace = 1.5 kN/m^2
Basic Wind speed = 50m/s
Seismic zone = IV
Soil type = II
Response reduction factor = 5

3. DESIGN OF METAL DECK SLAB

The sheeting is designed for Self-weight of the Slab and Sheeting, and Erection loads

Clear thickness of Concrete slab = 80.00 mm
D overall thick =155 mm
Avg thk. of Concrete slab within deck sheeting = 37.50 mm
average thick =118 mm
Service load =1 kN/m2
Partition load =1 kN/m2
Live load =3 kN/m2
Service+ partition + live load =5.000 kN/m2
Flooring thickness =50.00 mm
Flooring density = 24.00 kN/m3
Erection Load = 5.00 kN/m2
Sheeting thickness = 1.00 mm
Self-Weight of the sheeting = 11.96 kg/m2
Dead weight of deck slab =(0.08+0.0375) x 252+ 0.050 x 24+0.1196
= 4.3 kN/m2
Z of sheeting = 36.26 cm3
Spacing of beam (Maximum) = 2.00 m
Load to be carried by sheeting = 9.3 kN/m2
(80+35)*.025+5(Erection)+50x0.024+.1196(self weight)
Depth of the Decking Profile = 75.00 mm
Flange width of supporting beam assumed = 140.00 mm
Effective Span for the Decking Sheet Design = 1.94 m

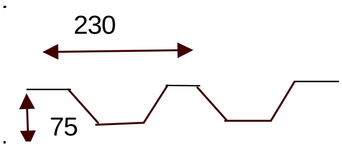

Fig -1: Deck Sheet Profile

B.M FACTOR FOR SHEETING = 8.00
Allowable bending stress in Sheeting = 165 N/mm2
(0.66 * 250MPa considered)
Bending Moment (9.3 x 2 x 2 x 1000/8) = 4.65 kN-m
Bending Stress (4650000/(36.26x1000))= 129.81 N/mm2
<165 O.k

Check for Deflection

Total Load = 9.3 kN/m/m
SPAN = 2.00 m
SPAN (Effective) = 1.94 m

IXX = 1473000 mm4
Defl. Coeff. = 5/384

Limiting Deflection Ratio for Deck Sheet = 200

Allowable Deflection = 9.68 mm
Vertical Deflection = 5.76 mm
(5x9.3x(1.935x1000)^4)/(384x200000x 1473000)
<<9.68 O.K

4. DESIGN OF SECONDARY BEAM

SPAN OF THE BEAM = 7.50 m
Provide Beam as = ISMB350
Width of the falange = 140.00 mm
Area of the section = 6671.00 mm2
Ixx of the section = 136303000 mm4
Zxx of the section = 778874 mm3
Rmin of the section = 28.40 mm
Depth of the section = 350.00 mm
Flange thickness = 14 mm
Web thickness = 8 mm
Flange width = 140 mm

Design of beam by using Composite action

Assumptions

1) Dead load of Concrete slab & self-weight of beam and construction load of 1.5 kn/sqm is taken by Steel beam only.

2) Only balance live load & flooring load is resisted by composite construction after the concrete is hardened.

3) Area of the concrete with in profile depth is ignored for effective width calculation of slab.

4) Design of shear connector as per IS:11384-1985 for ultimate shear capacity of concrete.

Modulur Ratio = 280 / 3 s cbc,
= 280 / 3 x 8.5= 10.98

Depth of Deck Sheeting = 70.00 mm
Area of reinforcement perpendicular to Beam=2.50 cm2 (Ast provided in slab)
Effective Width of Slab Lesser of the following

1) Span /4 = 7.5x1000/4 = 1875.00 mm
2) 12xslab thk.+Flange width = 12x80+140 = 1100.00 mm
3) Spacing of beams = 2000.00 mm

So effective width
= 1100.00 mm
Transformed width = 1100/10.98
= 100.18 mm

C.G from bottom
= (6671x350x0.5+100.2x80x[350+75+80x0.5])/(6671+100.2x80)
= 333.27 mm

Ixx of combined section
136303000 + 6671x(333.3-175)^2 + 100.2x80^3/12 + 100.2x80x(350+75+80x0.5-333.3)^2
= 4.47E+08 mm4
Zxx at bottom = 446757145.4/333.3
= 1.34E+06 mm3

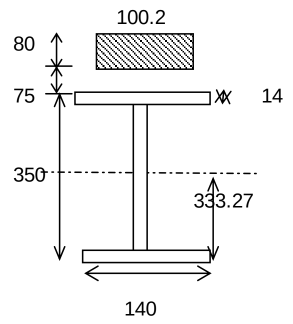

Fig -2: I section with deck slab in equivalent steel area

Stresses due to Dead weight + Construction live load (only Steel beam action)

Udl on beam WITH construction load of 1.5 kn/sqm
= 0.80 t/m
{(80+35)x0.001x2.5+0.01196}x2+0.006671x7.85+0.15

Bending Moment 0.801x7.5x7.5/8 = 5.63t-m
Bending stress =56340516.8/778874
= 72.34 N/mm2
Deflection in beam = 12.11 mm
(5x0.80x10x(7500)^4)/(384x200000x136303000)

Stresses due to Imposed Load (composite action)

Additional Equivalent UDL due to Brick Wall = 0.00kN/m
Additional live load is 5-1.5 = 3.5kn/sqm

Udl on beam =(5-1.5 +0.05x24)x2 = 9.40 kN/m
Bending Moment = 9.4x7.5x7.5/8 = 66.09 kN-m
Bending Stress at bottom of steel =66.09375x 10000000/1340542.46 = 49.30 N/mm2
Total Bending Stresses = 72.34+49.30 = 121.64 **N/mm**
< 165 O.K
Deflection due to balance Live load and finishing
5x9.4x(7500)^4/(384*200000x446757145.4) = 4.33 mm
Deflection Factor for Dead Load = 1000.00
Allowable deflection =7500/1000 =7.50 mm
(As Per IS 14687-1999 cl:7.5 (b))
Total 'deflection' =4.3+12.11
= 16.44 mm
< 23.1 O.K
Allowable deflection = 7500/325 = 23.08 mm
Zxx at top =446757145/(350+75+80-333.3)
= 2.60E+06 mm^3
Bending compressive stress in concrete
66.1x1000000/(2601447.5x10.98) = 2.31 N/mm2

< 8.33 O.K

Allowable bending comp. Stress in concrete = 8.33 N/mm2

For M25 Grade = 25/3

(Cl. 13.0 IS:11384 -1985)

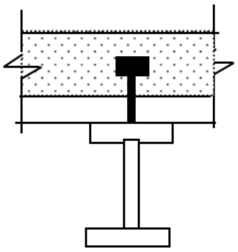

Fig -3: Composite I section

Check for Ultimate Limit state of Longitudinal Shear

Shear Stud Spacing:

Maximum Horizontal Shear (fcc) (Page No:7 IS:11384 -1985)0.36*fckbXu = 0.36x25x1100x80/1000 = 792.00 kN

Shear capacity of each stud = 31.42 kN

Dia of stud = 20 mm

Height of the stud = 100 mm

No. of studs at cross section = 2

No. of studs =792/(2x31.4159265358979)

= 12.61

Spacing of studs Reqired : 3750 / 12.6 = 297.50 mm

Spacing of studs provided

= 250.00 mm

<600mm

< 4 x 80mm

Shear per Meter length (Q) =792 / 3.75 = 211.20 KN/M

Shear resistance of slab is minimum of the following (Page No:10 IS:11384 -1985)

0.232x2x80x SQRT(25)+0.1x2.5x500*2 = 435.60 kN/m

0.623x2x80x SQRT(25) = 498.40 kN/m

211.200 < 435.6 O.K

Check for Ultimate Limit state of Vertical Separation

(CL. 10. IS:11384-1985)

Length of the shear connector

= 100 mm **> 50mm O.K.**

Projection of shear connector into the slab = 100-0, 100 mm **> 25mm O.K.**

Min. Diameter of Head = 1.5 xdia

= 30 mm

Design of Shear Studs

Dia of stud =20.00 mm

Yield stress of stud = 245.00 N/mm2

Maximum permissible shear stress =98.00 N/mm2

Area of stud =314.16 mm2

Shear capacity of stud =30.79 kN

Thickness of slab =250.00 mm

Floor thickness =50.00 mm

Total Load 1.0DL+0.5LL+EQL =11.19 kN/m2

Length of beam =7.50 m

Span of beam =2.00 m

Total Load =167.92 kN

Z = 0.24

I =1.50

Sa/g =2.50

R =5.00

Seismic coefficient,Ah =0.09

Horizontal force =22.67 kN

Spacing of stud =250.00 mm

No of studs provided =30.00

Say 30

Shear capacity of stud = 924 kN

> 22.67 kN OK

5. CONCLUSIONS

Structures made from steel sections are quickly built at the project site because majority of building components could be prefabricated at the workshop or Steel manufacturing facility.

The Expansion of any steel Structure can comparatively be very easy and fast.

Steel structures have good scrap value with respect to RCC. In tubular structures, members are capable to resist both direction of lateral forces due to the good inertia property in both directions.

Composite tubes constructions in columns is easy with respect to I section encased in concrete column.

In the composite tube construction, no shuttering, de shuttering, and bar bending is required.

Dynamic forces that change with time such as wind and/or seismic waves are smoothly resisted by the flexile nature of the steel.

Only one third energy is required to create new steel from scrapped material than fresh steel alloy achieved from iron ore.

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