5.3 Design Of Industrial Gantry Girders

Example 3

Design a hand operated travelling crane simply supported by gantry girder for the given data:

Span of gantry girder = 5m

Span of crane girder = 15m

Crane capacity = 200 KN

Self weight of crane girder excluding trolley = 200 KN

Self weight of trolley = 30 KN

Minimum hook approach = 1m

Distance between wheels = 3.5m c/c

Self weight of rails = 0.3 KN/m

Solution:

Step : 1 For calculating maximum moment

(a) Weight of trolley + load lifted by crane

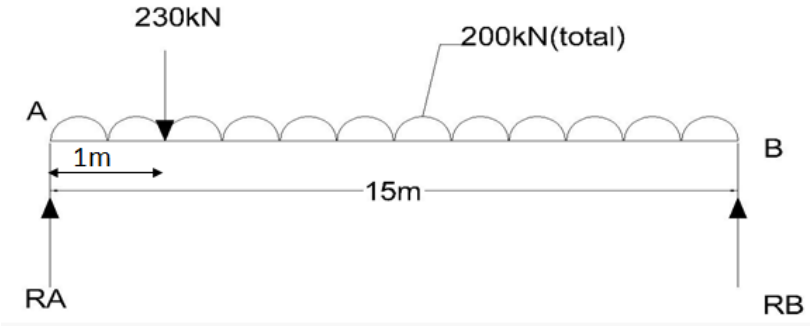
= 30+200

=230 KN

(b) Self weight of crane girder

= 200 KN

For maximum reaction on gantry girder, the moving load should be placed close to Gantry girder .



$\sum M_B = 0$ ie) taking moment of all forces about B

R_A X 15 – 230X7.5 =0

R_A = 4720/15

= 314.67 KN

This load is transferred to gantry girder through two wheels base which are at 3.5m c/c.

∴ Load on gantry from each wheel

= 314.67/2

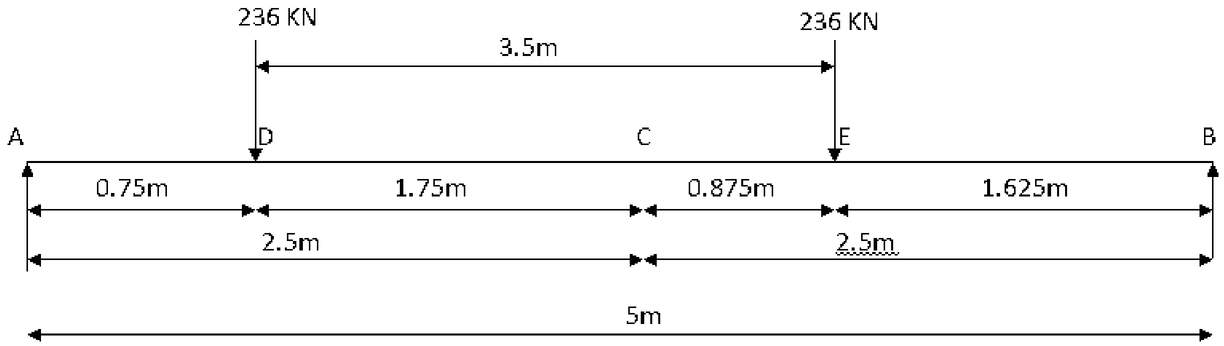
= 157.33 KN

Factored wheel load = 157.33x 1.5

= 236.00KN

The maximum moment due to moving loads occur under a wheel when the C.G (Center of gravity)

Wheel load and the wheel are equidistance from the center of girder.



R_B = [236X0.75 + 236 x (2.5+0.875)]/5

= 194.7 kN

Maximum moment at E = 194.7 x 1.625 (from support B)

= 316.38 KNm

Moment due to impact = 20% of max moment

= 0.2 x 316.38

= 63.277 KNm

Assume self weight of girder = 2 KN/m

∴ Dead load due to self weight + rails(given)

= 2 + 0.3

= 2.3 KN/m

Factored dead load = 2.3 x 1.5

= 3.45 KN/m

Moment due to dead load = WL^2/8

= 3.45 x 5^2/8

= 10.781 kNm

∴ Factored moment due to vertical load (M_Z)

= 10.781+63.277+316.38

= 390.438 kNm

Maximum moment due to horizontal force,

Horizontal force transverse to rails = 10% of weight of trolley + load lifted

= 10/100 (200+30)

= 23 KN

Assuming double framed wheels, this is distributed over 4 wheels.

∴ Horizontal force on each wheel = 23/4

= 5.75kN

Factored horizontal force on each wheel

= 1.5 x 5.75

= 8.625 Kn

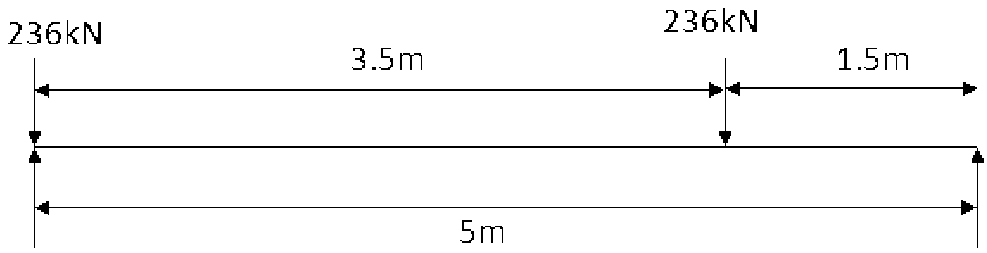
For max bending moment in gantry the position of loads is same except in horizontal,

M_Y = 8.625/236 x 316.38

= 11.56 kNm

Step 2 Shear force

For max shear force on the girder the trailing wheel should be just on the girder.



∴ Vertical shear due to wheel loads = 236 + 236x1.5/5

= 306.8 KN

Vertical shear due to impact = 0.2x306.8

= 61.36 kN

Vertical shear due to self weight = WL/2

= 3.45X5/2

= 8.625kN

Total vertical shear = 306.8+61.36+8.625

= 376.785 KN

By proportioning lateral shear due to surge

= (8.625/236)x306.8

= 11.21kN

Step 3 Selection of section

(i) Economic depth of section = L/12

= 5000/12

= 416mm ≈ 500mm

(ii) Compression flange width = L/25

= 5000/25

= 200mm

Let us try ISWB 500 with ISMC 300 on compression flange,

Properties of ISWB 500 @ 9.52N/m

A = 12,122mm^2

h = 500mm

b_f = 250mm

t_f = 14.7mm

t_w = 9.9mm

I_{zz} = 522.90x10^6mm^4

I_{yy} = 29.878x10^6mm^4

Properties of ISMC 300

A = 4564mm^2

h = 300mm

b_f = 90mm

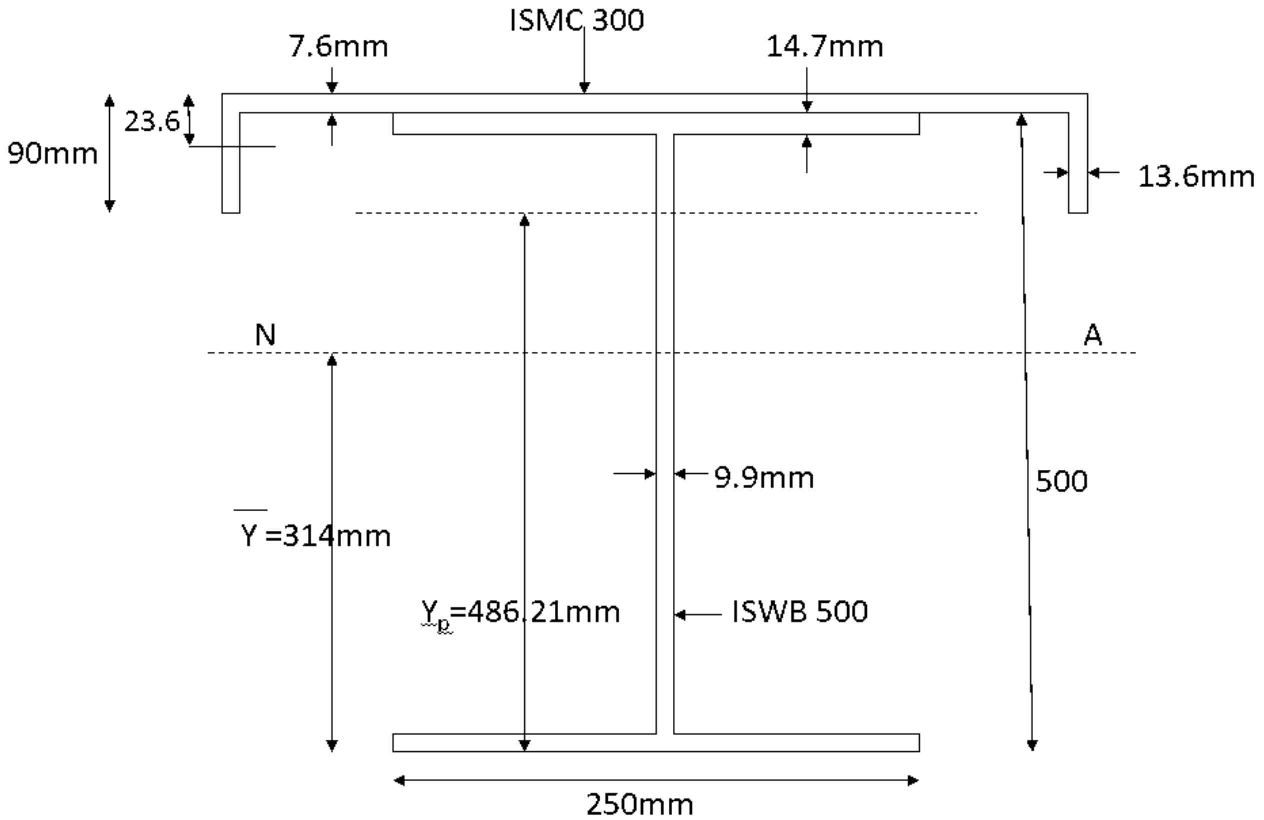
t_f = 13.6mm

t_w = 7.6mm

I_{zz} = 6362.6x10^4mm^4

I_{yy} = 310.8x10^4mm^4

C_{yy} = 23.6mm



To find N.A of the section from bottom flange (tension)

$\bar{Y}$ = [12122x250 + 4564x(500+7.6-23.6)]/(12122+4564)

$\bar{Y}$ = 314.00mm (from bottom flange)

I_{zz} = 522.90x10^6 + 12122(314-250)^2 + 310.8x10^4 + 4564(484-314)^2

= 1.015x10^9 mm^4

Z_e = I_{zz}/y

= 1.015x10^9/314

= 3.233x10^6mm^3

For compression flange about yy axis,

I_{yy} = 14.7x250^3 /12 +6362.6x10^4

= 82.766x10^6mm^4

Z_{ey} for compression flange = 82.766x10^6/150

= 551.77x10^3 mm^3

Now, plastic modulus of section

Total area of the section = 12122 + 4564

= 16686mm^2

Let plastic N.A be a distance Y_p from bottom flange,

∴ (Y_p – 14.7)x9.9+250x14.7 = A/2

9.9Y_p – 145.53+3675 = 16686/2

Y_p = 4813.53/9.9

=486.21mm

Plastic moment capacity of section M_p = ∑Moment of forces at yield about plastic N.A

M_p = 147x250[486.21 – 14.7/2]x fy + [(486.21-14.7)/2]x9.9 fy+[(500-14.7-486.21)^2/2] x 9.9 fy + 14.7x250[500-(14.7/2)-486.21]fy + 4564(500+13.6-23.6-486.21) fy

= 1.75x10^6 fy + 2.34x10^3 fy + 23.66x10^3 fy + 17.29x10^3 fy

= 1.793x10^6 fy

∴ Zp = Mp/fy

= 1.793x10^6 mm^3

For top flange,

Zpy = Mp/fy = ¼ x 14.7x250^2 + ¼(300-2x13.6)^2 x 7.6 +2x90x13.6[150 – 13.6/2]

= 229.68x10^3 + 141.39x10^3 + 350.55x10^3

= 721.62x10^3mm^3

Check for moment capacity,

b/t of flange of ISWB 500 = (250-9.9)/(2x14.7)

= 8.16 < 8.4є

d/t of web of ISWB 500 = (500-2 x 14.7)/9.9

= 47.53<84є

b/t of flange of channel section ISMC 300

= (90-7.6)/13.6

= 6.06<8.4є

∴ The section is plastic.

Local moment capacity for bending in vertical plane,

Md_z =(fy . Zp)/1.1

= 250x1.793x10^6 / 1.1

= 407.5x10^6 Nmm

= 407.5 kNm

1.2 x Ze fy /1.1 = 1.2x5.233x10^6x250 / 1.1

= 881.72x10^6 Nmm

= 881.721 kNm

Lesser of two values Md_z = 407.5kNm

For top flange, Md_z = fy. Zp/1.1

= (250x721.62x10^3)/1.1

= Md_y

= 164x10^6 Nmm

= 164kNm

$1.2 \times Z_e.fy / 1.1$ = (1.2x551.77x10^3x250)/1.1

=150.48kNm

∴ For top flange,Md_z = 150.48kNm

= Md_y

Check for combined local capacity,

$M_z/M_{dz} + My/M_{dy} \leq 1$

390.438/407.5 + 11.56/150.48 = 0.95 + 0.076

= 1.02 ≈1

∴ Section is adequate and economic

Check for buckling resistance,

$M_d = ß_b \cdot Z_p \cdot f_{bd}$

ßb = 1 (for plastic section)

$f_{cr,b} = 1.1\pi^2 E/(L_{LT}/r_y)^2 \, [1+1/20[(L_{LT}/r_y)/(h_f/t_f)]^2]^{0.5}$

L_{LT} = 5.0m

= 5000mm

E = 2X10^5 N/mm^2

h_f = 500+7.6

= 507.6mm

t_f =14.7mm

I_{yy} = 29.878x10^6 + 6362.6x10^4

= 93.50x10^6mm

A = 12122+4564

= 16686mm^2

∴ r_y = √(I_{yy}/A)

= √(93.5x10^6)/16.686

= 74.85mm

$f_{cr,b}$ =(1.1xπ^2x10^5)/(5000/74.85)^2{1+1/20

[(5000/74.85)/(507.6/14.7)]^2}^0.5

= 486.59 [1+1/20(66.80/34.53)^2]^0.5

= 530.165 N/mm^2

IS code:800-2007, clause 8.2.2

For $f_{cr,b}$ = 530.16

∴ f_{bd} = 191.34 N/mm^2 (by linear interpolation)

∴M_{dz} = 1.0x191.34x1.793x10^6

= 343.07x10^6 Nmm < 407.5x10^6

Check for biaxial bending,

M_{dy} = fy.Zy/1.1

Z_y = Iyy/150

= 93.50x10^6/150

= 623.33x10^3 mm^3

M_{dy} = 250x623.33x10^3/1.1

= 141.67x10^6Nmm

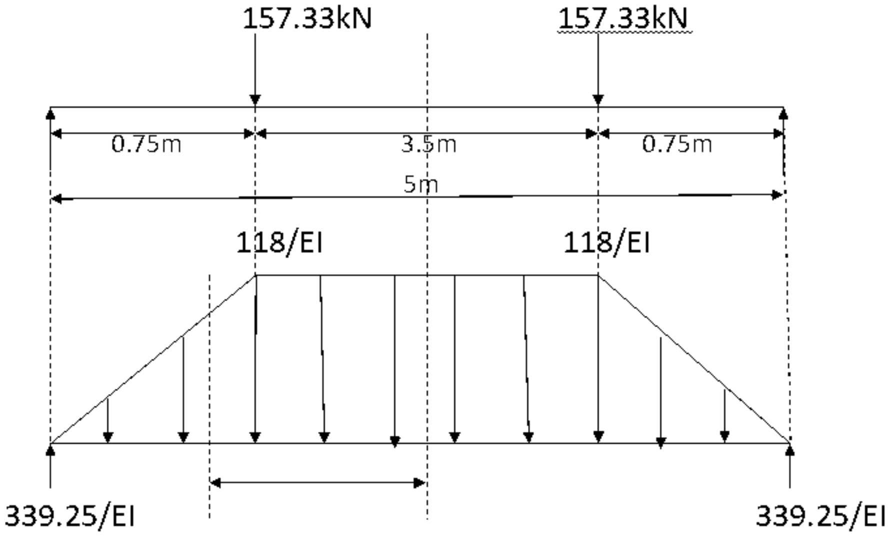
= 141.67 kNm

∴ Mz/Mdz + My/Mdy ≤ 1

390.43/407.5 + 11.56/141.67 = 1.03 =1

Check for deflection,

At working load, deflection is limited to L/750



Maximum deflection occurs at midspan = moment of M/EI load in conjugate beam

Reaction in conjugate beam = ½ x total M/EI diagram

= ½ x0.75x118/EI + 118/EI x5/2

= 339.25/EI

EIΔ = 339.25X5/2 – 1/2X118X0.75X2 – 1/2x3.5x118x1.75/2

= 848.125 – 88.8 – 180.68

= 578.94

EI = (2x10^5x1.015x10^9)/(1000x1000x1000)

= 203x10^3 kNm^2

Δ = 578.94/203x10^3

= 2.85x10^-3 m

= 2.85mm

Permissible deflection Δ =L/750

= 5000/750

= 6.67 mm

∴ Deflection requirement is satisfied

Hence, ISWB 500 with ISMC 300 can be suitable for gantry girder.