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Analysis & Design of Composite Beam

Jagruti V. Chavan[1] , Bhavana V. Chavan[2] , Swapnil A. Deshmukh[3] , Akshay V. Deshmukh[4]
[1, 2, 3, 4] *Assistant Professor, Civil Department, PLITMS, Buldana, Maharashtra, India.*

ABSTRACT

The composite materials used in various fields of civil engineering construction such as Building, Bridge, and other high performance engineering applications because of composite material are light in weight, having high performance material, strength material and stiffness. The construction using composite material is easy. The impact factor of various parameters on cross section of beam and different boundary condition of the beam and the effect of the length of beam. The study deals with the free vibration of laminated composite beam, Two-node finite element of three degrees of freedom and rectangular section are the free vibration analysis of the laminated composite beam.

Keyword : - Composite, Vibration, laminated, Beam

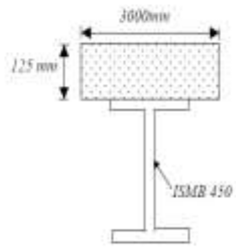
1. INTRODUCTION

1.1 General

In conventional composite construction, concrete slabs rest over steel beams and are supported by them. Under load these two components act independently and a relative slip occurs at the interface if there is no connection between them. With the help of a deliberate and appropriate connection provided between the beam and the concrete slab, the slip between them can be eliminated. In this case the steel beam and the slab act as a "***composite beam***" and their action is similar to that of a monolithic Tee beam. Though steel and concrete are the most commonly used materials for composite beams, other materials such as pre-stressed concrete and timber can also be used. Concrete is stronger in compression than in tension, and steel is susceptible to buckling in compression. By the composite action between the two, we can utilise their respective advantages to the fullest extent. Generally in steel-concrete composite beams, steel beams are integrally connected to prefabricated or cast in situ reinforced concrete slabs

2. DESIGN OF COMPOSITE BEAM

2.1 Problem Description



<u>Data assumed</u>

$(f_{ck})_{cu}$ 30 N/mm^2 , f_y 250 N/mm^2 , Density of concrete 24 kN/m^3

<u>Partial safety factors -</u>Load Factor, γf , for LL 1.5 , for DL 1.35 ,<u>Material Factor, γm</u>, Steel 1.15 , Concrete 1.5 ,Reinforcement 1.15

Step 1: Load Calculation

<u>Construction stage</u>

i) Self weight of slab = 3 * 0.125 * 24 = 9 kN/m ii) Self weight of beam = 0.71 kN/m (assuming ISMB 450)

iii) Construction load = 0.75 * 3 = 2.25 kN/m

Total design load at Construction Stage
= {1.5 * 2.25 + 1.35 * (9 + 0.71) =16.5 kN/m

<u>Composite stage</u>

Dead Load

i) Self weight of slab = 9 kN/m ii) Self weight of beam = 0.71 kN/m iii) Load from floor finish = 0.5 * 3 =1.5 kN/m

Total Dead Load = 11.2 kN/m

Live Load

i) Imposed load = 3 * 3 = 9.0 kN/m ii) Load from partition wall = 1.5 * 3 = 4.5 kN/m Total Live Load = 13.5 kN/m

Design load carried by composite beam= (1.35 * 11.2 + 1.5 * 13.5) = 35.4 kN/m

Step 2: Calculation of Bending Moment

<u>Construction Stage</u> M = 16.5 * 10^2/8 =206 kNm

Composite Stage $M = 35.4 * 10^2/8 = 442$ kNm

Step 3: Classification of Composite Section

Sectional Properties

T = 17.4mm; D = 450 mm; t = 9.4 mm $I_x = 303.9 * 10^6$ mm^4 $I_y = 8.34 * 10^6$ mm^4 $Z_x = 1350*10^3$ mm; r_y = 30.1 mm

Classification of composite section

0.5 B/T=0.5*150/17.4=4.3< 8.9ε

d/t= (450-2*17.4)/9.4=44.2 < 83ε

Therefore the section is a plastic section.

Step 4: Check for the adequacy of the section at construction stage

Design moment in construction stage = 206 kNm

Moment of resistance of steel section $= f_{yd} * Z_p$ = $[(250/1.15) * 1.14 * 1350.7 * 10^3]/10^6$ kNm =334.7 kNm> 206 kNm

As the top flange of the steel beam is unrestrained and under compression, stability of the top flange should be checked.

Step 5: Check for Lateral Buckling of the top flange

From clause 6.2.4, IS: 800-1984

Elastic critical stress, f_{cb} is given by

$$f_{cb} = k1\ \frac{C2}{C1}\ \frac{(26.5\times10^5)}{(\frac{l}{ry})^2}\ \left[\sqrt{1+\frac{1}{20}\left(\frac{lT}{ryD}\right)^2}+k2\right]$$

$$=\left[\frac{(26.5\times10^5)}{(\frac{10000}{30.1})^2}\sqrt{1+\frac{1}{20}\left(\frac{10000}{30.1\times450}\right)^2}+k2\right]=73\ \text{N/mm}^2$$

k_1 = 1 (as Ψ = 1.0) k_2 = 0 (as φ = 0.5) $c_2 = c_1$ = 225 mm; T = 17.2 mm; D = 500 mm; λ = 10,000 mm;

r_y = 35.2 mm

$$F_{cb}=\frac{73\times250}{\left((73)^{1.4}+(200)^{1.4}\right)^{\frac{1}{1.4}}}=64.9\text{N/mm}^2$$

Moment at construction stage = 206 kNm

Provide 2 lateral restraints with a distance of approximately 3330 mm between them

From clause 6.2.4, IS: 800-1984

$$\frac{26.5\times10^5}{(\frac{3330}{30.1})^2}\times\left[\sqrt{1+\frac{1}{20}\left(\frac{3330\times17.2}{30.1\times550}\right)^2}+k2\right]=299.6\ \text{N/mm}^2$$

$$f_{cb}=\frac{299.6\times250}{\left((299.6)^{1.4}+(250)^{1.4}\right)^{\frac{1}{1.4}}}=165.9\ \text{N/mm2}$$

Step6: Check for adequacy of the section at Composite stage

Bending Moment at the composite Stage, M = 442 kNm

Effective breadth of slab is smaller of

I. span /4 = 10000/4 = 2500 mm

II. C/C distance between beams = 3000 mm

Hence, b_{eff} = 2500 mm

Position of neutral axis

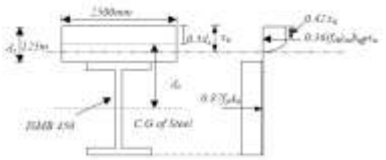
$$a=\frac{0.87f_y}{0.36(f_{ck})}=\frac{0.87\times250}{0.36\times30}=20.1$$

A_a = 9227 mm^2

$aA_a = 9227 \times 20.1 = 1.85\times10^5$ mm^2

$b_{eff}\ d_s = 2500 \times 125 = 3.13 \times 10^5$ mm^2 $> aA_a$

Hence PNA lies in concrete



Position of neutral axis

$$x_u=\frac{0.87\times250\times9227}{0.36\times30\times2500}=74.3\ \text{mm from the top of the slab}$$

Moment Resistance of the section, M_p

$M_P=0.87\times A_a f_y(d_c+0.5d_s-0.42x_u)$

=0.87*9227*250(287.5+0.5*125-0.42*74.3) =640 kNm>442 kNmm

As per Table 1(Composite Beam-II), the design strength of 20 mm (dia) headed stud for M30 concrete is 58 kN

∴Number of shear connectors required for 10/2 m = 5 m length

= 2006 /58 ≈ 34

These are spaced uniformly

Spacing = 5000/34 = 147 mm ≈ 145 mm

If two connectors are provided in a row the spacing will be = 145 * 2 = 290 mm

Step 8: Serviceability check

Modular ratio for live load = 15

Modular ratio for deal load = 30

(1) Deflection

For dead load deflection is calculated using moment of inertia of steel beam only

$$\delta_d=\frac{5\times9.71\times10000^4}{384\times2\times10^5\times303.91\times10^6}=10.06\ \text{mm}$$

Position of neutral axis

$$A(d_g-d_s)\leq\frac{1}{2}\left(\frac{beff}{ae}\right)ds^2$$

$9227\ (350 - 125) < ½ \times 2500/15 \times 125^2$

$2.80 \times 10^6 < 1.30\times 10^6$ which is not true

∴N.A. depth exceeds d_s

$$A(d_g-X_u)=\left(\frac{beff}{m}\right)ds\left(Xu-\frac{ds}{2}\right)$$

$$9227(350-Xu)=\frac{2500}{15}\times125\left(Xu-\frac{125}{2}\right)$$

Xu=150.75

$$I_g = I_x + A_a(dg-Xu)^2+\frac{beff}{ae}\times ds\left[\frac{ds^2}{12}+(Xu-ds)^2\right]$$

$=303.91\times10^6+9227$

$(350-150.75)^2+\frac{2500}{15}\times125(\frac{125^2}{12}+(150.75-125)^2)$

$=859.6\times10^6$ mm4

$\delta_1=\frac{5\times15\times10000^4}{384\times2\times10^5\times859.6\times10^6}$

$=11.4<\frac{\lambda}{325}$

Total deflection$=\delta_d+\delta_1$

$=20.8+11.4$

$=32.2\text{mm}\geq\frac{\lambda}{325}$

The section fails to satisfy the deflection check.

(2) Stresses

Composite Stage

Dead Load In composite stage, dead load W_d W_d = 11.2 kN/m M = $11.2\times\frac{10^2}{8}$ = 140 kNm

Position of neutral axis

Assuming neutral axis lies within the slab

$A(d_g-d_s)\leq\frac{1}{2}(\frac{beff}{ae})ds^2$

$9227\ (350-125)<½\times2500/15\times125^2$

$2.07\times10^6>6.5\times10^5$

∴N.A. depth exceeds d_s

Location of neutral axis

$A(d_g-X_u)=\left(\frac{beff}{m}\right)ds(Xu-\frac{ds}{2})$

$9227(350-Xu)=\frac{2500}{30}\times125(Xu-\frac{125}{2})$

Xu=197.5mm

Moment of Area of the Section

$I_g=I_x+A_a(dg-Xu)^2+\frac{beff}{m}\times ds\left[\frac{ds^2}{12}+(Xu-ds)^2\right]$.

$=303.91+9227$

$(350-197.5)^2+\frac{2500}{30}\times125(\frac{125^2}{12}+(197.5-125)^2)$

$=721.9\times10^6$ mm4

Live load

In composite stage stress in steel for live load

$W_l=13.5$ kN/m M = $13.5\times10^2/8$ = 168.75 kNm

Stress in steel flange$=\frac{168.75\times10^6(450+125-150.75)}{859.6\times10^6}$

=83.29 N/mm2

In a similar procedure the stress in concrete is found.

$\frac{1}{30}\left\{\frac{140\times10^6\times197.54}{721.9\times10^6}\right\}+\frac{1}{15}\left\{\frac{168.75\times10^6\times150.75}{859.6\times10^6}\right\}$

$=3.25\leq\frac{fck}{3}$

The section is safe.

Since the section does not satisfy the deflection check, therefore trial can be made with higher steel section

Step 9: Transverse reinforcement

Shear force transferred per meter length

$V_r=\frac{2\times58}{0.29}KN/m$

=400KN/m

$Vr\leq0.232\ L_s\sqrt{fck}+0.1Asvfy\ n$

Ls=2×125 =250mm

fy=250

n=2

$0.232\times25\sqrt{30}+0.1\times Asv\times250\times2$ =317.7+50Asv

400=317.7+50Asv

Asv=165mm2/m

Minimum Reinforcement =400mm2/m

Provide 12 mm ϕ@280mm c/c

- All above calculation is for ISMB450 after that I Design for ISMB500 and ISMB550 with the same design procedure and compare the results

3. RESULTS AND COMPARISION OF DIFFERENT CROSS SECTION

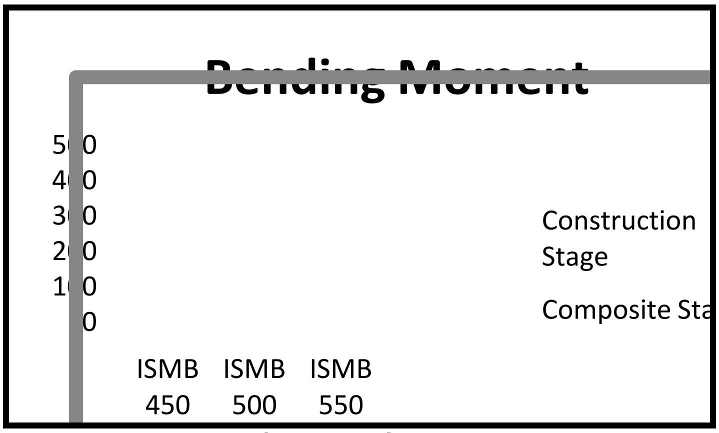
Results are shown in table form as already calculated as above and comparision of section ISMB450, ISMB500, ISMB550

Table No. 1:- Results

		ISMB450	ISMB500	ISMB550
Imposed load		3.0 KN/m2	3.0 KN/m2	3.0 KN/m2
Partition Load		1.5 KN/m2	1.5 KN/m2	1.5 KN/m2
Floor Finish load		0.5 KN/m2	0.5 KN/m2	0.5 KN/m2
Construction load		0.75 KN/m2	0.75 KN/m2	0.75 KN/m2
Fck		30 N/mm2	30 N/mm2	30 N/mm2
Fy		250 N/mm2	250 N/mm2	250 N/mm2
Total design Load at Construction stage		16.5 KN/m	16.68 KN/m	16.91 KN/m
Design Load carried by composite beam		35.4 KN/m	35.58 KN/m	35.81 KN/m
Bending Moment	Construction Stage	206 KNm	208.5 KNm	211.375 KNm

Composite Stage	442 KNm	444.75 KNm	447.62KN m
Elastic critical stress	165.9 N/mm2	170.88N/mm2	186.48N/mm2
Area of steel section	9227mm2	11074mm2	13211 mm2
Position of neutral axis	74.3mm	89.20 mm	106.42 mm
Moment Resistance of the section	640 KNm	812.98 KNm	1020.92 KNm
Deflection	32.2mm	21.12mm	22.17mm

As shown in graph the bending moment is increases as the section is changes to ISMB 450, ISMB 500,ISMB 550 the bending moment is 206KNm, 208KNm , 211.375 KNm respectively at construction stage and at composite stage As shown in graph the bending moment is increases as the section is changes to ISMB 450, ISMB 500,ISMB 550 the bending moment is 442 KNm, 444.75KNm , 447.62 KNm respectively .



Graph No. 1:- Bending Moment

4. CONCLUSIONS

There are various advantages related to the steel concrete composite construction. They are as follows: The most compelling utilization of steel and concrete is achieved. Keeping the span and loading unchanged; a more economical and efficient steel section in view of depth and weight is competent in composite construction in comparison to the conventional non-composite construction.

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