Zeitschrift: IABSE reports = Rapports AIPC = IVBH Berichte

Band: 79 (1998)

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DOI: https://doi.org/10.5169/seals-59984

Use of I-Beams in Slim Floor Construction

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Summary

The use of I-beam in Slim floor instead of the Universal column (UC) or Top Hat sections is the focus of this study. The investigation is limited to the design of simply supported beam under uniformly distributed load using limit state approach. The design formulation has the provision for both top and bottom flange plates. The results indicate the suitability of using such beams in Slim floor construction especially for structures subjected to heavier loads like those in warehouses, bridges etc. The cost competitiveness has also been established despite two times increase in steel consumption as compared to RCC structure.

1. Introduction

Slim floor construction is a special type of composite construction, where the beam is contained within the depth of the floor slab. The success of this type of construction using top hat sections as beam elements in Nordic countries, especially in Sweden in the last decade, has resulted in the adaptation of this type of construction in UK tailored to suit their requirement, using UC sections and bottom flange plates, supporting either the profile deck or precast slab both having concrete topping (1).

The major advantages of this type of construction lies in its ability to cover large column free areas, reduce building height, reduce overall weight of the structure, better seismic and fire resistance, faster construction, unhindered passage for service lines, elimination of the use of shuttering and props for the slab-beam system and better cost competitiveness despite increase in consumption of steel.

The work carried out till date has been limited to the use of top hat sections and UC sections. The suitability of using I-beams in place of UC section or top hat section in Slim floor construction was felt to be important as I-beams are the most commonly available beam section in developing countries. This study aims at introducing I-beams in Slim floor construction.

2. Structural Configuration and Design

The simply supported Slim floor beam (Fig.1) considered here consists of a rolled I-beam having a bottom flange plate supporting a deep profile deck topped with concrete. The beam can also have a top flange plate to increase its efficiency and strength. The RCC topping can be either of normal weight concrete(NWC) or light weight concrete(LWC). Shear stud connectors welded to the top flange of the I-beam ensures composite action.

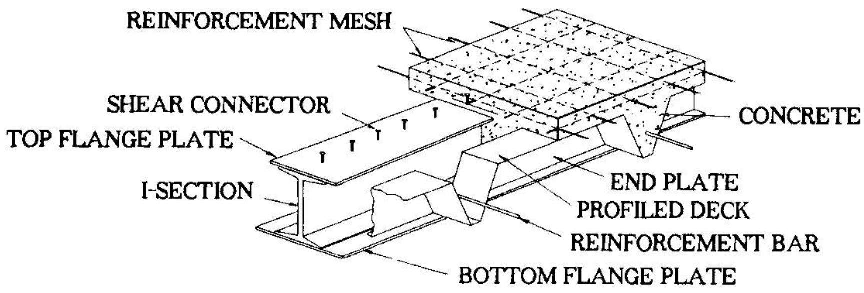


Fig.1 Schematic View Of A Slim Floor Beam

2.1. Basis of Design

Limit state approach has been followed for design. Factored load was used for strength design and working load for serviceability limits. In the absence of any uniform design guidelines in different countries, the provisions of the British codes (2,3) in general and those of Indian codes (4,5) in particular have been followed.

Only plastic or compact rolled beam sections in conjunction with rectangular stress block have been used for design. To ensure non-occurrence of irreversible deformations, the steel stress was limited to design stress and the concrete stress to 0.5 times the cube strength. The design steel stress may be either the yield stress or its reduced value depending on the code of practice to be followed.

2.2. Steps in Design

In line with the sequence of construction that is followed, the design was carried out for both the construction stage and the composite stage loads.

Construction stage

The bottom flange plate was designed for biaxial state of stress caused by the deck loading and overall bending of the beam. Von-Mises Yield criteria (6) was used to obtain the moment capacity.

The combined steel section was designed considering the effect of lateral transverse buckling (LTB) caused due to the top flange being unrestrained (2).

During construction stage, the out of balance load on the beam caused by one side being fully loaded (concrete poured) results in torsion in the section. This was treated in a simplified manner by replacing these forces by equal and opposite horizontal transverse forces in the flanges in equilibrium with the torsion caused by the out of balance load.

The unity factor condition was checked for the combined stresses caused by biaxial bending. The beam was also checked for LTB in case of bending moment caused by the total construction load on the beam.

Composite stage

The effective breadth of concrete compression flange was taken as ¼ of the span but was limited to centre to centre distance of the beam. The modular ratio was taken as 10 and 15 for NWC and LWC respectively. The plastic moment capacity which depends on the degree of shear connection (assumed as 40%) was obtained in terms of the resistance of various elements of the beam by rearranging the stress diagram in a manner similar to that explained in British code (3).

Transverse reinforcement was provided to enable the concrete flange to transfer the longitudinal forces at ultimate limit state into the slab without splitting of concrete (3).

Serviceability Limit Check

All critical serviceability stresses (3) in concrete and steel were checked using cracked section properties. Deflection checks (3) were carried out for both construction stage and composite stage. Since most of these beams were quite long, the calculated natural frequency of vibration, based on the total dead load plus 10% imposed load, was limited to 4 Hz.

2.3. Computer Programme

A programme in FORTRAN77 has been developed for the automated design of Slim floor beams having both top and bottom flange plates. The input data consists of a trial I-beam section, flange plate dimensions, span, loads and details about the profile deck and material properties. The output from the programme consists of the most optimum I-beam section, the final flange plate dimensions, number of shear connectors and the thickness of RCC topping.

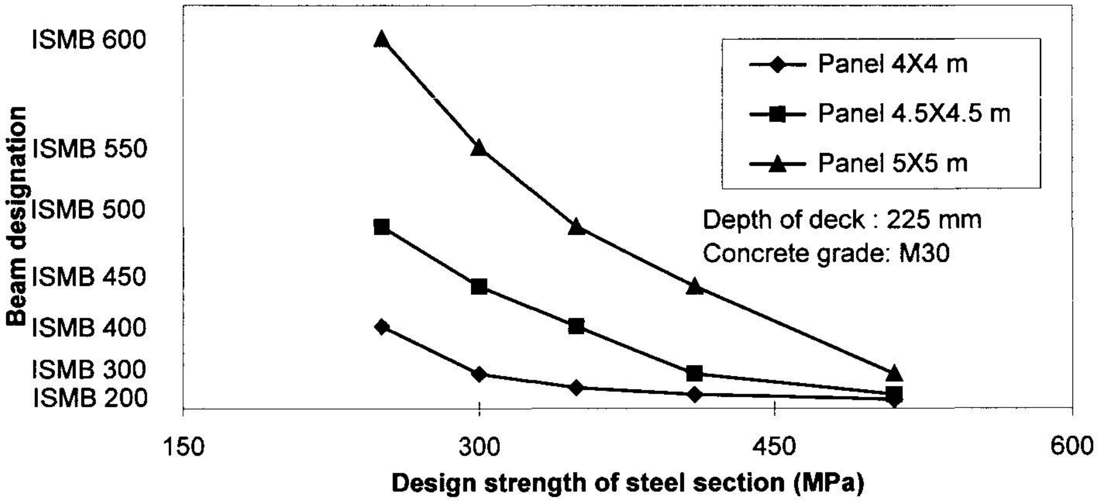
3. Results and Discussion

A few design examples with only bottom flange plate configuration have been worked out to study the various aspects of using I-beams in Slim floor construction. The I-beams and plates used have been restricted to those manufactured by Steel Authority of India Ltd.

Example 1 : A Slim floor beam for a 4.5 m x 4.5 m panel having imposed load of 6.0 kN and LWC (grade M30) topping have been designed using I-beam and compared with that using UC section as shown in Table 1. In both the cases yield strength of steel was 510 MPa, bottom flange plate thickness was 16 mm and steel decking was 210 mm deep. The smaller depth for UC section using British code can be attributed to higher distribution of material in its flanges making it a more efficient section as compared to the I-beams. The higher load factor values as prescribed in Indian code, have led to even greater overall and section depth.

Item	British Code Load Factor		Indian Code Load Factor
	UC Section	I-Section	I-Section
Overall depth (mm)	295	310	335
Section depth (mm)	176.8	225	250

Example 2 : A comparative study of the effect of the steel strength on the size of I-beams is depicted in Fig.2. As expected, the size of I-beams decreases with the increase in the design stress of the material. Moreover, it is also noticed that as the steel strength increases, the effect



of panel dimension on the size of beam reduces in an asymptotic manner indicating greater moment capacity of beams with higher design strengths.

Example 3 : A seven storied commercial building having 400 sq.mt. area in each floor has been

Items	Type of structure			
	RCC		Slim floor	
	Quantity	Total (Rs)	Quantity	Total (Rs)
Reinforcement bars	66.53 T	11,84,378	15.95 T	2,84,052
SAIL-MA (Y S 410MPa)	-	-	86.24 T	21,99,120
IS: 513 sheet (Y S 250MPa)	-	-	45.01 T	11,20,749
Plastering wall	4018 M^2	1,86,354	2774.1 M^2	1,27,786
Plastering ceiling	2800 M^2	1,53,748	-	-
Brick work	416.15 M^3	6,10,076	344.4 M^3	5,04,890
Concreting	621.74 M^3	22,63,134	585 M^3	21,19,400
Shuttering	2800 m^2	3,39,780	-	-
False ceiling	2800 m^2	12,60,000	-	-
Interest	5 months	4,50,650	-	-
Total cost		64,48,120		63,55,997

designed as conventional RCC construction and also as Slim floor construction for cost comparison studies. Occupational and partition loads have been assumed as 4.0 kN/m^2 and 1.0 kN/m^2. The RCC design has been carried out using limit state approach (7). The cost analysis shown in Table 2 is based on the current market price in India (Rs. 38=1US \$). The cost of both the structures are practically same. However, Slim floor construction has the added advantage of the building being available earlier for occupation due to faster construction and the salvage value of steel. The increase in steel consumption in case of Slim floor construction using I-beams is 2.2 times that of RCC construction as against about 4 times with UC-section (8).

Example 4 : Table 3 depicts the maximum imposed load a particular beam section can withstand for a fixed span. In all the cases the flange plate thickness was 16 mm, the grade of concrete was M30 and the yield strength of steel was 350 MPa with 210 mm deep steel decking. It is evident

Panel width (m)	Span (m)		
	4.0	5.0	6.0
	Maximum Imposed load (kN/m^2)		
4.0	22 (ISMB 225)	50 (ISMB 450)	> 50 (ISMB 550)
5.0	38 (ISMB 250)	> 50 (ISMB 500)	> 50 (ISMB 600)
6.0	40 (ISMB 350)	> 50 (ISMB 550)	--

that upto a certain span the design is governed by the construction load and is not sensitive to the imposed load.

Example 5 : Keeping in mind the requirement of reducing the dead load due to concrete, two sizes of profile decks of depth 225 mm and 290 mm were considered in the design along with I-beams in Slim floor construction. The results are presented in Table 4 for LWC which shows that after a particular panel size, the Slim floor construction with deeper deck is advantageous. Same trend has also been observed using NWC.

Panel size	225 mm Deck			290 mm Deck		
	Depth of section (mm)	Plate thickness (mm)	Overall depth (mm)	Depth of section (mm)	Plate thickness (mm)	Overall depth (mm)
3.0 m X 3.0 m	200	8	295	225	8	360
4.0 m X 4.0 m	250	12	335	250	8	360
4.5 m X 4.5 m	400	24	485	300	22	385
5.0 m X 5.0 m	500	20	585	500	10	585
5.5 m X 5.5 m	600	8	685	550	28	635

4. Conclusion

The analysis of the preceding examples brings out certain important features of Slim floor construction using I-beams .

1. It is cost competitive as compared to RCC construction.
2. The use of high strength beams for longer spans are more economical as compared to ordinary structural steel beams with yield strength of 250 kN/mm^2.
3. The ability of the Slim floor beams to support heavier imposed loads makes them suitable for use in warehouses, bridge decks etc. Conversely, for a particular imposed load condition, it is possible to cover longer span.

As the present study was restricted to simply supported beam under uniformly distributed load, it may be worthwhile to develop design and construction technique for primary and secondary beam system to cover even larger column free areas. For extending the Slim floor construction concept to bridge decks, study of dynamic behaviour of such construction needs to carried out.

Acknowledgement

The present work was carried out at the Application Engineering Centre of Steel Authority of India Limited as a part of its continuing programme on increase steel usage in building structures. The authors gratefully acknowledge the support extended by the R&D Centre for Iron and Steel, Steel Authority of India Limited.

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