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Composite Truss - A new Approach to Composite Framing Structures

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ABSTRACT

Steel-concrete composite construction has become increasingly popular in advanced countries like USA and UK and is fast catching-up in developing countries. When we look at the scenario of composite construction in India, efforts are underway for making composite construction as evidenced by bureau of Indian standards introducing a separate code IS: 11384-1985. This code deals with the design and construction of only simply supported composite beams. In this work a concept of Steel-Concrete composite truss option is introduced, which has an advantage over strength, weight, and cost of the conventional structure. Since no Indian code is available for design of steel concrete composite truss using metal decking, this work is based on British code BS:5950 part 1, 3 & 4 and Euro code part 3 & 4.

In conventional composite structures, concrete slab rest over a steel beam. Under loading, a relative slip occurs between interface of beam and slab. But In typical composite construction, a floor slab in buildings is attached to a steel component, such as an I–section beam or truss with the help of shear connectors. The methodology of composite design involves efficient use of both concrete in compression and steel in tension.

Keywords:

Introduction:

The economical span for a uniform reinforced concrete slab is little more than that it which its thickness becomes sufficient to resist the point load on which it may be subjected or, in buildings, to provide the sound insulation required. For span of more than a few meters (4 to 8 m), it is cheaper to support the slab on beams, ribs, or walls than to take it. At spans of more than about 10 m, and especially where the susceptibility of steel to loss of strength from fire is not a problem, as in most bridges, steel beams often become cheaper than concrete beams. But by about 1950 the development of shear connectors had made it practicable to connect the slab to the beam, and so to obtain the T-beam action that had long been used in concrete construction. A composite beam construction is formed when a floor slab attached to a steel component (such as I section) with the help of shear connectors. The monolithic action between a concrete slab and a steel section leads to the composite beam action. By the composite action between the two we can utilize their respective advantages to the fullest extent. The moment resisting capacity of composite section is very high as compare to ordinary steel or concrete section. But due to some restriction such as span depth ratio, deflection limit, frequency of the floor or equipment etc, the length of composite beam is limited up to range between 6 to 10 m. In the construction of long span structures, integration of services plays a vital role, especially in commercial buildings. For such buildings, integration of the structures and services is the optimum solution. One of the best solutions for beams in the range of 12m - 22m spans is the `Composite Truss` option. Presence of maximum void zone between chords and bracing members in trusses facilitates to pass through easily. The use of lightweight steel-concrete composite floors is a preferred option for use in wide range of building because of it light weight construction, less work involvement at site, greater construction accuracy, simple and speedy construction, and elements manufactured under controlled conditions in factory to ensure high quality etc... . The span ranges of different types of floor systems are depicted in fig. 1.

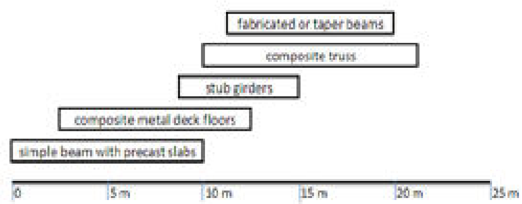


Fig. 1. Preferred range of different floor system

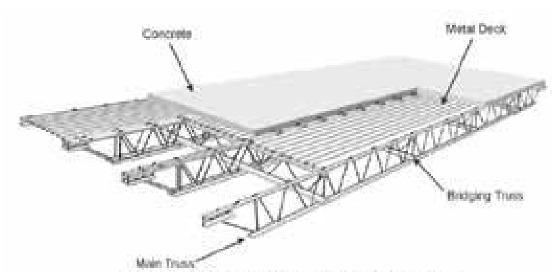
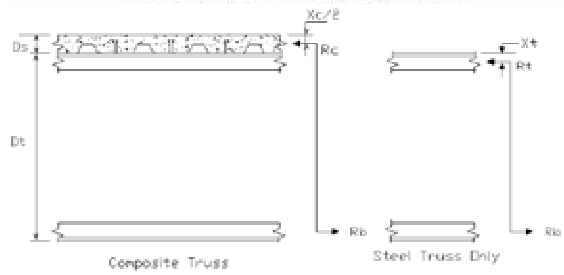
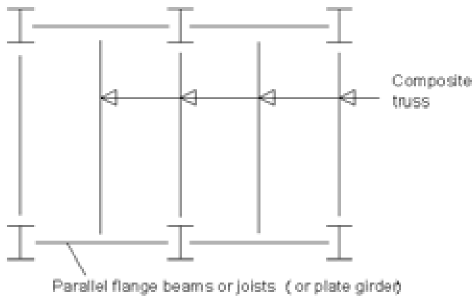


Figure — Schematic of composite floor truss system.

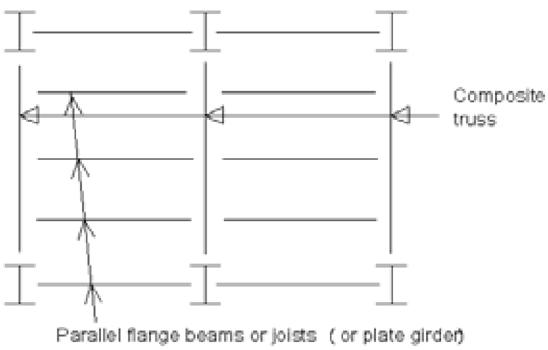


Structural framing of Composite truss

Experiences abroad have shown that trusses are economically viable for spans greater than 12m. Composite truss system are most often used with composite slabs comprising steel decking which act as a main reinforcement and permanent shuttering. Other system such as pre-cast planks or cast in situ slab can be used but are usually less cost effective. Composite trusses normally have two basic framing arrangements. In one type of arrangement, the trusses form the secondary framing elements and support the decking directly. In the other type, the trusses form the primary framing elements and support the secondary beams, which is support the decking.

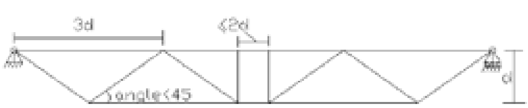


Composite truss used as secondary beams (or plate girder)



Composite truss used as primary beams (or plate girder)

Truss configuration
A number of truss configurations may be considering for use as composite truss. Pratt and warren truss configurations are most common and desired ones. A conventional warren truss configuration limits service duct sizes to those that will fit between the diagonal bracing members. However, the use of vierendeel panels without bracing member will be permitted in most truss applications, which greatly increase the zone of services. The preferred dimensional stipulations for composite truss are shown in following figure.



Analysis and design:
For the analysis of composite truss, three methods can be considered, all of which would provide an adequate factor of safety:

1. Design all members using force equilibrium (elastic) methods for the full composite case, assuming pinned connections. This is manual analysis method.
2. Design all members for the combination of forces resulting from elastic analysis of loading applied to the non-composite truss, plus the forces resulting from superimposed loads applied to the composite truss. This is appropriate for computer analysis.
3. Plastic analysis of truss. This analysis, which takes account of development of plastic hinges in the members, is only appropriate for computer analysis (and is dependent on the sections used).

The design procedure of composite truss depends upon the class of the compression flange and web. The local bucking can be avoided by limiting the width to thickness ratio of each element of a cross section subject to compression due to moment and axial load. The elements and cross section can be classified as plastic, compact, semi-compact and slender.

Class 1 or Plastic: The cross section which can develop plastic hinges and have the rotation capacity required for the failure of the structure by the formation of a plastic mechanism.

Class 2 or compact: The cross section which can develop their plastic moment resistance, but have inadequate plastic hinge rotation capacity because of local buckling.

Class 3 or semi-compact: The cross section in which the elastically calculated stress in the extreme compression fiber of the steel member, assuming an elastic distribution of stress, can reach the yield strength, but local buckling is liable to prevent the development of the plastic moment resistance.

Class 4 or slender: Cross section in which local buckling will occur even before the attainment of yield stress in one or more parts of the cross section.

The basic idea of designing a composite section is that the coefficient of thermal expansion of both concrete and steel are nearly same, which is also the basis for the development of RCC designs. In India BIS initiated efforts by introducing IS: 11384–1985 as design guideline for composite design. The general analysis procedure consists of the following stage of elastic analysis:

1. To determine factored forces resulting from the truss self weight and slab dead load applied to the non-composite truss.
2. To determine factored forces resulting from all superimposed loads applied to the composite truss.

The above two analysis are carried out, and then the members checked to verify that their load capacities are greater than the factored forces applied to them, for the structure to be considered as safe.

An additional load case that may need to be considered is for designing of virendeel panels. In order to take account to possible unequal loading along the truss in the vierendeel panels, these should be designed for shear force also.

The typical design procedure consists of the following steps

1. Find out Effective length (Le=0.85L) of top chord member.
2. Choose Section for chord (top & bottom) members & determine Section classification.
3. Determine axial, shear & moment capacity- Pc = Agpc, Pv = 0.6*Py*Av, Mcx,top = Py*Zx respectively.
4. Determine Neutral axis depth in concrete, 0.45fcuBeXc= A*py
5. Determine composite moment capacity, Mc = Rb(Dt+Ds-0.5 Xc-Xb)
6. Determine Moment resistance for vierendeel bending, Mv= Mcv+2Mb(1-T/Rb)+2Mt
7. Find out spacing and numbers of shear stud.
8. Check vierendeel for unbalanced imposed loads.
9. Design of other truss member i.e. diagonal member, vertical member etc.
10. Check for deflection and natural frequency.(as per euro code 4)

Where ,

$$A_t = X - sectional\ area\ of\ the\ top\ chord$$
$$A_c = X\ sectional\ area\ of\ concrete\ in\ the\ effective\ breadth\ od\ slab$$
$$B_e = Effective\ breadth\ of\ the\ concrete\ slab$$

D_t = *Overall depth of truss*
D_s = *overall depth of slab*
D_p = *Depth of profiled deck*
d = *Depth of angle or tee section, Diameter*
f_{sk} = *characteristic strength of reinforcement*
f_{cu} = *Cube strength of concrete*
M_{cv} = *Moment capacity due to composite action of the top chord*
M_t = *Moment capacity of the top chord*
M_b = *Moment capacity of the bottom chord*
P_c = *Axial resistance of concrete*
R_t = *Compressive or tensile resistance of the top chord*
R_b = *Tensile resistance of the bottom chord*
r_{vv} = *Radius of gyration about the weakest axis*
α_e = *Effective modular ratio, depends in long & short term loading*
γ_f = *Partial safety factor for loads*
γ_m = *Partial safety factor for material*

M_{cv}= moment resistance due to composite action of top chord & slab = $R_t[(D_s+D_p)/2+X_t]$

R_b = tensile capacity of bottom chord = A_bP_y

$M_{b,min}$= moment capacity of bottom chord = P_yZ_x

Conclusion

In all the roof framing system, it is observed that the composite truss provide the best solution in the range of 12 - 22 m spans and it has a least steel weight. The analysis and design of the composite truss is depends upon the class of the compression flange and web. The truss system can facilitate the concentration of material at the structurally most efficient locations for transfer of force; hence theoretically composite truss can provide the least steel weight of any steel framing system.

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