24 COMPOSITE FLOORS - II

1.0 INTRODUCTION

This chapter describes the basis for design of composite floors using profiled deck sheets adopting the equations described in the chapter on composite floors - I based on limit state design philosophy. To make it applicable to practice in India IS 456: 2000 has been followed wherever it is applicable.

The main economy in using profiled deck is achieved due to speed in construction. Normally *3* to *4 m* spans can be handled without propping and spans in excess of *4 m* will require propping. The yield strength of decking steel is in the range of *220* to $460\ N/mm^2$. Though light - weight concrete is preferable both from reducing the effect of ponding deflection as well as increasing the fire resistance, the normal practice in India is to use concrete of grade *M 20* to *M 40*. With the availability of ready mixed concrete, pumped pours become possible to the extent of $500\ m^3$ a day.

The profiled deck depth normally available ranges from *40* to *85 mm* and the metal thickness *0.6 mm* to *2.5 mm*. The normal span/depth values for continuous composite slab should be chosen to be less than *35*. The overall depth of the composite slab should not be less than *90 mm* and thickness of concrete, h_c, shall not be less than *50 mm*.

2.0 DESIGN SITUATIONS

The most important aspect of designer is to ensure an adequate degree of safety and serviceability of structure. The structure should therefore be checked for ultimate and serviceability limit states. In the design of composite floors with profiled decking the following situations are considered.

2.1 Profiled steel sheeting as shuttering

Verification is required for the profiled steel sheeting at the construction stage when it is acting as formwork for the wet concrete, construction loads and storage loads if any. While calculating the loads on the profiled sheet, increased depth of concrete due to deflection of the sheeting i.e., ponding effect has to be considered. Account should be taken of the effect of props, if any.

If the central deflection (d) of the profiled deck in non-composite stage is less than $\ell/325$ or *20 mm*, whichever is smaller, then the ponding effect may be ignored in the design of profiled deck.

2.1.1 Loads on profiled sheeting

Design should make appropriate allowances for construction loads, which include the weight of operatives, concreting plant and any impact or vibration that may occur during construction. These loads should be arranged in such a way that they cause maximum bending moment and shear. In any area of *3 m* by *3 m* (or the span length, if less), in addition to weight of wet concrete, construction loads and weight of surplus concrete should be provided for by assuming a load of $1.5\ kN/m^2$. Over the remaining area a load of $0.75\ kN/m^2$ should be added to the weight of wet concrete.

2.1.2 Effective span

The continuous slab is designed as a series of simply - supported spans, for simplicity. The effective span can be taken as the lesser of the two following:

- Distance between centres of supports
- The clear span plus the effective depth of the slab

If, profiled deck sheet is propped during construction then, effective span is calculated using the formula. (This rule is taken from BS 5950:Part 4 as there is no provision in Eurocode). The width of the prop is neglected here.

$$\ell_e = \frac{\ell - B + d_{ap}}{2} \tag{1}$$

where, B – Width of top flanges of the supporting steel beams
d_{ap} - The depth of the sheeting
ℓ - Actual span of the composite floor

2.2 Composite slab

Verification is required for the floor slab after composite behaviour has commenced and any props have been removed. Total loading that is acting on the composite slab is considered in the design checks for the ultimate Limit State. The loads are applied in such a way that the load combination is most unfavourable. Load factors of *1.35* for dead load and *1.5* for imposed load are employed in design calculations.

Generally it is sufficient to consider the following load combinations in buildings mostly subjected to uniformly distributed loads:

- Alternate spans carrying total factored loading due to imposed and dead loads. Other spans carrying only factored loading due to dead load.
- Any two adjacent spans carrying total factored load due to imposed and dead load and all other spans carrying only factored dead load.

3.0 ANALYSIS FOR INTERNAL FORCES AND MOMENTS

3.1 Profiled steel sheeting as shuttering

Elastic analysis shall be used where sheeting is considered. The design based on elastic distribution of bending moment is conservative, as it does not take into account redistribution of moments that can occur between support and mid span sections. The following treatment is based on moment redistribution at the ultimate stages.

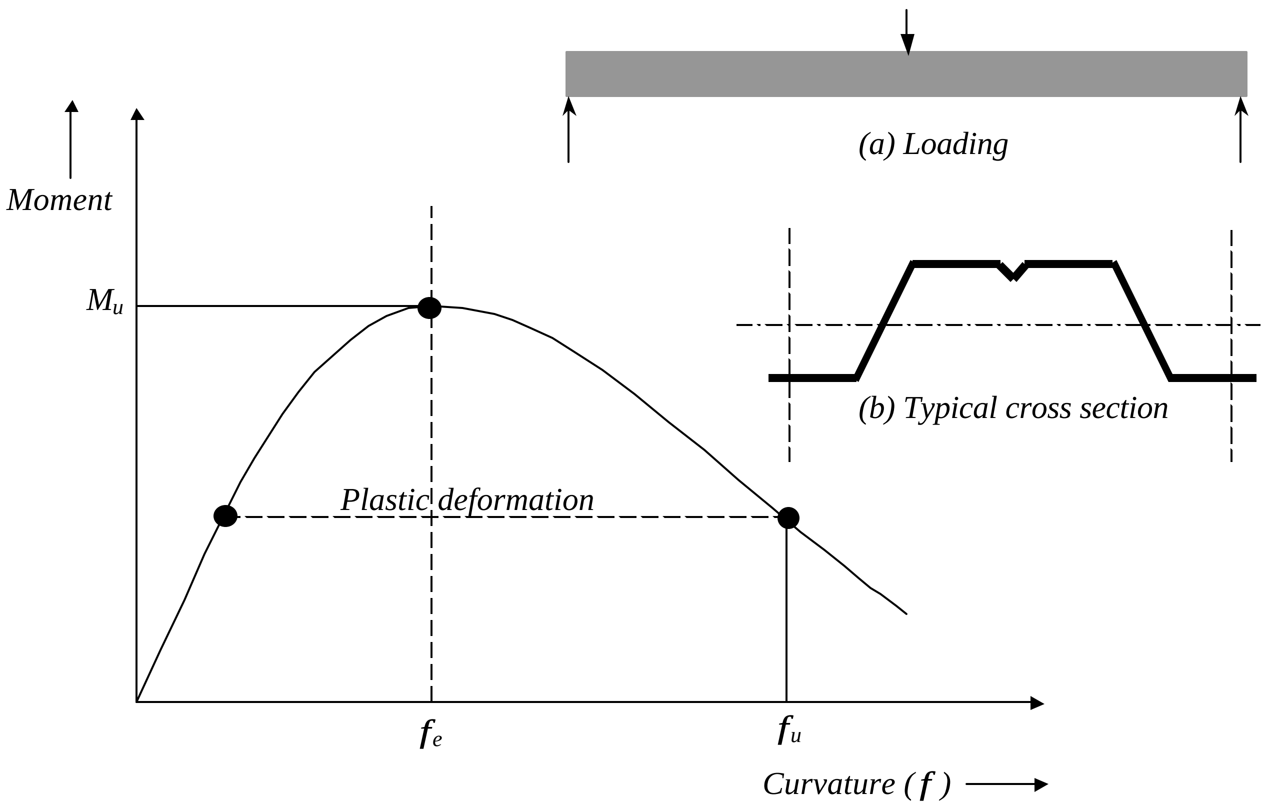
A moment - curvature relationship for typical section of metal deck is shown in Fig. 1.

Fig. 2 shows the elastic moment at the onset of yield and the moment at failure utilising the plastic deformation of the hinges formed earlier for a typical two span continuous beam.

If M_p and M_n are the moment capacities of deck at mid-span and support sections respectively, then at failure only a portion of M_n i.e. kM_n at support can be realised because of the available ductility. Thus,

$$w = \frac{8}{\ell^2}\left(M_p + 0.46kM_n\right) \qquad (2)$$

The value of k can be determined experimentally for the type of profile used.



(c) Moment – curvature variation of critical cross section

Fig. 1 Moment – curvature relationship for a metal deck floor

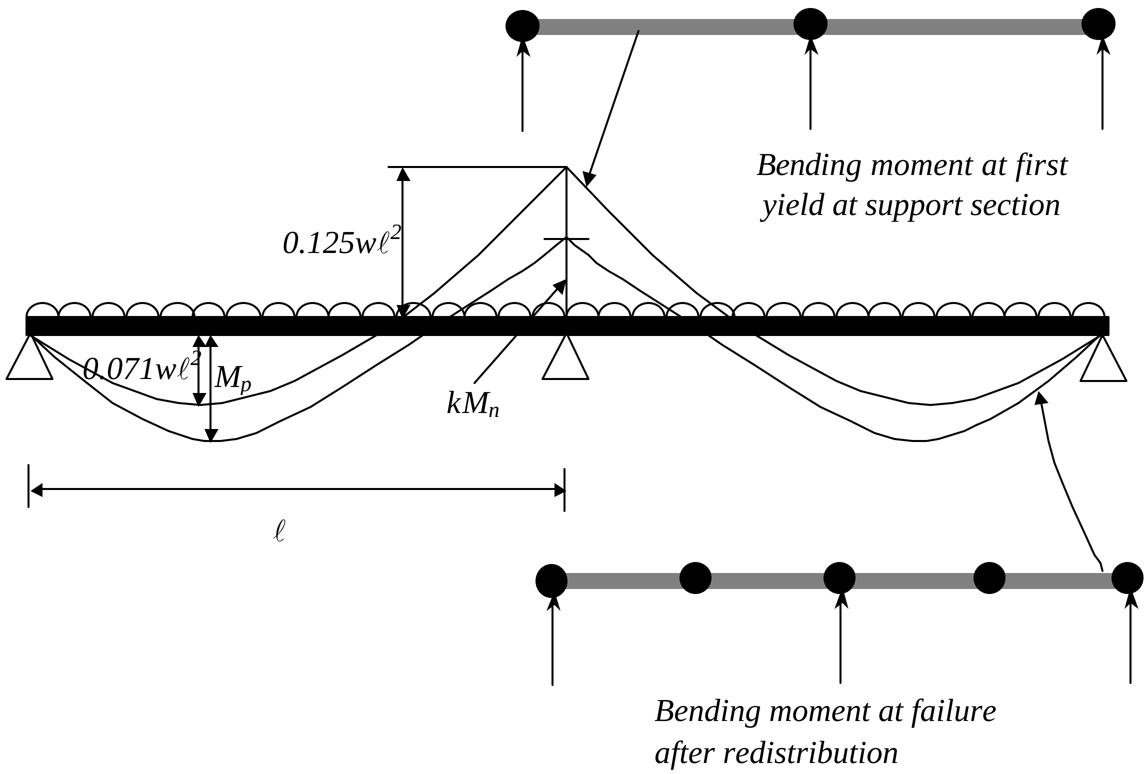


Fig. 2 Bending moment variation on two span decking

The load span tables given by manufactures of the profile deck are based on tests and hence take advantage of post elastic strength. They are satisfactory for spans *10* to *15%* in excess of the corresponding values based on elastic design. However, IS: 456 – 1978 gives coefficients for bending moments and shear forces for continuous beams which can be used for calculating moments and shear forces for composite floors also. Table –7 and table – 8 in the Chapter on Composite Beams – II gives moment and shear coefficients respectively. These coefficients do not make any allowance for redistribution and may be too conservative.

3.2 Composite slab

The following methods of analysis may be used:

- Linear analysis with or without redistribution
- Rigid-plastic global analysis based either on the kinematic method or on the static method provided that it is shown that sections where plastic rotations are required have sufficient rotation capacity
- Elastic-plastic analysis taking into accounts the non-linear material properties.

The application of linear methods of analysis is suitable for the serviceability limit states as well as for the ultimate limit states. Plastic methods, with their high degree of simplification, shall only be used in the ultimate Limit State.

Equations for evaluating moment, longitudinal shear and vertical shear are given in the previous chapter.

4.0 DESIGN TABLES

The manufacturers of the steel profiled sheets normally provide design tables for different decks made by them. These tables give information regarding recommended slab depth and profile thickness to be adopted for different type of support conditions such as single span without prop, with prop or for multiple spans for different imposed load rating. The spans that could be achieved with propped condition are generally greater because the governing criteria will be composite condition. However it is necessary to check deflections in such cases for serviceability.

5.0 SERVICEABILITY LIMIT STATES FOR COMPOSITE SLABS WITH PROFILED DECKS

5.1 Cracking of concrete

The profiled deck sheeting protects the lower surface of the slab. Cracking will occur in the top surface where the slab is continuous over a supporting beam in the hogging moment regions. Crack width will be wider over the supports if each span of the slab is designed as simply supported, rather than continuous, and if the spans are propped during construction

To counter cracking, longitudinal reinforcement should be provided above internal supports. The minimum recommended amounts are as *0.2%* of the area of concrete above the sheeting, for unpropped construction, and *0.4%* if propping is used. (According to Eurocode 4). If the environment is corrosive, the slabs should be designed as continuous, with cracking controlled by providing additional reinforcement and ensuring that the concrete cover for reinforcement is suitably enhanced.

5.2 Deflection

The limitations on deflection for composite slabs are not explicitly provided for in IS: 11384 – 1985. Eurocode 4 gives explicit guidance, which is explained below. The deflection of profiled sheeting due to its own weight and the wet concrete slab should not exceed $\ell_e/180$ or *20 mm*, where ℓ_e is the effective span.

For the composite slab stage, the rare loading combinations described in section 2.2 are normally used. The maximum deflection below the level of the supports should not exceed *span/250*, and the increase of deflection after construction (due to creep and to variable load) should not exceed *span/300*, or *span/350* if the floor supports brittle finishes or partitions.

The deflections may not be excessive when span-to-depth ratios are kept within certain limits. These values are given in Eurocode 4 as *25* for simply supported slabs, *32* for spans with one end continuous and *35* for internal spans. These limitations are regarded as "deemed to satisfy" the serviceability deflection limits. 'Depth' limits relate to effective depths, so for composite slabs the depth should be taken as depth of composite slab over centroidal axis of the profiled deck sheet rather than total depth of the slab.

Broadly speaking, slip occurs after reaching working load in a well-designed slab. If the slip occurs earlier it will cause an increase in deflection even in the Serviceability State, which is not desirable. So, slip factor to be taken care of while designing the slab.

6.0 FIRE RESISTANCE

In general no fire tests are required before the design of profiled steel sheeting, as their manufacturers carry out these tests for general use in buildings, before releasing the products in the market.

Standard fire-resistance tests are carried out by them, using independent testing centres, to ensure

- Strength or stability under load
- Ability to transmit smoke and flame
- Insulation so that upper part of the slab is not excessively heated.

Adequacy is checked by ensuring that deflection does not exceed *span/20* under fire tests. The load carrying capacity is checked by considering only embedded steel. In buildings the in-plane resistance and negative reinforcements at points of continuity add to the strength under fire condition. While simply supported slab under fire test exhibits an endurance period of *30* minutes, the continuous slab withstands *30* minutes or even more with an imposed load of $6.7\ kN/m^2$. Under fire condition with this imposed load and with reduced strength of elements and elevated temperature the safety is checked so that plastic capacity gives a load factor of *1.0* or more. For larger fire protection using fire engineering method, the area of embedded mesh reinforcement is suitably increased by additional emergency reinforcement as per the increase in the fire resistance period desired. Simple design tables for common cases of fire resistance of composite deck slabs are given in reference 3. These tables can be judiciously converted and used in the absence of test results for specific cases required.

7.0 DIAPHRAGM ACTION OF DECK SLAB

Deck slab transmits in-plane loads for ensuring lateral stability of the building system. For this the deck slab is attached on all the four sides at spacing exceeding *600 mm* on either the beams or supporting walls. The diaphragm action is excellent if through deck welding is resorted to. The steel decking also provides lateral support to the steel beams it supports. However, beams running parallel to the decking are laterally supported only at transverse beam connections.

8.0 STEPS IN THE DESIGN OF PROFILED DECKING

The following are the steps for design of profiled decking sheets:

(i) List the decking sheet data (Preferably from manufacturer's data)

(ii) List the loading

(iii) Design the profiled sheeting as shuttering
- Calculate the effective length of the span
- Compute factored moments and vertical shear
- Check adequacy for moment
- Check adequacy for vertical shear
- Check deflections

(iv) Design the composite slab – Generally the cross sectional area of the profiled decking that is needed for the construction stage provides more than sufficient reinforcement for the composite slab. So, the design of short span continuous slabs can be done as series of simply supported slabs and top longitudinal reinforcement is provided for cracking as given in section 5.1. However, long-span slabs are designed as continuous over supports.
- Calculate the effective length of the span
- Compute factored moments and vertical shear
- Check adequacy for moment
- Check adequacy for vertical shear
- Check adequacy for longitudinal shear
- Check for serviceability, i.e. cracking above supports and deflections

9.0 CONCLUSIONS

'Floors using profiled deck sheets' is a very new design concept in the Indian context and hence no appropriate codes are available. These chapters on composite floors are intended to provide the most upto-date information and hence largely Eurocodes are followed. A design example is included to illustrate the method employed in the choice of profiled decking and for verifying its adequacy.

10.0 REFERENCES

1. Mark Lawson and Peter Wickens "Composite Deck Slab", Steel Designers Manual (Fifth edition), The Steel Construction Institute, UK, 1992.

2. Bryan E.R. and Leach. P "Design of Profiled sheeting as Permanent Formwok", Construction Industry Research and Information Association (CIRIA), Technical Note 116, 1984.

3. Data Sheet: Fire resistance of Composite Slabs with Steel Decking, Construction Industry Research and Information Association (CIRIA), Special Publication 42