4. Development of Program For Composite Slabs

4.1 Introduction

A composite slab is defined as a floor system comprising normal or light weight structural concrete placed permanently over cold-formed steel deck in which the steel deck performs dual roles of acting as a form for the concrete during construction and as positive reinforcement for the slab during service. Such slabs are generally used in framed structures, with steel floor beams as shown in **Fig. 4.1.** Composite deck slabs are particularly competitive where the concrete floor has to be completed quickly and where medium level of fire protection to steel work is sufficient. However, composite slabs with profiled decking are unsuitable when there is heavy concentrated loading or dynamic loading in structures such as bridges. The alternative composite floor in such cases consists of reinforced or pre-stressed slab over steel beams connected together to act monolithically. The structural behaviour of these floors is similar to a RC slab, with the steel sheeting acting as the tension reinforcement.

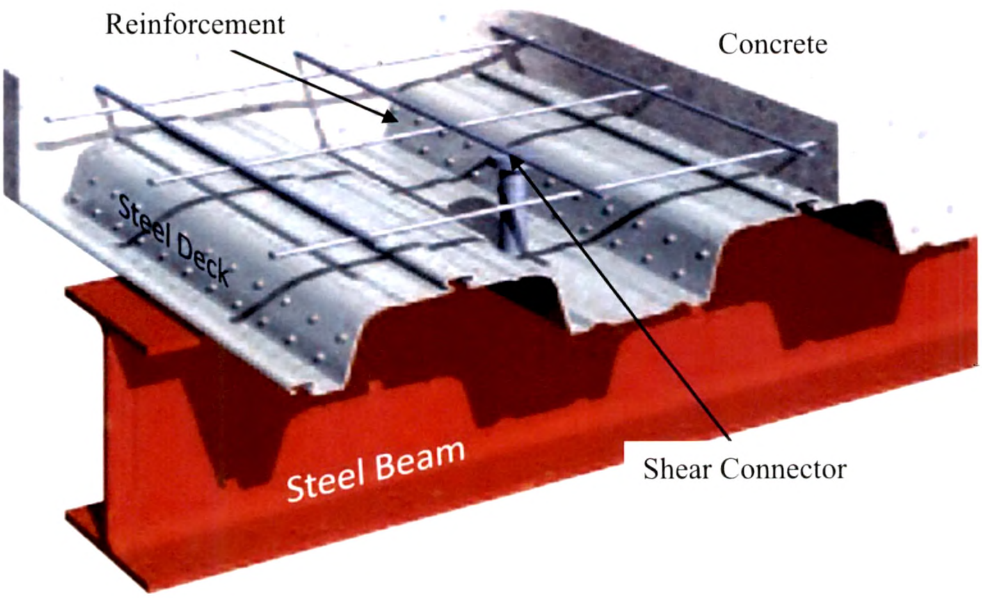

Fig. 4.1 Composite Slab[2]

The steel decking performs a number of roles, such as:

- It supports loads during construction and acts as a working platform.
- It develops adequate composite action with concrete to resist the imposed loading.
- It transfers in-plane loading by diaphragm action to vertical bracing or shear walls.
- It stabilizes the compression flanges of the beams against lateral buckling.
- It reduces the volume of concrete in tension zone.
- It distributes shrinkage strains, thus preventing serious cracking of concrete.
- It accommodates ducts for electrical line and other services.

Care has to be taken in the construction of composite floors with profiled decking to prevent excessive ponding, especially in the case of long spans. The profiled sheet deflects considerably requiring additional concrete at the centre that may add to the concreting cost. Thus, longer spans will require propping to eliminate substantial deflection.

4.2 THE COMPOSITE SLAB ELEMENTS

Composite floors with profiled decking consist of the following structural elements along with in-situ concrete and steel beams:

- Profiled decking
- Shear connectors
- Reinforcement

4.2.1 PROFILED SHEET DECKING

There are many types of profiled sheets used for the construction of composite slabs. Profiled sheets are basically cold formed sheets made of thin steel coils which vary in form, rib depth, rib spacing, sheet size, style of lateral over-lapping, with yield strength varying between 240 MPa to 550 MPa, and in the methods of mechanical connection which ensure bond between the steel sheet and concrete slab. The steel deck is normally rolled into the desired profile from 0.9 mm to 1.5 mm galvanized coil. It is profiled such that the profile heights are usually in the range of 38 -75 mm and the pitch of corrugations is between 150 mm and 350 mm. Generally, spans of the order of 2.5 m to 3.5 m between the beams are chosen and the beams are designed to span between 6 m to 12 m [90]. There are two well-known generic types of profiles.

- Re-entrant (Dovetail) profile **(Fig. 4.2(a))**
- Trapezoidal profile with web indentations **(Fig. 4.2 (b-d))**

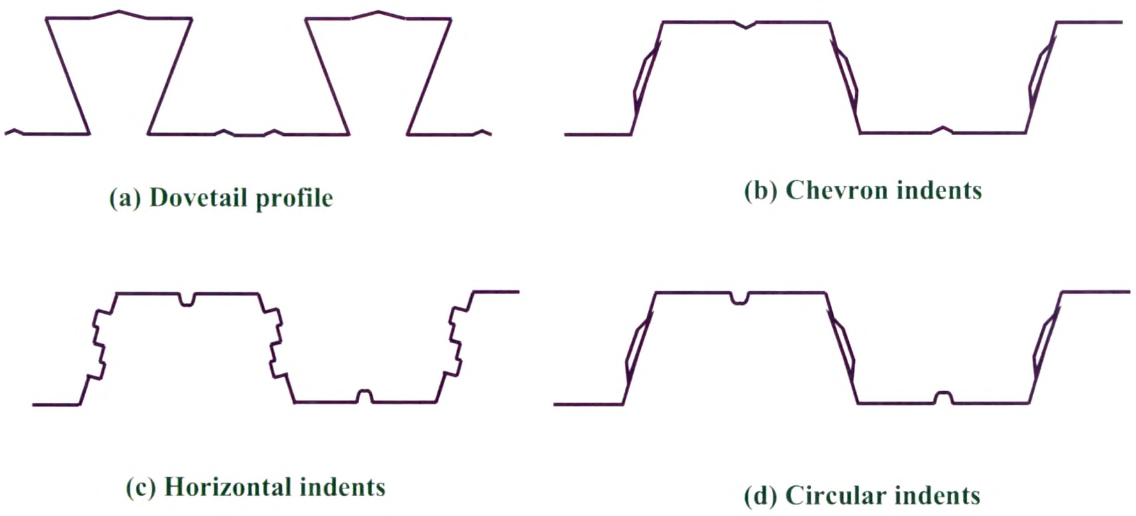

Fig. 4.2 Different Types of Profiles

In case of shorter slab span, the stresses in the composite slab after the concrete has hardened are low. For such floors, trapezoidal steel sheets with limited horizontal shear resistance are used. They have the lowest steel weight per square meter of floor area. While in case of longer slab span, the final composite slab is highly stressed. In this case steel sheeting will require good horizontal shear bond resistance. In this case, re-entrant profiles are used leading to the higher steel weight per square meter of floor area.

4.2.2 Shear Connectors

Shear connectors are steel elements such as studs, bars, spiral or any other similar devices as shown in **Fig 4.3** which are welded to the top flange of the steel section and intended to transmit the horizontal shear between the steel section and the cast in-situ concrete and also to prevent vertical separation at the interface.

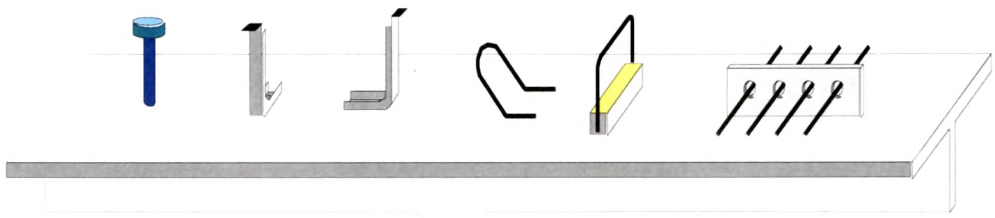

Fig. 4.3 Types of Shear Connectors [2]

4.2.3 Reinforcement

It is generally useful to provide reinforcement in the concrete slab for: Load distribution of line or point loads; Local reinforcement of slab openings; Fire resistance; Upper reinforcement in hogging moment area; Controlling cracking due to shrinkage.

4.3 ANALYSIS OF COMPOSITE SLAB

The following methods of analysis may be used:

- Linear elastic method.
- Linear elastic method with moment redistribution.
- Plastic method according to the theory of plastic hinges.
- A higher order analysis which takes into account non-linear material behaviour and slip between the profiled sheeting and the concrete slab.

The application of linear methods of analysis is suitable for the serviceability limit states as well as for the ultimate limit states. Plastic methods should only be used at the ultimate limit state. A continuous slab may be designed as a series of simply supported spans. In such a case, nominal reinforcement should be provided over intermediate supports.

4.3.1 ANALYSIS FOR THE ULTIMATE LIMIT STATES

In most cases the analysis of composite slabs, which is continuous over several spans is performed according to the elastic method considering a slab of unit width (1m).

It is possible to take concrete cracking into account in followings:

- Arbitrarily reduce the moment at the supports (maximum reduction 30%) and consequently increase the span moments.
- Totally neglect reinforcement over the supports and consider the slab as a series of simply supported beams. Minimum reinforcement must always be placed over intermediate supports for serviceability reasons.
- Consider that the slab is a beam with variable inertia, depending on the reinforcement. The assumed inertia is that of the cracked section.

4.3.2 ANALYSIS FOR THE SERVICEABILITY LIMIT STATES

Analysis of composite slab, for calculating deflection, may be carried out with the following assumptions:

- The slab is comparable to a continuous beam of constant inertia, equal in value to the average inertia of the cracked and uncracked section.
- Long-term loading effects on the concrete are taken into account using a variation in the modular ratio Ea/Ec. For simplification, Eurocode 4 recommends an average value of E_a/E_c for both long and short term effects.

Possible slip between the profiled sheeting and concrete slab must be taken into account at the serviceability limit states. Slip may occur in the span and greatly influence deflection. It is necessary, therefore, to fully understand the behaviour of composite slabs through testing.

4.4 Resistance of Composite Slab to Bending

The structural properties of profiled sheet along with reinforcement provided and concrete with a positive type of interlock between concrete and steel deck is the basis of a composite floor. Some loss of interaction and hence slip may occur between concrete - steel interface. Such a case is known as 'Partial interaction'. Failure in such cases occurs due to a combination of flexure and shear.

The width of the slab 'b' shown in **Fig. 4.4 (a)** is one typical wavelength of profiled sheeting. The overall thickness h_t, as required by EC4, should not be less than 80 mm; and the thickness of concrete above the 'main flat surface' of the top of the ribs of the sheeting should not be less than 40 mm. Normally, this thickness is 60 mm or more, to provide sufficient sound or fire insulation, and resistance to concentrated loads.

Except where the sheeting is unusually deep, the neutral axis for bending lies in the concrete, where there is full shear connection; but in regions with partial shear connection, there is always neutral axis within the steel section. The local buckling of steel sections should then be considered.

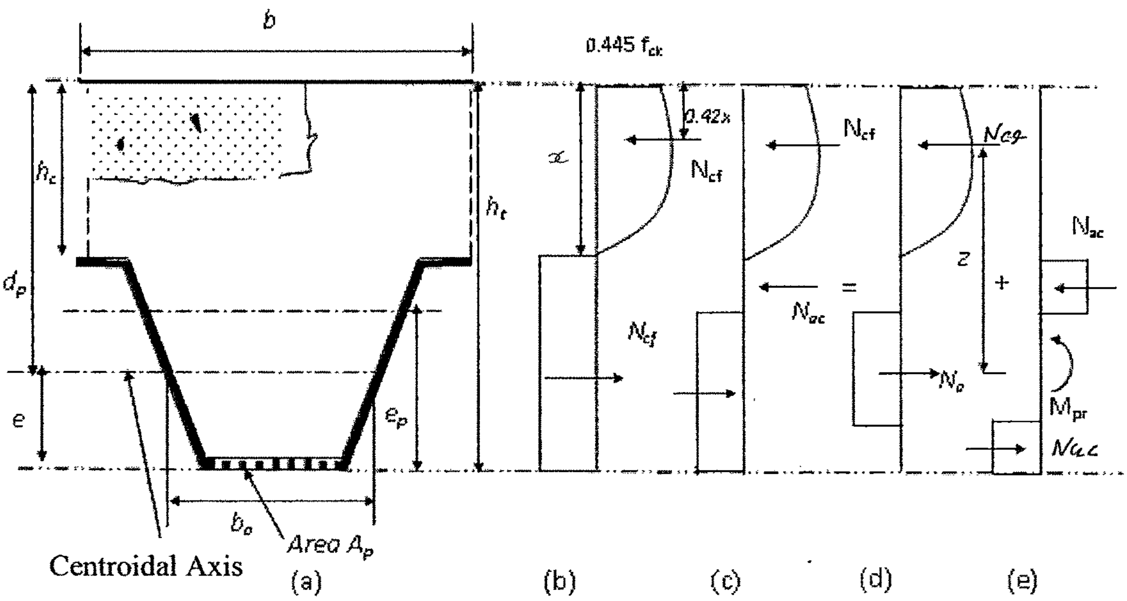

Fig. 4.4 Resistance of Composite Slab to Sagging Bending

4.4.1 NEUTRAL AXIS ABOVE THE SHEETING (FIG. 4.4 (b))

Full shear connection is assumed. Hence, compressive force N_{cf} in concrete is equal to yield force N_{pa} in steel.

$$N_{cf} = N_{pa} = \frac{A_p f_{yp}}{\gamma_{ap}} \qquad \text{... (4.1)}$$

$$N_{cf} = 0.36\, f_{ck}.b.x$$

Where, A_p = Effective area per meter width,

f_{yp} = *Yield* strength of steel,

γ_{ap}= Partial safety factor (*1.15*).

The neutral axis depth x is given by

$$x = \frac{N_{cf}}{b(0.36\, f_{ck})} \qquad \text{... (4.2)}$$

This is valid when $x \leq h_c$, i.e. when the neutral axis lies above steel decking.

$$M_{p\,Rd} = N_{cf}\,(\,d_p - \;0.42\,x\,) \qquad \text{...(4.3)}$$

Note that centroid of concrete force lies at $0.42x$ from free concrete surface. $M_{p.Rd}$ is the design resistance to sagging bending moment.

4.4.2 NEUTRAL AXIS WITHIN SHEETING AND FULL SHEAR CONNECTION (FIG. 4.4 (c))

The stress distribution is shown in **Fig. 4.4 (c).** The force N_{cf} is now less than N_{pa}, and is given by

$$N_{cf} = \;(bh_c \times 0.36\, f_{ck}) \qquad \text{... (4.4)}$$

because compression within ribs is neglected, for simplicity. There is no simple method of calculating x, because of the complex properties of profiled sheeting, so the following approximate method is used. The tensile force in the sheeting is decomposed, as shown in **Fig. 4.4 (d)** and **Fig. 4.4 (e),** into a force at the bottom equal to N_{ac} (the compressive force) and a force N_a, where $N_a = N_{cf}$ and the remaining force N_{ac} such that the total tensile force is $N_{ac} + N_a$. The equal and opposite force N_{ac} provide resisting moment M_{pr}. Note that this M_{pr} will be less than M_{pa}, the flexural capacity of steel sheeting. The relationship between M_{pr}/M_{pa} and N_{cf}/N_{pa} is shown in **Fig. 4.5 (a)** with the dotted line. For design this can be approximated by line ADC that can be expressed as

$$M_{pr} = 1.25 M_{pa}\left[1 - \frac{N_{cf}}{N_{pa}}\right] \leq M_{pa} \qquad \text{... (4.5)}$$

The moment of resistance is given by

$$M_{p.Rd} = (N_{cf})Z + M_{pr} \qquad \text{... (4.6)}$$

Sum of resistance is shown in **Fig. 4.4 (d)** and **Fig. 4.4 (e)**, which is equal to the resistance shown in **Fig. 4.4 (c)**.

The lever arm z can be found by examining the two extreme cases. **For case (i)** where $N_{cf} = N_{pa}$ or $N_{cf}/N_{pa} = 1.0$, $N_{ac} = 0$ and hence $M_{pr} = 0$.

$$M_{p.Rd} = N_{pa}(d_p - 0.42\, h_c) \qquad \text{... (4.7)}$$

$$z = d_p - 0.42 h_c = h_t - e - 0.42 h_c \qquad \text{... (4.8)}$$

This is indicated by point F in **Fig. 4.5 (b)**.

For case (ii), on the other hand,

$N_{cf} \cong 0$; $N_a = 0$.

$M_{pr} = M_{pa}$. The neutral axis is at a height e_p above the bottom. Then

$$z = h_t - 0.42 h_c - e_p \qquad \text{... (4.9)}$$

This is represented by point E. Thus the equation to the line EF is

$$z = h_t - 0.42 h_c - e_p - \frac{(e_p - e)N_{cf}}{N_{pa}} \qquad \text{... (4.10)}$$

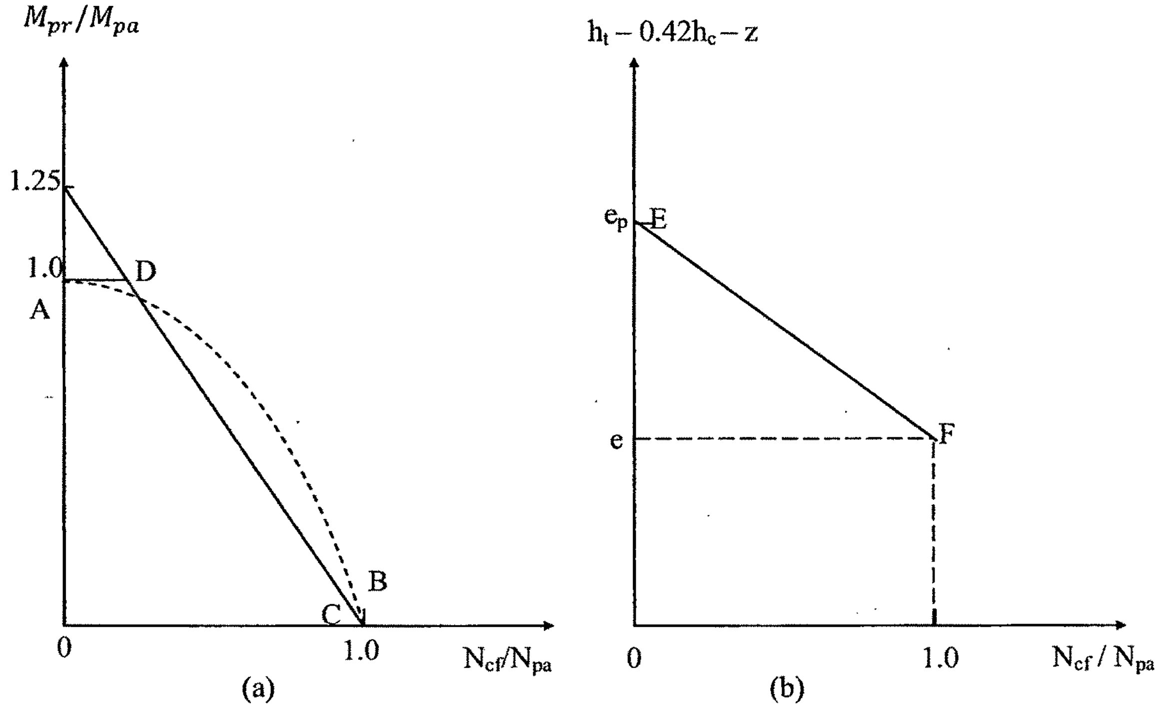

Fig. 4.5 Resistance Moment of Profiles

4.4.3 PARTIAL SHEAR CONNECTION ($N_C < N_{CF}$)

In this case, the compressive force in the concrete N_c is less than N_{cf} and depends on the strength of shear connection. The stress blocks are as shown in **Fig. 4.4 (b)** for the slab (with N_c in place of N_{cf}) and **Fig. 4.4 (c)** for sheeting.

The depth of stress block is,

$$x = \frac{N_c}{b(0.36\, f_{ck})} \leq h_c \qquad \text{... (4.11)}$$

In this case, Eq. (4.5), Eq. (4.6) and Eq. (4.10) get modified by substituting $N_c = N_{cf}$ and $N_{cf} = N_{pa}$ and $x = h_c$. Thus,

$$z = h_t - 0.42x - e_p \frac{(e_p - e)N_c}{N_{cf}} \qquad \text{... (4.12)}$$

$$M_{pr} = 1.25 M_{pa} \left[1 - \frac{N_c}{N_{cf}}\right] \leq M_{pa} \qquad \text{... (4.13)}$$

$$M_{p.Rd} = N_c z + M_{pr} \qquad \text{... (4.14)}$$

4.5 SHEAR RESISTANCE OF COMPOSITE SLAB

The shear resistance of composite slab largely depends on connection between profiled deck and concrete. The adhesion between the steel profile and concrete is generally not sufficient to create composite action in the slab and thus an efficient connection is achieved with one or several of the following:

- Friction interlock provided by re-entrant shape of the ribs (**Fig. 4.6**).
- Mechanical interlock provided by indentation of profile sheet (**Fig. 4.7**).
- End anchorage like headed bolts, angle studs or end-deformations of the steel sheeting brings a very concentrated load introduction at the ends and therefore a sudden increase from the bare steel to the composite resistance (see **Fig. 4.8**).

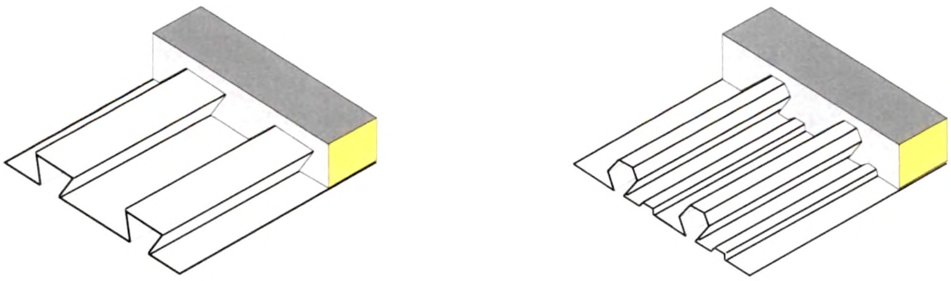

Fig. 4.6 Frictional Interlock in Composite Slabs

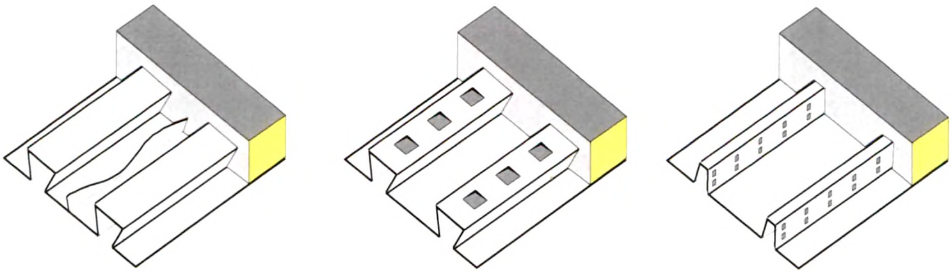

Fig. 4.7 Mechanical Interlock in Composite Slabs

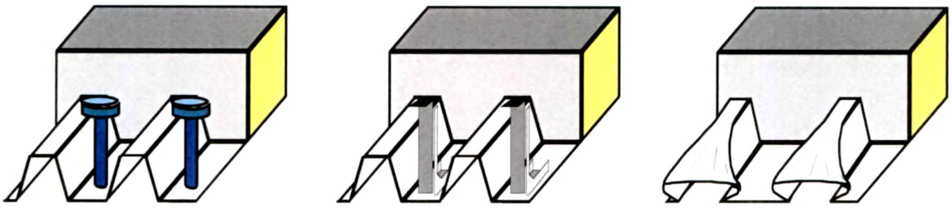

Fig. 4.8 End anchorage for Composite Slabs [3]

4.5.1 RESISTANCE TO LONGITUDINAL SHEAR

At section B-B **(Fig. 4.9)** failure corresponds to the resistance to longitudinal shear. The verification method is to evaluate the average longitudinal shear resistance existing on shear span L_s and compare this with the applied force. This resistance depends on the type of the sheeting and must be established for all proprietary sheeting as the value is a function of the particular arrangements of embossment orientation, surface conditions etc.

The direct relationship between the vertical shear and the longitudinal shear is only known for elastic behaviour, if the behaviour is elastic-plastic, the relationship is not simple and the *m-k* method, which is a semi-empirical approach, is used. The test is described below. The failure of the beam is initiated by one of the following three modes:

(i) Flexure at a cross section such as A-A

(ii) Shear at support, along a length as B-B

(iii) Shear bond mode, at a cross section such as C-C.

Here, ℓ_s is the shear span and ℓ is effective span.

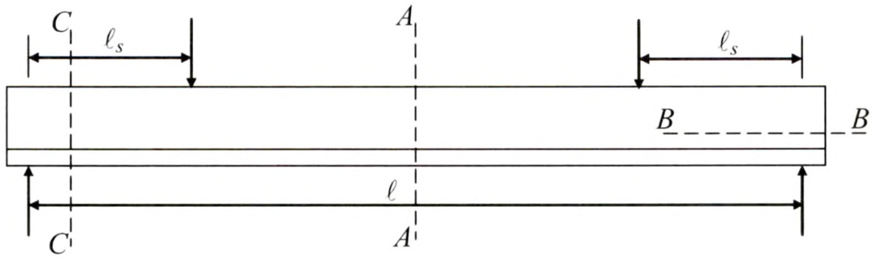

Fig. 4.9 Critical Sections and Failure Modes

The design resistance of the slab against longitudinal shear is determined by a standardised semi-empirical method called as *m-k method* which was originally proposed by Porter and Ekberg [91] in 1976. The factors *m* and *k* are obtained from standardised full-scale tests. The *m* and *k* values depend on the sheeting type and the dimensions of the section of the slab and are generally given by profiled steel manufacturers.

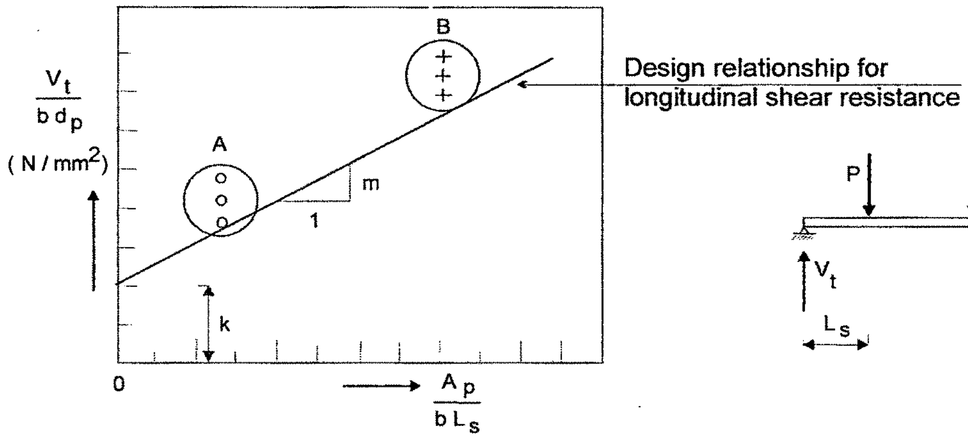

Fig. 4.10 Derivation of m and k from Test Data

The shear resistance as per EC4 is given by equation

$$\frac{V_t}{bd_p} = m\left(\frac{A_p}{bL_s}\right) + k \qquad \text{... (4.15)}$$

Where, V_t = maximum design vertical shear, b = width of slab, m = slope of the line, k = the intercept of y-axis, ℓ_s = shear span, d_p = average depth of the composite slab and A_p = effective area of shearing.

For design, L_s depends on the type of loading. For a uniform load applied to the entire span L of a simply supported beam, L_s equals L/4. This value is obtained by equating the area under the shear force diagram for the uniformly distributed load to that due to a symmetrical two point load system applied at distance L_s from the supports. For other loading arrangement, L_s is obtained by similar assessment. Where the composite slab is designed as continuous, it is permitted to use an equivalent simple span between points of contraflexure for the determination of shear resistance. For end spans, however, the full exterior span length should be used in design.

4.5.2 Resistance To Vertical Shear

At section C-C (**Fig. 4.9**) failure corresponds to the resistance to vertical shear. The resistance to vertical shear is mainly provided by the concrete ribs. For open profiles it should be taken as effective width. The resistance of a concrete slab with ribs of effective width b_0 at a spacing of b is given by:

$$V_{v.Rd} = b_0 d_p k_1 k_2 \tau_{Rd} \quad \text{... (4.16)}$$

Where, b_0 = mean width of the concrete ribs (minimum width for re-entrant profile), τ_{Rd} = basic shear strength to be taken as $0.25 f_{ckt}/\gamma_c$, f_{ctk} = approximately equal to 0.7 times mean tension resistance of the concrete f_{ctm}, A_p = effective area of the steel sheet in tension considering width b_o; $k_1 = (1.6 - d_p) \geq 1$ with d_p express in m, $k_2 = 1.2 + 40\rho$, and $\rho = A_p/b_0 d_p \leq 0.02$.

4.6 Design of Composite Slab

4.6.1 Design Situations

When designing composite slabs two distinct structural states must be checked: firstly, the temporary state of execution, when only the sheeting resists the applied loads; secondly, the permanent state, after the concrete is bonded to the steel giving composite action. Relevant limit states and load cases are considered for both design situations.

a) Profiled sheeting as shuttering : Verifications at the ultimate limit state and the serviceability limit state are required, with respect to the safety and serviceability of the profiled sheeting acting as formwork for the wet concrete. The effects of any temporary props used during execution, must be taken into account in this design situation.

b) Composite slabs : Verifications at the ultimate limit state and the serviceability limit state are required, with respect to the safety and the serviceability of the composite slab after composite behaviour has commenced and any props have been removed.

4.6.2 Actions

The loads and other actions to be considered, for the ultimate and serviceability limit state, are given in the relevant Eurocodes and Indian codes.

For the situation where the profiled sheeting acts as formwork, the following loads should be considered in the calculations, taking into account any propping effects:

- Self-weight of the profiled sheeting.
- Weight of the wet concrete.
- Execution loads.
- Temporary storage load, if applicable.

The execution loads represent the weight of the operatives, any loads due to placing the concrete, and also take into account any impact or vibration likely to occur during execution.

In accordance with EC4, a representative value of execution loads (including any excess of concrete) can be taken to be 1.5 kN/m^2, distributed on an area 3m x 3m (or the span of the sheeting, if less) and 0.75 kN/m^2 on the remaining formwork surface.

For the situation where the steel and the concrete act compositely, the loads acting on the slab should comply with Eurocode 1 [92].

- Self-weight of the slab (profiled sheeting and concrete);
- Other permanent self-weight loads (not load carrying elements);
- Reactions due to the removal of the possible propping;
- Live loads;
- Creeping, shrinkage and settlement;
- Climatic actions (temperature, wind, etc.).

4.6.3 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 following two:

- 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. which is is taken from BS 5950: Part 4 [93] as there is no provision in EC 4.

$$l_e = \frac{l - B + d_{ap}}{2} \qquad \text{... (4.17)}$$

Where, B = width of top flanges of the supporting steel beams, d_{ap}= the depth of the sheeting, and l = actual span of the composite floor.

4.6.4 SERVICEABILITY LIMIT STATES FOR COMPOSITE FLOOR

4.6.4.1 Deflections

The limitations on deflection for composite slabs are not explicitly provided in IS: 11384 - 1985 [1]. EC4 gives explicit guidance, which is as follows. The deflection of profiled sheeting due to its own weight and the wet concrete slab should not exceed $l_e/180$ or 20 mm, where l_e is the effective span.

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 EC4 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.

4.6.4.2 Cracking of Concrete

The crack width in hogging moment regions of continuous slabs should be checked in accordance with Eurocode 2 [94]. In normal circumstances, as no exposure to aggressive physical or chemical environments and no requirements regarding water proofing of the slab exist, cracking can be tolerated with a maximum crack width of 0.3 mm. If the crack width is higher than this limit, reinforcement should be added according to usual reinforced concrete rules.

Where continuous slabs are designed as a series of simply supported beams, the cross-sectional area of anti-crack reinforcement should not be less than 0.2 % of the cross-sectional area of the concrete on top of the steel sheet for unpropped construction and 0.4 % for propped construction according to EC4.

4.6.4.3 End Slip

For external spans, end slip can have a significant effect on deflection. For non-ductile behaviour, initial end slip and failure may be coincident while for semi-ductile behaviour, end slip will increase the deflection.

Where test behaviour indicates initial slip at the desired service load level for the non-anchored slab, end anchorage (studs, cold formed angles...) should be used in external slabs. Such end slip is considered as significant when it is higher than 0.5 mm. Where end slip exceeding 0.5 mm occurs at a load below 1.2 times the design service load, then end anchors should be provided or deflections should be calculated including the effect of the end slip.

4.7 ILLUSTRATIVE EXAMPLE

Check the adequacy of the continuous composite profiled deck slab with spans of 3.5 m. The cross section of the profiled sheeting is shown in **Fig. 4.11.** The slab is propped at the centre during construction stage. Here γ_{ap} = 1.15 and M_{20} grade of concrete is used.

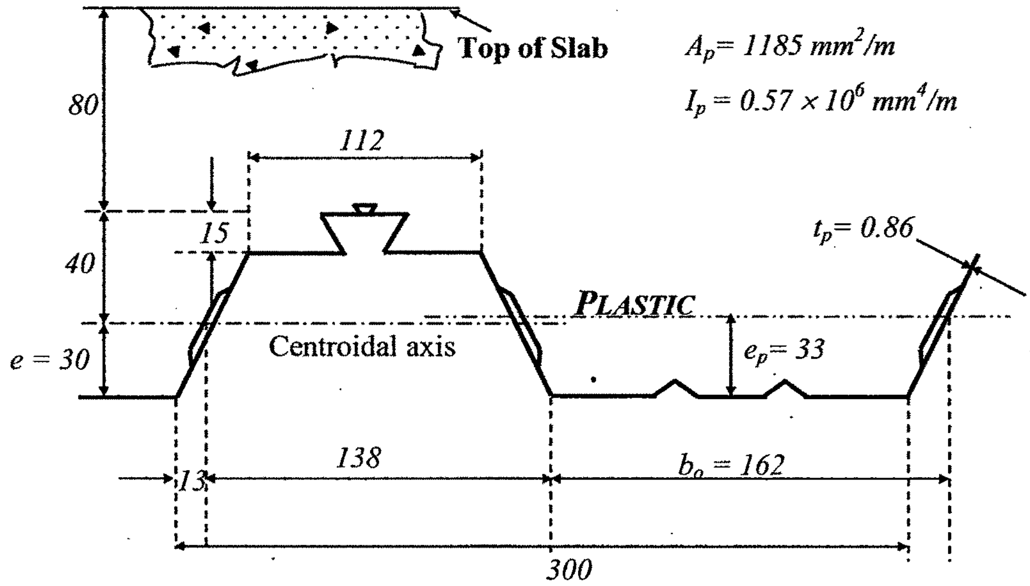

Fig. 4.11 Cross Section of Composite Slab

Decking Sheet Data: (As per manufacturer's tables)

Yield strength of steel,	f_{yp}	= 280 N/mm^2
Design thickness, allowing for zinc,	t_p	= 0.86 mm
Effective area of cross-section,	A_p	= 1185 mm^2/m
Moment of inertia,	I_p	= 0.57 * 106 mm^4/m.
Plastic moment of resistance	M_{pa}	= 4.92 kN-m/m
Distance of centroid above base	e	= 30 mm
Distance of plastic neutral axis above base,	e_p	= 33 mm
Resistance to vertical shear,	V_{pa}	= 49.2 kN/m
For resistance to longitudinal shear,	m	= 184 N/mm^2, k = 0.0530 N/mm^2
Modulus of elasticity of steel,	E_a	= 2.0 * 10^5 N/mm^2

Load Data:

Type of Load	Load Intensity (kN/m^2)	Factored load (kN/m^2)
Imposed load	4.5	4.50 * 1.50 = 6.75
Dead load of slab	2.41	2.41 * 1.35 = 3.25
Construction load	1.5	1.50 * 1.50 = 2.25

Profiled steel sheeting as shuttering:

Effective length of the span: The profiled deck sheet is propped at the centre as shown in **Fig. 4.12**. Assume the top flanges of the supporting steel beams are at least 0.15 m wide and the width of the prop is neglected.

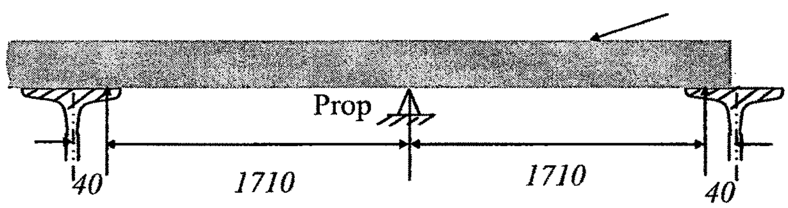

Fig. 4.12 Profiled sheeting During Construction

The effective length of each of the two spans is given by:

$$l_e = \frac{l - B + d_{ap}}{2} = \frac{3500 - 150 + 70}{2} = 1710$$

The depth of the sheeting is 70 mm.

Factored moments and vertical shears: Assume end supports are unrestrained.

Moments:

$$Sagging\ Moment = \left(\frac{W_{u,DL}}{12} + \frac{w_{u,LL}}{10}\right) l_e^{\,2} = \left(\frac{3.25}{12} + \frac{2.25}{10}\right)(1.71^2)$$

= 1.45 kNm/m

$$Hogging\ Moment = \left(\frac{W_{u.DL}}{10} + \frac{w_{u.LL}}{9}\right) l_e^{\,2} = \left(\frac{3.25}{10} + \frac{2.25}{9}\right)(1.71^2)$$

= 1.68 kNm/m

Vertical Shear:

$$Shear\ force\ at\ A = (0.5w_{u.DL} + 0.5w_{u.LL})l_e = (0.5 \times 3.25 + 0.5 \times 2.25)(1.71)$$

= 4.7 kN/m

$$Shear\ force\ at\ B = (0.6w_{u.DL} + 0.6w_{u.LL})l_e = (0.6 \times 3.25 + 0.6 \times 2.25)(1.71)$$

= 5.64 kN/m

Check for moment:

Design Moment = M_{pa}/γ_{ap}= 4.92/1.15 = 4.27 kN-m/m > 1.68 kN-m/m

Hence, the profiled deck is safe in flexure at construction stage.

Check for shear:

Vertical shear rarely governs design of profiled sheeting.

Design Shear = V_{pa}/γ_{ap}= 49.2/1.15 = 42.8 kN-m/m > 5.64 kN-m/m

Design shear is more than actual vertical shear, hence OK.

Check for deflection:

Design load at construction stage(Assuming prop does not deflect) = 2.41 + 1.5 = 3.91 kN/m^2

The maximum deflection in span AB, if BC is unloaded, is

$$\delta_{max} = \frac{wl_e^4}{185E_a I_p} = \frac{3.91 \times 1.71^4}{185 \times 0.20 \times 0.57} = 1.6mm$$

This is less than span/1068, which is very low.

Composite Slab:

Effective span: [Propping is removed]

Distance between centre of supports = 3.5 m

Clear distance between the supports + effective depth of the slab

= (3.5 – 0.15) + 0.12 = 3.47 m

Hence, effective length = 3.47 m

Flexure and vertical shear:

The design ultimate loading = $(w_{u,DL} + w_{u,IL})$ = 3.25 + 6.75 = 10.0 kN/m^2

Mid-span bending moment is

M_{sd} = 10.0 * (3.47)^2/8 = 15.1 kN-m/m

For vertical shear consider effective span as 3.5 m.

Then, vertical shear at supports is

V_{sd} = (3.5 * 1.0 * 10.0)/2 = 17.5 kN/m

Check for moment:

For the bending resistance,

$$N_{cf} = \frac{A_p f_{up}}{\gamma_{ap}} = 1185 \times \frac{0.28}{1.15} = 289\ kN/m$$

Design compressive strength of the concrete =0.36 * 20 = 7.2 N/mm^2

So, from equation (2) of a previous chapter, the depth of the stress block is

$$x = \frac{N_{cf}}{b(f_{ck})} = \frac{289}{1 \times 7.2} = 40.1\ mm$$

This is less than h_c.

$M_{p.Rd}$ = 289 (0.12 - 0.017) = 29.8 kN m/m > 15.1 kN m/m

Hence, the bending resistance is sufficient

Check for vertical shear:

b_o = 162 mm, b = 300 mm, d_p = 120 mm.

The area A_p is

$A_p = 0.86\,(162 - 26 + 66) = 174\ \text{mm}^2$,

$$\rho = \frac{A_p}{b_0 d_p} = \frac{174}{162 \times 120} = 0.09$$

and $k_v = 1.62 - 0.12 = 1.48m$

The basic shear strength is $\tau_{Rd} = 0.30\ \text{N/mm}^2$,

$$V_{v,Rd} = \frac{162}{300} \times 120 \times 0.3 \times 1.48(1.2 + 36) = 45\ kN/m$$

$V_{v.Rd} > V_{sd,}$ hence composite slab is OK in shear.

Check for longitudinal shear:

Longitudinal shear is checked by 'm-k' method.

B = 1.0 m

m = 184 N/mm^2

d_p = 120 mm

k = 0.0530 N/mm^2

A_p = 1185 mm^2/m

γ_{vs} = 1.25

ℓ_s =ℓ/4 =3470/4 = 867 mm.

The m-k method gives the vertical shear resistance as

$$V_{i.Rd} = bd_p \frac{\left(\frac{mA_p}{bl_s}\right)}{\gamma_{vs}} = (1000)(120)\frac{\left[\frac{184 \times 1185}{1000 \times 867} + 0.053\right]}{1.25} \times 10^{-3} = 29.2\ kN/m$$

Note that partial safety factor for shear studs is taken as 1.25.

Check for serviceability:

Cracking of concrete above supporting beams : The steel beams should be provided by reinforcement of area 0.4% of the area of concrete, since the floor is propped during construction. Hence, provide reinforcement of

A_s = (0.4/100) * 1000 * 80 = 320 mm^2/m.

Deflection : In calculation of deflection, effects due to the use of propped construction and the presence of the reinforcement of area, A_s, provided for cracking are neglected. Both effects reduce deflection.

Span/depth = 3470/120 = 28.9 < 32 (For end span)

Hence, there is no need for deflection check.

4.8 Program for Composite Slabs

4.8.1 General

Constant need for cost-effective structural forms has led to the increasing use of composite construction. However, complication in the analysis and design of composite structures, has led numerous researchers to develop simplified methods so as to eliminate a number of large scale tests needed for the design. Here details of a program developed in VB.NET for the analysis and design of composite slabs are given.

Normally, fabricators of steel sheeting provide engineers and builders with design tables for commonly used spans and thicknesses in order to facilitate the design of composite slabs. However, engineers need to justify their calculations. Acceptance of steel-concrete composite construction is dependent on availability of ready design, efficient code provisions and cultural congenial to steel intensive construction.

4.8.2 Screen Shots of The Program For Composite Slab

Here a program is developed for the design of composite steel concrete slab. Start-up screen and main form of the developed program are shown in **Fig. 4.13** and **Fig. 4.14** respectively. A form depicted in **Fig. 4.15** is included for selecting the manufacture's data for profiled sheet based on the test for different depth of profile sheet and also for entering user defined data in form given in **Fig. 4.16.** Also, a form is developed which gives choice to the user to provide concrete properties and partial safety factor for design as shown in **Fig. 4.17** and to provide different loading data as depicted in **Fig. 4.18.** Steel table is also attached with this form as shown in **Fig. 4.19**, so that the designer can choose from the available steel sections for the composite slab and thus their properties can be automatically used for design. Just with one click on the check button, one can apply the check for moment of resistance of section, shear and deflection as shown in **Figs. 4.20** and **4.21.** After that one can check the neutral axis position using form given in **Fig. 4.22.** Form for checking bending moment and shear for composite stage is shown in **Fig. 4.23.** Where as form for check for serviceability is shown in **Fig. 4.24.**

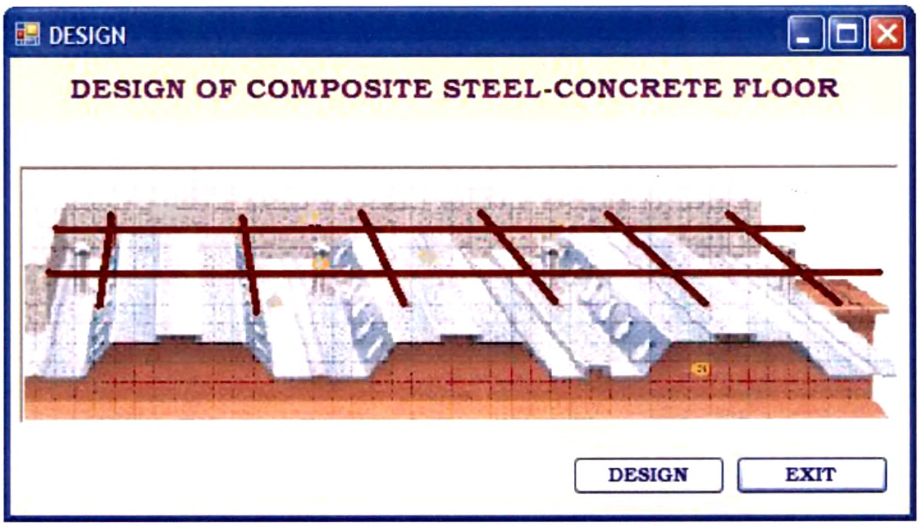

Fig. 4.13 Start Up Screen for Composite Floor

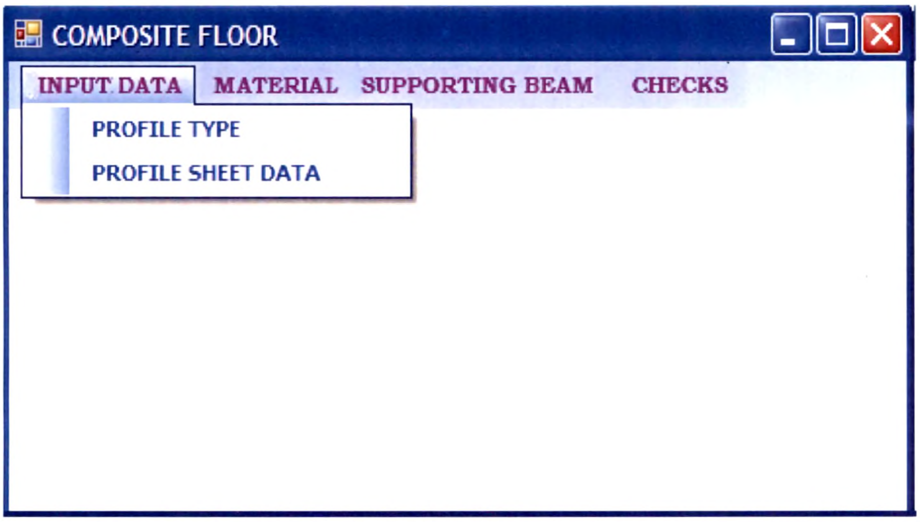

Fig. 4.14 Main Form for Composite Floor Design

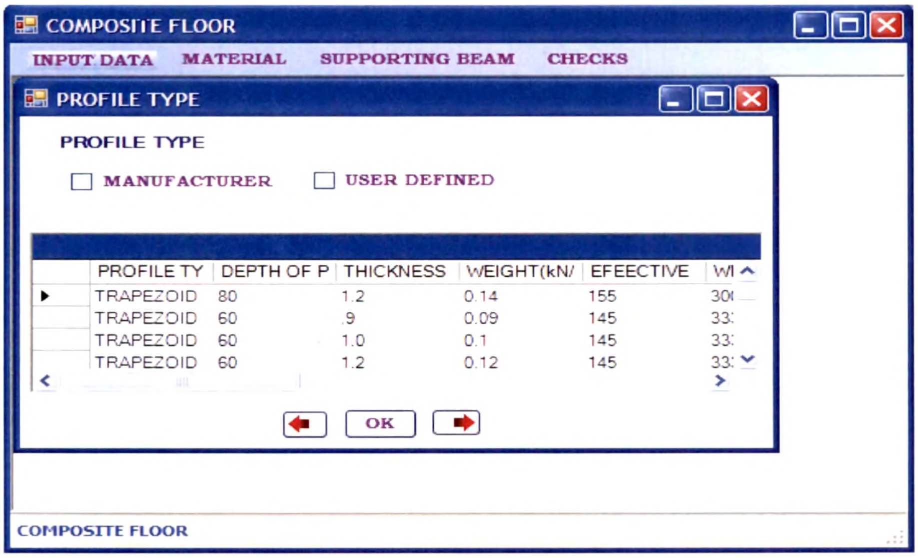

Fig. 4.15 Form for Selecting Data for Profiled Steel Sheet

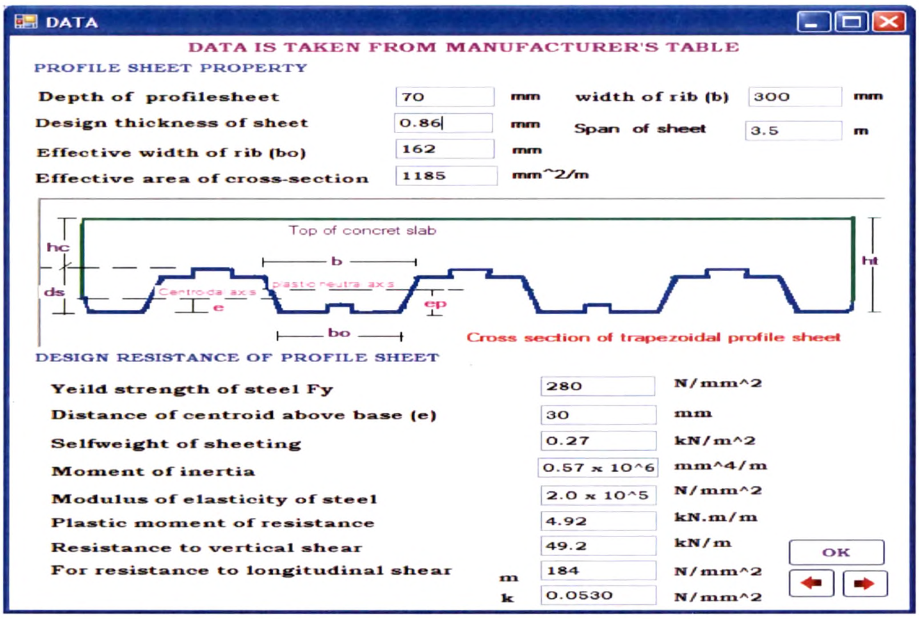

Fig. 4.16 Form for Entering the Data for Profiled Steel Sheet

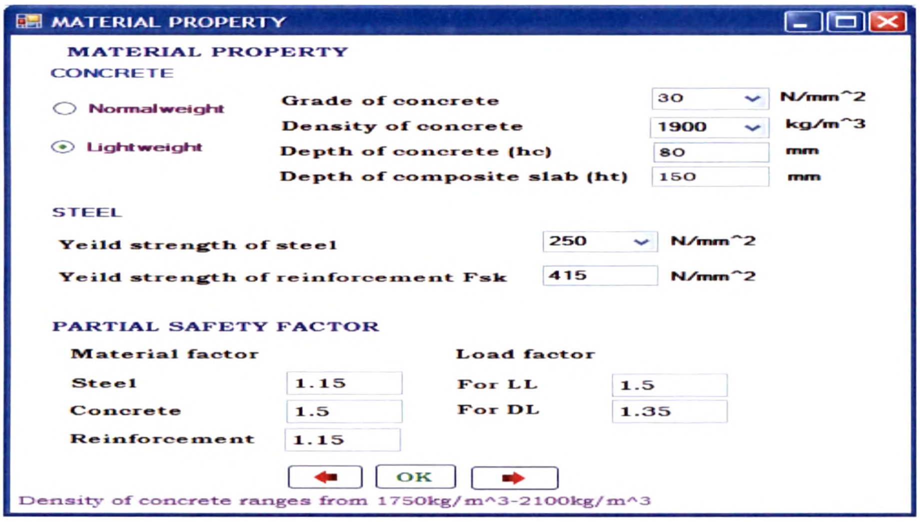

Fig. 4.17 Form for Entering the Material Property

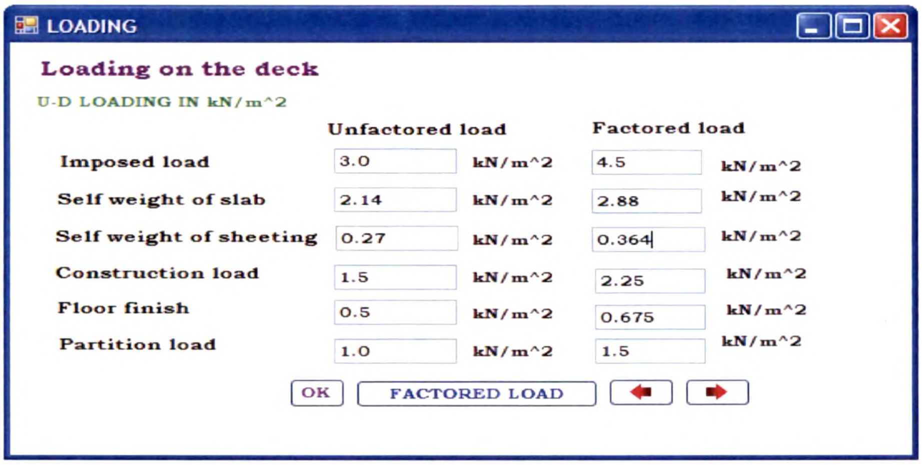

Fig. 4.18 Form for Calculating the Factored Load

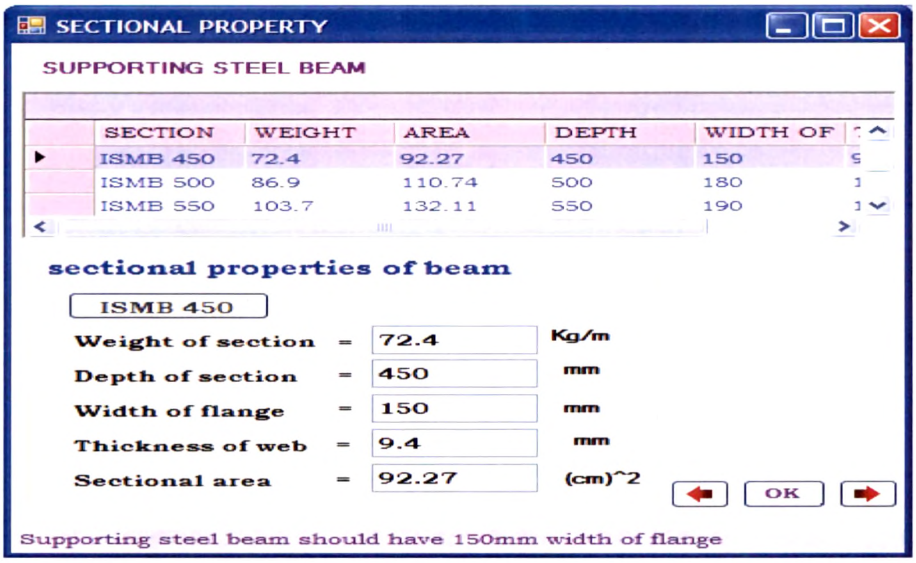

Fig. 4.19 Form for Sectional Property of Supporting Steel Beam

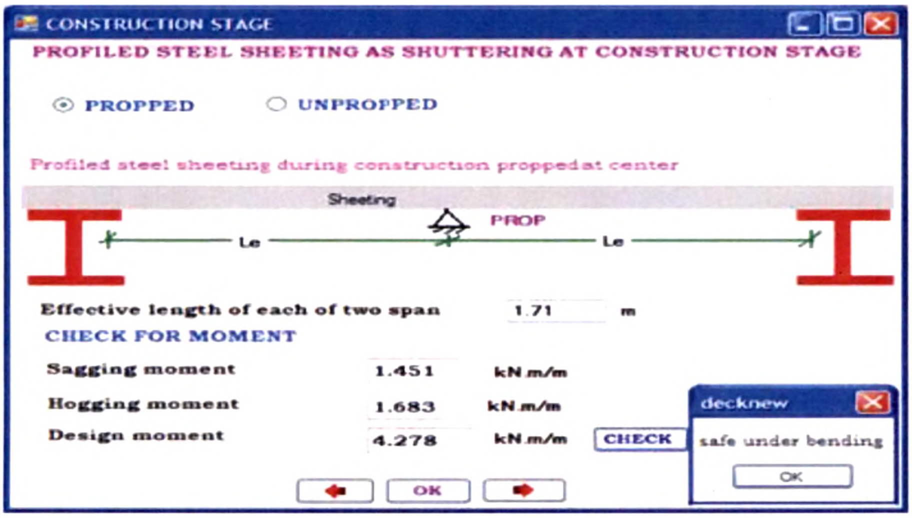

Fig. 4.20 Form for Bending Moment at Construction Stage

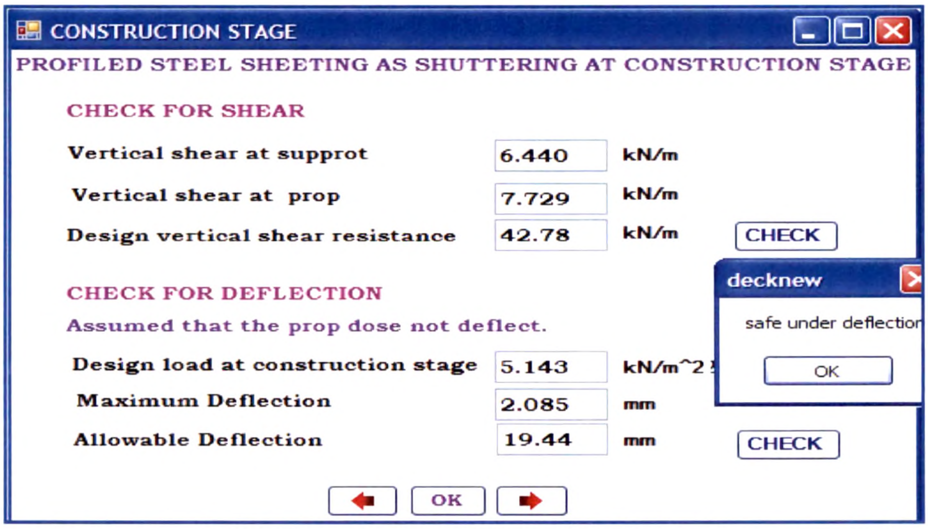

Fig. 4.21 Form for Shear & Deflection Check at Construction Stage

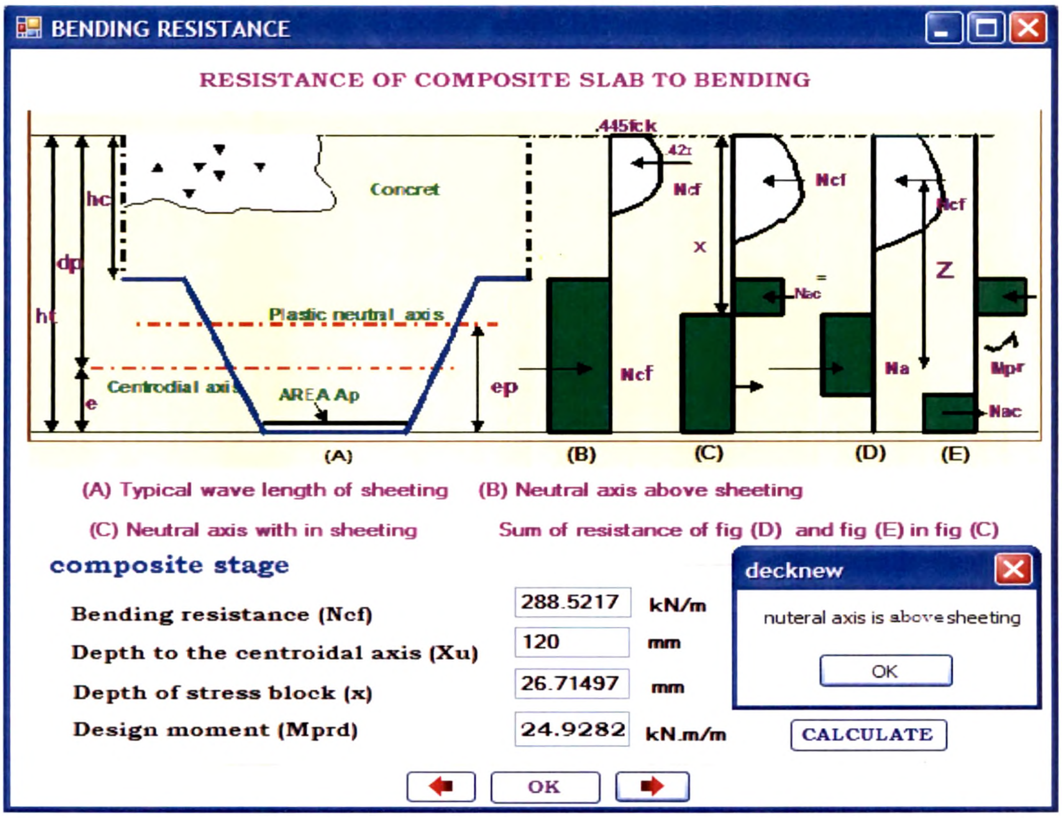

Fig. 4.22 Form for Shear & Deflection Calculation at Composite stage

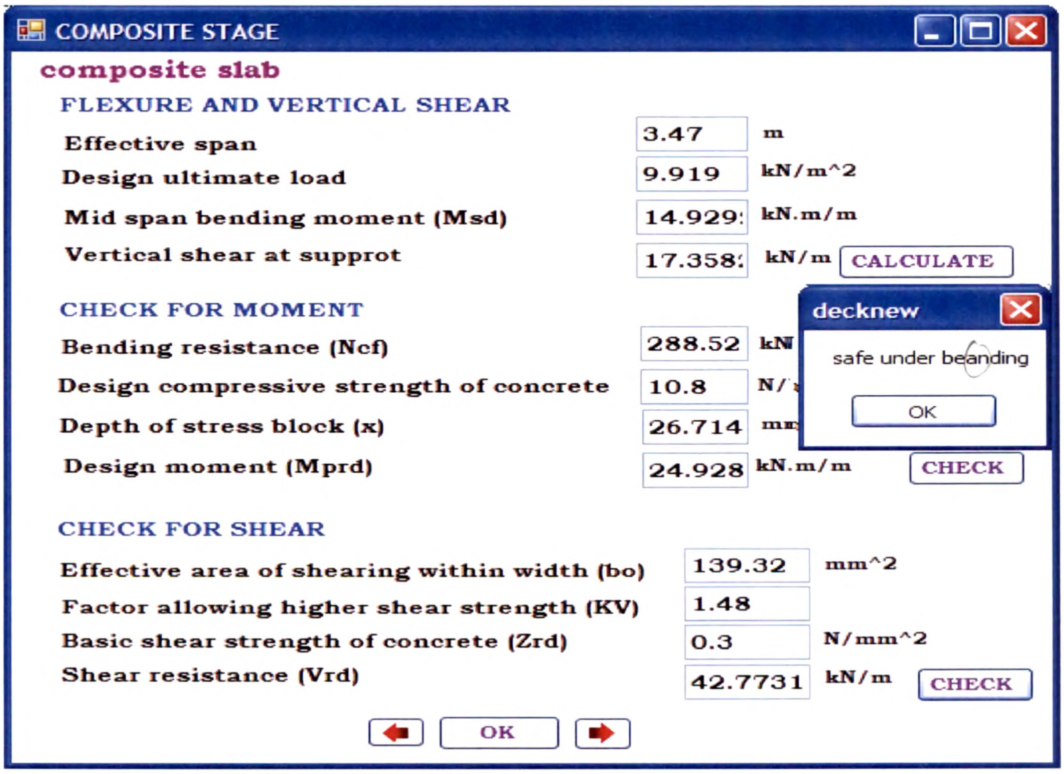

Fig. 4.23 Form for Shear & Moment Check at Composite Stage

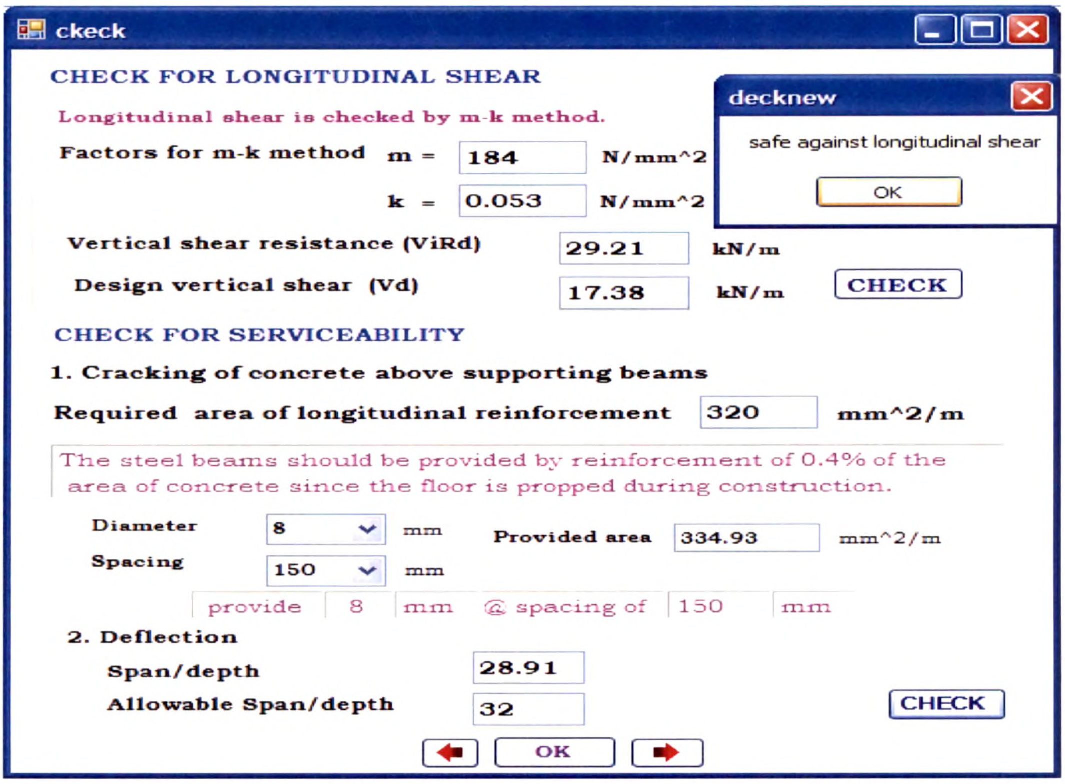

Fig. 4.24 Form for Check for Longitudinal Shear & Deflection