Design Principles and Examples for TRUEDEK®

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Design Capacity Examples

TRUEDEK140 Top Plate 2.4 mm, Base Plate 1.0mm, Web 0.7 mm.

Bending Capacity

From Table 1 (see Appendix) for the 1.0 mm Base pan we get the following results:

I_{bp} = 10904.6 mm^4
A_{bp} = 339.6 mm^2
y_{bp} = 6.36 mm

From Table 2 (see Appendix) for the 2.4 mm top plate we get the following results, as the 140 deep Truedek (D_t = 140 mm) utilises the 180 mm wide top plate:

I_{tp} = 7270.6 mm^4
A_{tp} = 499.2 mm^2
Y_{tp} = -2.48 mm

Consequently

$$y_t = \frac{499.2 \times (140 - 2.48) + 339.6 \times (6.36)}{499.2 + 339.6}$$

$$= 84.42 \text{ mm}$$

$$I_t = 7270.6 + 10904.6 + 499.2 \times (84.4 - 137.52)^2 + 339.6 \times (84.4 - 6.36)^2$$

$$= 3495031 \text{ mm}^4$$

Using equations (3) and (4) the section modulus are determined, the yields stresses are then utilised to derive the bending capacity with the lower value of the top plate and base pan being the governing design load.

$$Z_{tt} = \frac{3495031}{84.42} = 41400.5 \text{ mm}^3$$

$$Z_{tb} = \frac{3495031}{(140 - 84.42)} = 62882.9 \text{ mm}^3$$

The yield stress for the top plate (σ_{tp}) is 250 MPa and the yield stress of the base pan (σ_{bp}) is 500 MPa. Consequently from Equation (6) the design capacity of the Truedek 140 as specified is:

Composite Design Principles

Design Bending Capacity

Similar to that of other composite decks, determination of the Ultimate Bending Capacity of the Truedek® under composite action assumes that the base place is fully effective as the tensile member, effectively replacing the bottom reinforcement . The contribution to strength of the webs in the composite behaviour is ignored. While the top plate may result in some contribution positive strength it is generally ignored. The following example utilise the provisions as outline in AS3600-2010 Concrete Structures Standard.

Composite Design Examples

200 mm Thick Slab with a TRUEDEK140

Slab Details

Truedek® Details – TrueDek140 - Top Plate 2.4 mm, Base Plate 0.9mm, Web 0.7 mm.
Concrete Details – Slab Depth (D_c) 200 mm, Concrete Strength (f_c') 32 MPa

Strength of Slab in Bending

The design for ultimate bending capacity assumes that the base plate is fully effective in tension and acts as the tensile reinforcement, as stated the material in the webs and the top plate are in this case ignored for bending strength.

It is assumed that the design is per unit with of slab, and is determined in accordance with AS3600-2009.

A_{st} = 305.6* x 1000 /250 = 1222.4 mm^2/m (*area of steel from Table 1)

Assuming the rectangular stress block and in accordance with AS3600-2009

$\alpha_2 = 0.85$, $\gamma = 0.826$, §8.1.3

$f_{ct}' = 2.04$ MPa, $f_{ct.f}' = 3.39$ MPa §3.1.1.3

$d_n = 29.9$ mm, $k_u = 0.15 < 0.36$ OK

The lever is determined using the depth of the slab minus the height of the centroid of the base plate from Table 1 and the depth to the centre of the stress block.

$z = 200 - 6.4 - \gamma \times 29.9/2 = 181.3$ mm

$\phi M_u = \phi \times T \times z = 0.64 \times 672320 \times 181.3 = 78.0$ kNm/m

Minimum strength requirements

$A_{st.min} = 153.3$ mm^2/m, $(M_{uo})_{min} = 27.1$ kNm/m §8.1.6

Strength of Slab in shear

The ultimate shear strength is determined in accordance with AS 3600-2009. Again it is assumed that the Truedek® webs do not contribute to the shear strength under composite action and that the shear is carried by the slab.

$$\phi V_u = \phi \times \beta_1 \times \beta_2 \times \beta_3 \times b_v \times b_o \times f'_{cv} \times \left(\frac{A_{st}}{b_v \times b_o}\right)^{1/3} \qquad \S 8.1.6$$

$\beta_1 = 1.55$; $\beta_2 = 1.0$; $\beta_3 = 1.0$; $f_{cv} = 3.17$

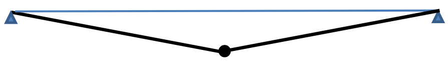
$\phi V_u = 123.1$ kN/m

Slab Fire Principles

General Principles

For fire design the slab is required to have sufficient capacity for both thermal insulation and structural integrity. The design moments under fire conditions can be determined in accordance with AS 3600-2009 and are generally lower than the ultimate conditions. To maintain the structural integrity of the system the design must avoid the formation plastic moments in the structure that create collapse mechanisms.

- As an example for a single span slab system a collapse mechanism forms when a plastic moment at mid span due to no restraints at the supports.



Single Span Mechanism

- However for a two span system a collapse mechanism requires a number of plastic moments to form, for an isotropic beam these will from within the span and at the support location as shown below. For this example at a given load a plastic hinge first forms at the support, at this point there is no mechanism. With continued loading a second plastic hinge forms within the span and a mechanism occurs, this load at which the mechanism forms is deemed to be the capacity of the system.

no mechanism *mechanism*

Double Span

Potential Critical Cross-sections

To enable the fire design the Potential Critical Cross-sections (PCC's) of the slabs need to be identified, and the capacities between each of these PCC's determined, then establish if the capacities are exceeded. Factors that define a potential critical cross section include:

- Change in positive reinforcement
- Change in negative reinforcement

- Change in slab thickness

For each Potential Critical Cross-section the positive and negative moments should be determined and compared with the relevant design actions at each point to ensure that the capacities are not exceeded.

TrueDek® Fire Design

It is assumed that under the fire condition the base plate of the Truedek provides no contribution to the structural integrity to positive (sagging) moments as there is no insulation from elevated temperatures. The web steel and top plate are also generally ignored although through a detailed cross-sectional analysis these components may enable the utilisation of this steel as reinforcement if temperature effects on the strength are considerd.

The reinforcement in the negative region is considered to have sufficient concrete cover and assuming the slab is continuous through the Truedek®, then the full slab negative capacity may be developed.

Single Span

For a single span Truedek® slab to achieve a structural integrity and prevent a plastic moment forming within the span reinforcement is required to be placed between the decking as a minimum distance as prescribed by AS3600, This reinforcement can then be utilised for fire reinforcement.

Multiple Spans

For a multiple span Truedek® slabs the negative regions will have significant steels for the ultimate conditions, this steel and the inherent negative capacity may be utilised to achieve a structural integrity with plastic hinges forming with in the spans and redistribution of the loading such that a plastic mechanism does not form.

Fire Design Examples

220 mm Thick Slab with a TRUEDEK140

Slab Details

True Deck Details – TrueDek140 - Top Plate 2.4 mm, Base Plate 0.9mm, Web 0.7 mm.
Multiple span 4200 mm between supports, N12@250 effective to 1300 mm into span.
Positive fire reinforcement is N10@500, 55 mm from the soffit over the full span.
Concrete Details – Slab Depth (D_c) 230 mm, Concrete Strength (f_c') 32 MPa

Moment Capacities

Assume that the cover to the negative reinforcement is 20 mm the negative capacity is

$$\phi M_u = 28.9 \text{kNm/m}$$

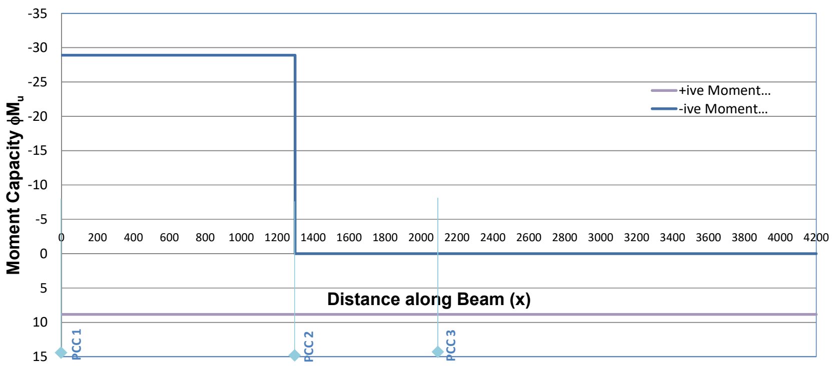
Based on the 45mm cover to the positive reinforcement the positive capacity is

$$\phi M_u = 8.8 \text{kNm/m}$$

The potential critical cross sections are identified as follows:

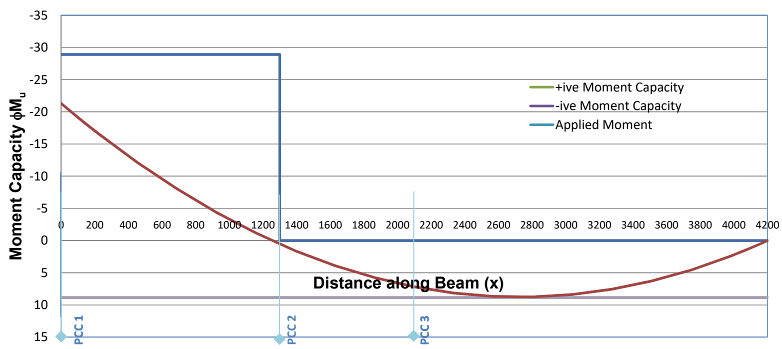
i. PCC1 - Support highest moment for end span Point (x=0)
ii. PCC2 - Curtailment of reinforcement (x=1300)
iii. PCC3 - Mid-span highest positive moment (x=2100)

As the reinforcement is dement fully effective from 1300mm then a potential critical cross sections is identified at support at x = 1300 mm where for simplicity ϕM_u^- changes from 28.9 to 0 kNm/m as a result of the reinforcement terminating. With the prescrbed fire reinforcement ignoring the TrueDek® the positive capacity ϕM_u^+ is determined as 8.8 kNmm/m across the full span. The moment capacities both positive and negative along the beam as shown in the following chart.



The factored fire design loading for the example including all dead and live load was determined as 8.1 kNm /m, for a two span beam this results in a negative design moment of M^{-*} = 17.9 kNm/m and a positive moment M^{+*} = 10.0 kNm/m.

Based on these design moments and the calculated capacities a plastic hinge will form with in the span ($M^* > \phi M_u^+$) between the mid-span and the pinned end. Once the plastic hinge is formed the actions are redistributed to negative regions as shown in the figure below, with the support moment increasing to 21.3kNm/m.



It should be noted that for this example if the potential critical cross-section, specified by the curtailment of the reinforcement was 1000 mm, a second hinge would form at this location resulting in plastic mechanism and a system with insufficient fire capacity.

Appendix A

Table 1 - Base Pan Stiffness's

Base Pan thickness (mm)	Centroid (y_{bp}) (mm)	Area (A_{bp}) (mm^2)	Stiffness (I_{bp}) (mm^4)
1.0	6.36	339.6	10904.6
0.9	6.36	305.6	9811.8
0.75	6.36	254.7	8174.0

Table 2 –Top Plate Stiffness's (Top Plate width dependent on truss Height)

Base Pan thickness (mm)	***200 mm Top Plate***			***180 mm Top Plate***		
	Centroid (y_{tp}) (mm)	Area (A_{tp}) (mm^2)	Stiffness (I_{tp}) (mm^4)	Centroid (y_{tp}) (mm)	Area (A_{tp}) (mm^2)	Stiffness (I_{tp}) (mm^4)
2.4	-2.26	547.2	7561.9	-2.48	499.2	7270.6
1.9	-2.26	433.2	5937.8	-2.48	395.2	5714.0
1.6	-2.30	358.3	4944.8	-2.48	332.8	4794.5