LCP LYCORDECK®

Structural Steel Deck
Technical Manual
(Designed to Eurocode)

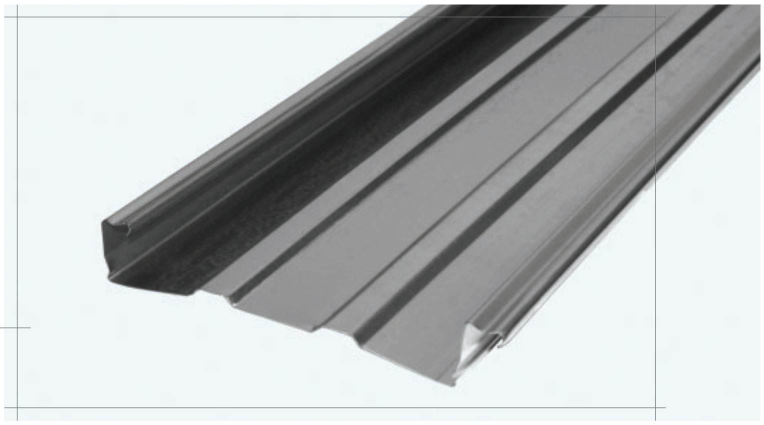
Integrity In Partnership

CERT NO. FM 59595
BS EN ISO 9001 : 2008

FEATURE

LCP LYCORDECK® (formerly known as CONDECK® HP) Steel Decking is designed to be used in composite slab construction and save reinforcing material and construction time.

All relevant and latest Eurocodes were used to ensure that **LCP LYCORDECK®** Steel Decking performs at the highest level in accordance with the latest Singapore and International requirements.



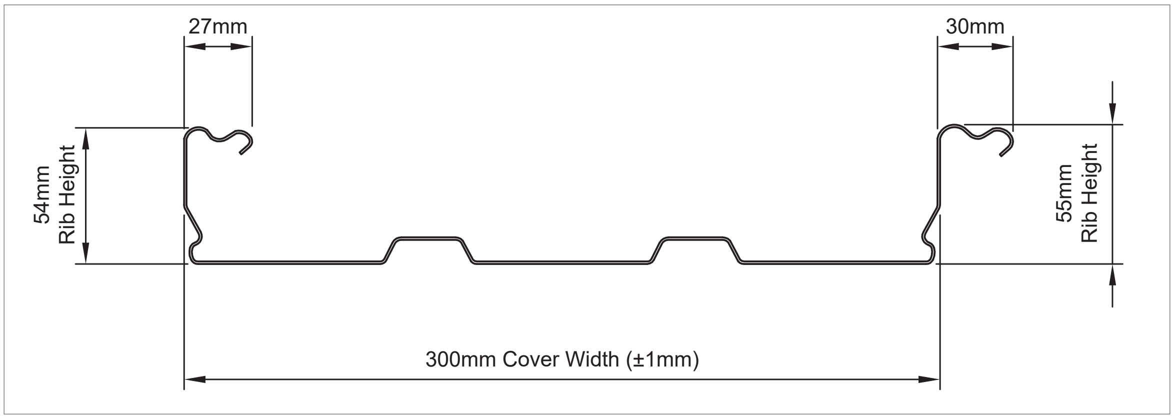
INTRODUCING UPDATED LCP LYCORDECK® STEEL DECKING

With a constant need to keep abreast of international standards meeting industry needs and building authority requirements, **LCPBP** engaged a local academic institution to conduct full-scale tests to ascertain that its design adheres to Eurocodes 1, 3 & 4. With this update, we launch the steel decking as **LCP LYCORDECK®** in line with our brand of building products trusted by many of our clients.

The steel decking will still retain the advantages derived from its unique characteristics, i.e. the closed rib profile, which sets it apart from its competitors.

LCP LYCORDECK® superior benefits:

- Superior span performance – for greater span capacity.
- Substantially reduced side lap fasteners – reduced installation time.
- Facility for ceiling system suspension – for quicker ceiling installation if required.
- Improved fire resistance periods – for even more cost effective slabs.



MATERIALS

LCP LYCORDECK® Steel Decking is a cold formed section manufactured from high strength galvanised steel in base thickness of 0.75mm, 1.00mm and 1.20mm. Steel product is G550 base material (550MPa minimum yield stress) for 0.75mm and 1.00mm Lycordeck Steel Decking and G500 base material for 1.20mm **LCP LYCORDECK®** Steel Decking, both with Z275 galvanised coating (275 grams per square meter minimum coating mass) in accordance with AS1397:1993.

LCP LYCORDECK®

PROPERTIES

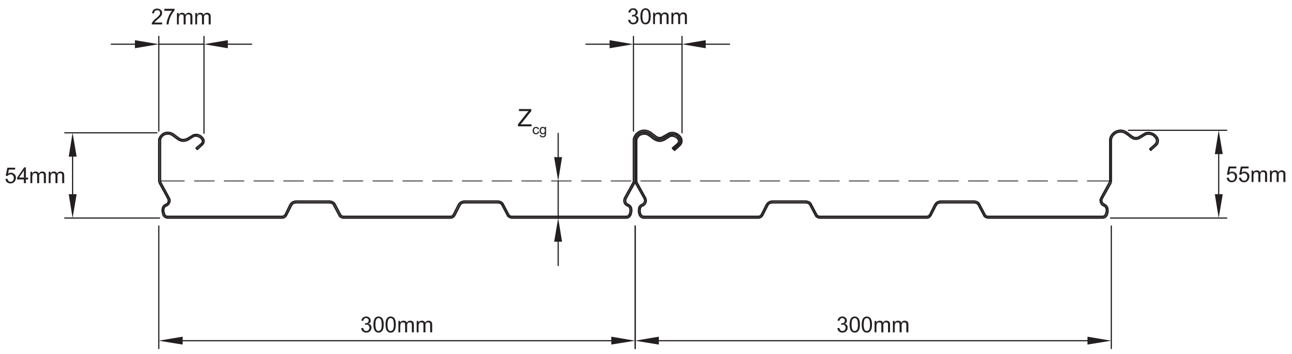
LCP LYCORDECK® - Mass/Thickness Table			
Thickness		Material Mass	
BMT (mm)	TCT (mm)	kg/m²	kg/m
0.75	0.78	10.1	3.0
1.00	1.03	13.2	4.0
1.20	1.23	15.8	4.8

Special request options:

1. 1.2mm Base Metal Thickness.
2. Heavier galvanised coatings.
3. Pre-painted coating to **LCP LYCORDECK®** ceiling and soffit.

Please contact **LCPBP** for Technical Specification.

SECTION PROPERTIES



Section Properties (per metre width) SS EN 1993-1-3

BMT	Mass	Gross Section Properties					Stiffness for deflection calculation		f_{yb}	Moment resistance		Shear resistance	Local transverse resistance
		Area	Z_{cg}	I	$W_{g,bot}$	$W_{g,top}$	I_{single}	I_{cont}		$M^+_{c,Rd}$	$M^-_{c,Rd}$	$V_{b,Rd}$	‡ $R_{w,Rd}$
mm	kg/m²	mm²	mm	$x10^3mm^4$	$x10^3mm^3$	$x10^3mm^3$	$x10^3mm^4$	$x10^3mm^4$	MPa	kNm	kNm	kN	kN
0.75	10.1	1215	15.6	484	31.0	12.3	428	318	550	4.9	6.8	55.9	49.5
1.00	13.2	1620	15.7	636	40.6	16.1	595	487	550	8.0	9.0	99.3	80.1
1.20	15.8	1944	15.7	755	48.2	19.2	722	621	500	9.4	9.8	123	103

Z_{cg} - Distance from base of rib to centre of gravity of panel
I - Second moment of area of section
I_{single} - Second moment of area for computing rib deflection of single spans
I_{cont} - Second moment of area for computing rib deflection of continuous spans

M_p - Ultimate moment capacity of positive moment regions
M_n - Ultimate moment capacity of negative moment regions
$V_{b,Rd}$ - Ultimate shear capacity
$R_{w,Rd}$ - Ultimate web crushing resistance

‡ Based on 200mm stiffener support bearing.

UNPROPPED SPAN TABLE

Designers can use this table to determine the required unpropped span.
Please note, the slab will still need to be checked for composite design and if necessary fire resistance design.

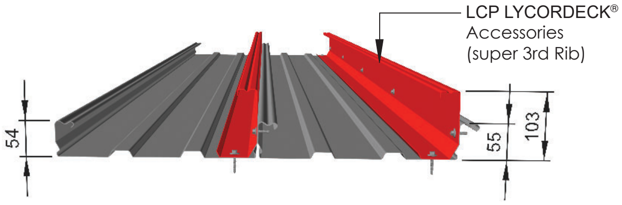
LCP LYCORDECK® Unpropped Formwork Span (mm)

Slab Thickness (mm)	0.75 mm BMT			1.0 mm BMT			1.2 mm BMT		
	Single Span	Double Span	Triple Span	Single Span	Double Span	Triple Span	Single Span	Double Span	Triple Span
100	2640	3050	2940	2920	3620	3360	3100	3830	3620
105	2600	3000	2900	2880	3560	3320	3060	3780	3570
110	2570	2950	2870	2850	3500	3280	3020	3720	3530
115	2540	2900	2830	2810	3460	3240	3000	3670	3490
120	2510	2850	2800	2780	3400	3200	2950	3620	3450
125	2480	2800	2770	2750	3350	3170	2920	3580	3410
130	2450	2760	2740	2720	3300	3130	2890	3530	3380
135	2430	2720	2700	2690	3260	3100	2860	3480	3350
150	2350	2600	2630	2610	3130	3010	2770	3350	3250
175	2250	2430	2510	2500	2940	2880	2650	3150	3110
200	2160	2280	2410	2400	2780	2770	2550	2980	2990
225	2080	2160	2330	2320	2640	2670	2460	2830	2890
250	1990	2040	2250	2240	2500	2590	2390	2700	2800
275	1910	1940	2160	2180	2400	2520	2320	2580	2720
300	1840	1850	2060	2120	2290	2450	2260	2480	2650

Note: Concrete density adopted is 2500kg/m^2, the spanning capacity can be enhanced by adopting **LCP LYCORDECK®** 3rd Rib accessory, consult **LCPBP** Technical Department. Values are rounded down to the nearest 10mm.

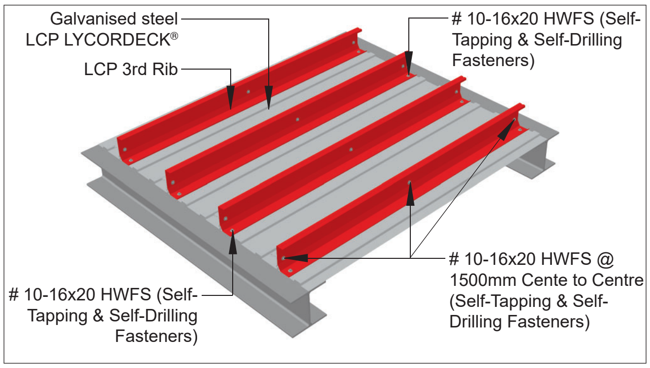
3RD RIB ENHANCED SPANNING

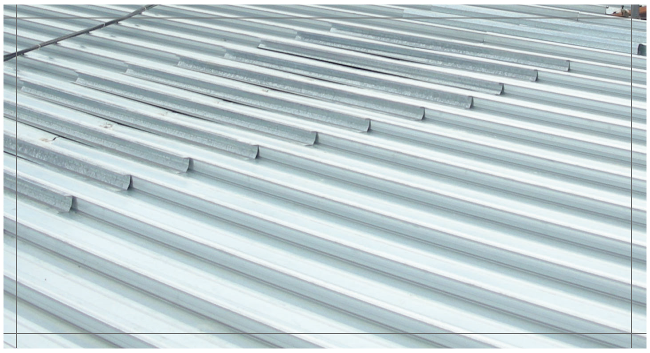
The exclusive **LCP LYCORDECK®** 3rd Rib accessory, developed by **LCPBP**, is fastened along the side of the end span ribs to significantly reduce end span deflection under wet concrete. This effectively eliminates the design limits imposed by end spans. **LCP LYCORDECK®** 3rd Rib accessory can be used to increase unpropped end spans.



LCP LYCORDECK® 3rd Rib accessory increases the spanning performance of **LCP LYCORDECK®** composite decking in several ways.

Besides reducing lateral rib distortion and tray deflection, it increases the stiffness of the composite slab and increases the deck spans. With greater deck span, there is a reduction in the amount of propping required. This accessory is simple to install and is only required on decking end spans. Please consult LCP Technical Department.





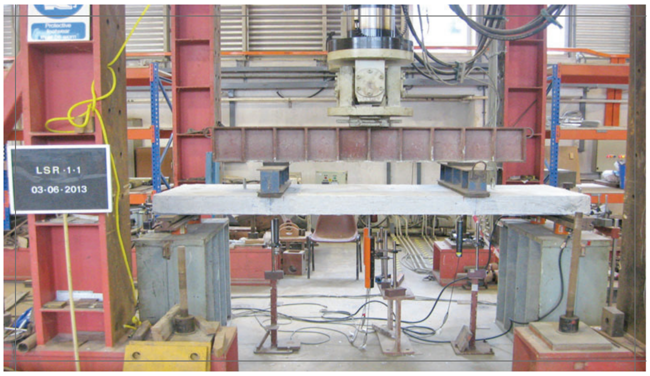
TESTING PROGRAMME

Design data for **LCP LYCORDECK®** composite decking is based on thorough testing of performance in formwork, composite and fire design modes.

Full-scale and pilot tests were carried out by the School of Civil and Environmental Engineering (CEE), Nanyang Technological University (NTU) and Building Research Association of New Zealand (BRANZ).

The tests conducted on **LCP LYCORDECK®** with reference to Eurocode 4 include:

- ▶ Shear and bending resistance of **LCP LYCORDECK®** at ambient temperature.
- ▶ An experimental study of heat transfer through **LCP LYCORDECK®** composite slabs to evaluate temperature distributions across the thickness of the slab.
- ▶ **LCP LYCORDECK®** composite slab under loading in fire situation.



EC3 & BS LOADING COMPARISON

Construction Stage	**EUROCODE**	**BRITISH STANDARD**
Construction load	Working personnel with small site equipment, Q_{ca}:$q_{ca,k}$ = 0.75 kN/m^2 [Considered in Actions (1) and (2)] Weight of fresh concrete for design thickness, Q_{cf}: $q_{cf,k}$ = project requirements [Considered in Actions (2) and (3)] {Refer to **SS EN-1991-1-6:2009, 4.11.2, Table 4.2** for definition of Actions}	1.5 kN/m^2 [Spans ≥ 3m] 4.5/span kN/m^2 [Spans < 3m] {Refer to **BS5950: Part 4: 1994**}
Partial Safety Factor	Permanent: 1.35 Variable: 1.5 {Refer to **SS EN-1990:2008**}	Dead load: 1.4 Construction load: 1.6 {Refer to **BS5950: Part 4: 1994**}
Composite Stage	**EUROCODE**	**BRITISH STANDARD**
Partial safety factors for reinforcing steel		
Persistent & Transient design situation	y_s=1.15 {Refer to **SS EN 1992-1-1:2004**}	y_m=1.05 {Refer to **BS8110: Part 1: 1997**}

KEY ADVANTAGES AT DIFFERENT STAGES

Construction stage

- Ease of installation
- Labour savings during installation
- Time savings during installation
- No need for rib-end closures

Composite stage

- Reduced steel reinforcement
- Resistance to deflection
- Flexible placement of shear studs
- Maintains sound and vibration insulation

Fire Emergency stage

- Embedded ribs act as Fire Emergency Reinforcement (F.E.R.)
- Unrestricted placement of fire reinforcement

ADVANTAGES IN CONSTRUCTION STAGE

Ease of installation

The 300mm sheet width of **LCP LYCORDECK®** composite decking makes it easy to carry, simple to cut and trim and easier to fit to the floor layout with minimal wastage. Its light weight allows two people to carry long continuous lengths. Once in place the wide pan is easy and safe to walk in.

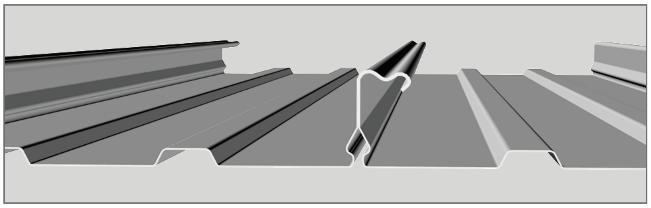
Labour savings

LCP LYCORDECK® decking requires no timber formworks and can be installed by semi-skilled labour under supervision. The wide trays allow easy installation of penetrations.

Time savings

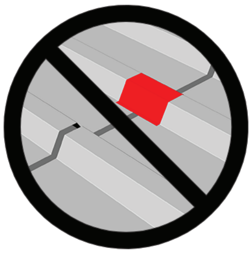
The characteristic sheet interlocking of **LCP LYCORDECK®** composite decking ensures quick and cost-effective installation. Side lap fasteners are often not required to connect the interlocking sheets.

Fastening to attach the sheet to the structure is minimal.



No need for rib-end closures

The closed ribs of the **LCP LYCORDECK®** does not require rib end closures or taping of joints therefore lowering installation time and costs.



ADVANTAGES IN COMPOSITE STAGE

Reduced steel reinforcement

Generally, conventional positive reinforcement is not required. **LCP LYCORDECK®** composite decking acts as positive reinforcement to optimize strength and control composite slab deflection.
Negative reinforcement may be reduced in many continuous slabs by applying partial shear connection strength factor to take account of moment redistribution.

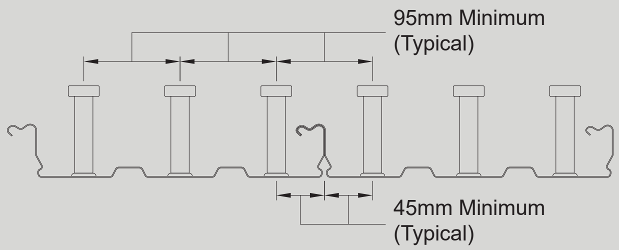
Resistance to deflection

Deflection of completed composite slab is often the governing design criterion. **LCP LYCORDECK®** composite decking has excellent resistance to deflection due to its ribs being fully enclosed in the concrete slab. The ribs are embedded in the slab to provide maximum stiffness.

Flexible placement of shear studs

There are effectively no restrictions on the placement of shear studs with **LCP LYCORDECK®** composite slab. Therefore, flexibility in beam design provide engineers with the opportunity to reduce the size of I-beams by up to 20%.

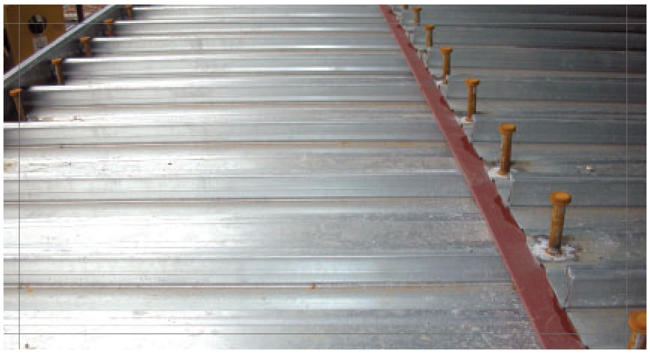
Design virtually any stud configuration with 100mm, 200mm or 300mm centres.



10 stud/metre (single row) - nominal 100mm spacing

Maintains sound and vibration insulation

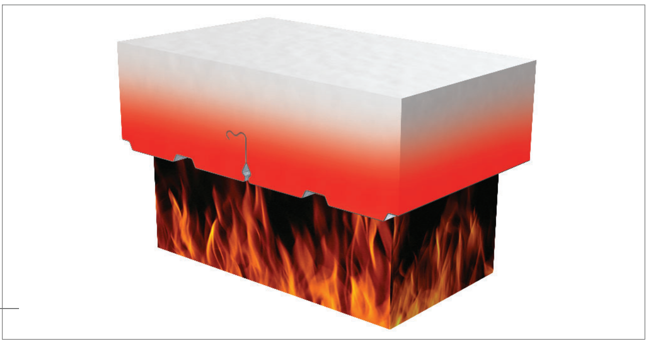
The **LCP LYCORDECK®** composite slab does not compromise on sound insulation and vibration as it is similar to a solid slab with the ribs being completely encased in concrete with no voids in between.



ADVANTAGES IN FIRE EMERGENCY STAGE

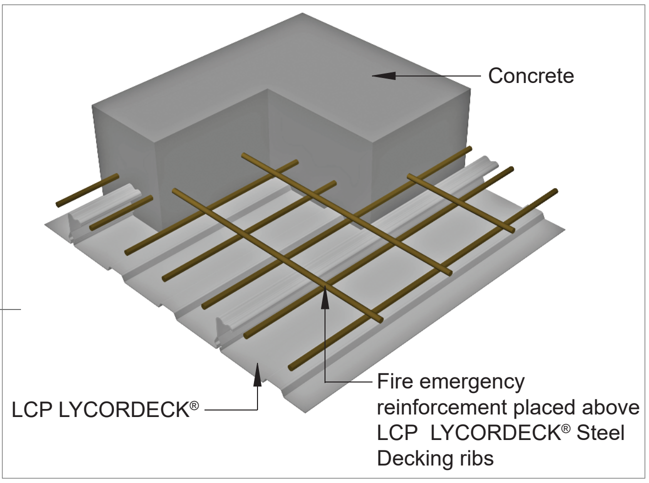
Embedded ribs act as Fire Emergency Reinforcement (F.E.R.)

LCP LYCORDECK® composite decking has all its profile ribs embedded in finished concrete slab giving thermal insulation comparable to a solid slab.
Compared with trapezoidal and re-entrant decks, there are no gaps at the soffit of the slab for heat to penetrate. This allows the ribs to remain cool and act as FER.
Based on the simplified FER design method for **LCP LYCORDECK®** composite decking, minimal or even no additional reinforcement may be required.



Unrestricted Placement of F.E.R.

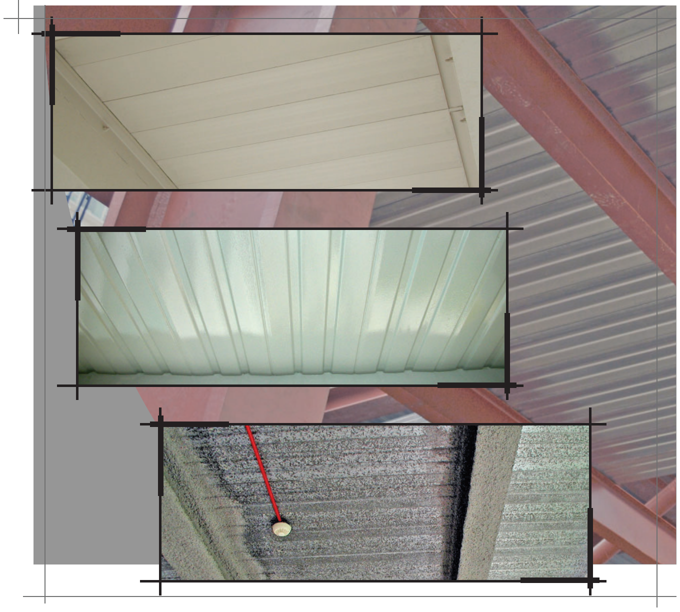
Since the ribs of **LCP LYCORDECK®** are embedded in the concrete, F.E.R. may be placed anywhere above the ribs, unlike trapezoidal or re-entrant decks where F.E.R. placement is limited.



OTHER ADVANTAGES

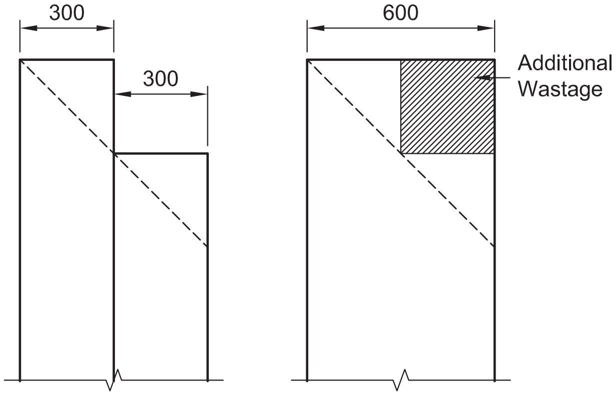
Flat Base

The flat base of **LCP LYCORDECK®** is aesthetically pleasing and if required, painting **LCP LYCORDECK®** soffit is straightforward. Pre-coated colour finish underside is available. Please check LCP Building Products Pte. Ltd. Sales Department.



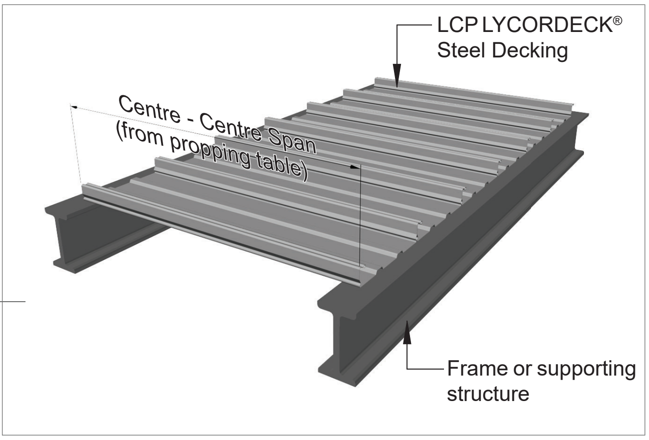
Skew Cut Savings

The wastage from skew cutting of 300mm cover width **LCP LYCORDECK®** is reduced as compared to skew cutting a 600mm cover width decking sheet.

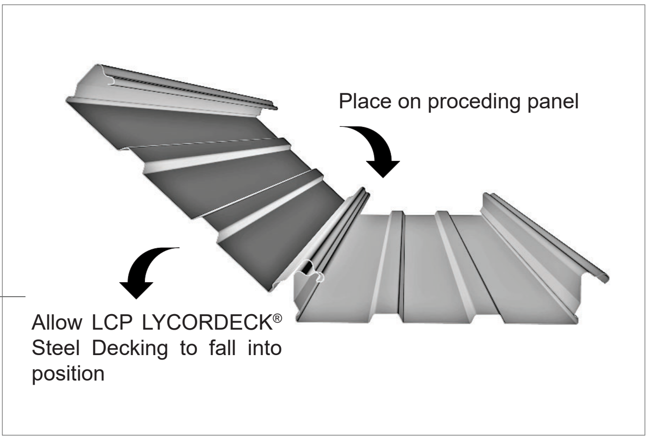


INSTALLATION PROCEDURES

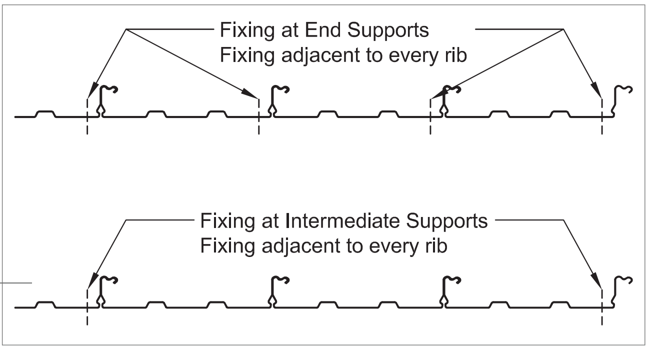
1 **LCP LYCORDECK®** is usually designed to support weight of wet concrete plus a temporary construction load without propping. However, if temporary props are required, the temporary continuous prop line must be able to carry the relevant loads.



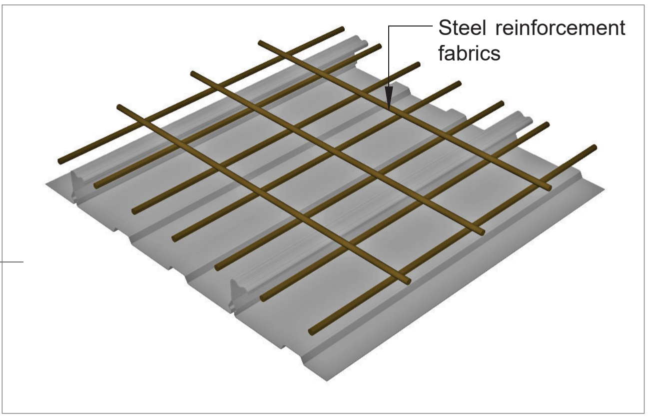
2 Place the first **LCP LYCORDECK®** panel with the narrower male rib facing direction of laying. Align this panel over the supports ensuring a minimum overhang or end bearing of 50mm.



3 Panel should be secured immediately in outdoor condition against wind uplift after placing over supports and before concrete casting. Fixing options are puddle weld, steel pins, screw or shear stud depend on the substrate. Heavy point loads during construction should be distributed by means of timber planking. Install side lap fasteners when required.

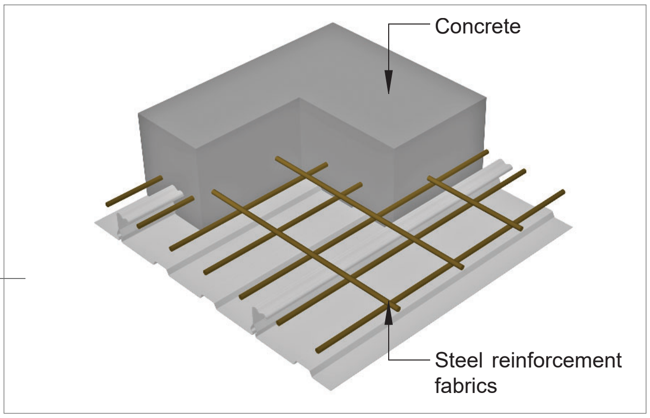


4 Place the shrinkage and temperature reinforcement (fabric) such that minimum cover (generally 20mm to 30mm cover from top of slab) is satisfied.

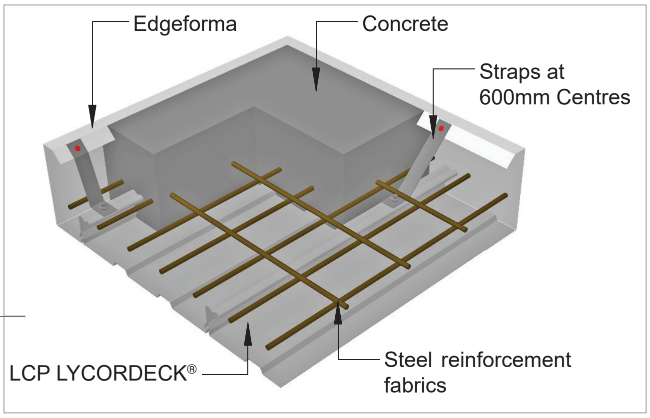


INSTALLATION PROCEDURES

5 The concrete must be poured evenly to the panel ends on the prepared clean deck, in the direction of span of the decking. Heaping of wet concrete must be avoided. Vibrator compaction is recommended.

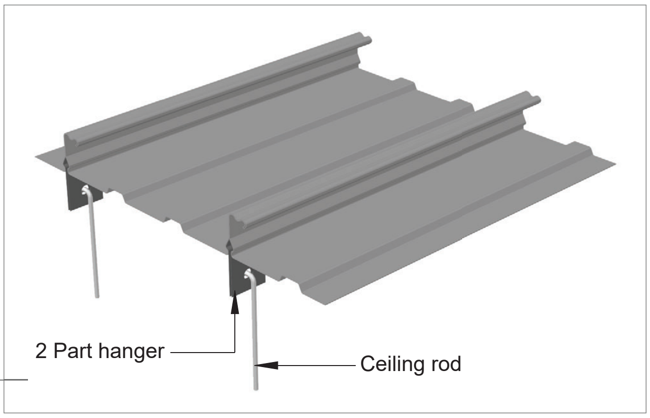


6 Edgeforma is a lightweight, easy to use edge form. Edgeforma is available in a range of heights to suit different slab depths. The top flange of the Edgeforma should be tied back to **LCP LYCORDECK®** steel decking ribs every 600mm with galvanised strapping using self-drilling fasteners. For unsupported deckings, edge fix Edgeforma at 300mm centres.



7 **LCP LYCORDECK®** steel decking has provision for suspended ceiling installation or support of building services. A two part bracket is simply inserted into the underside of any rib and held in place by the suspension rod. The ceiling hanger is capable of supporting a load of 2.5kN after the concrete is in place.

Note: Side lap fasteners, installed through the vertical web of the ribs - at no more than 500mm centers either side of the hanger, are required if ceiling hanger is loaded before the concrete pour. In this case, the maximum capacity of the hanger is reduced to 0.6kN.



Construction Stage Design Examples

BACKGROUND INFORMATION

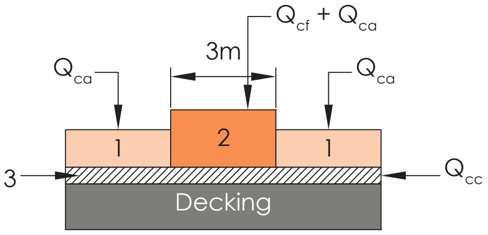
Slab thickness	120	mm	No propping required
Slab span	Double		
Thickness (BMT)	1	mm	
width of slab	1000	mm	
E (elastic modulus)	210	Gpa	
Length of Span	2.8	m	
Mass of decking	13.07	kg/m	
Density of wet concrete	2500	kg/m^3	
I (second moment of area)	0.487	$10^6 mm^4$	

Design load

Factored construction load (SS EN 1991-1-6, Clause 4.11.1(2), table 4.1&4.2).
Actions to be taken into account when concreting:

1. **Q_{ca}** Construction Load
(10% of concrete weight under 1m width slab or 0.75 whichever is higher.)
(10% of the concrete weight under 1m width slab = 0.46 kN/m)
factored Construction Load

$Q_{ca} = W_f = 1.125$ kN/m



2. **Q_{cc}** self-weight of decking
Unfactored self-weight of decking

$W_d = 0.128$ kN/m

Factored self-weight of decking

$Q_{cc} = W_{df} = 0.173$ kN/m

3. **Q_{cf}** weight of fresh concrete
Unfactored self-weight of wet concrete (without ponding effect)

$W_c = 2.943$ kN/m

Factored self-weight of wet concrete (without ponding effect)

$W_{cf} = 3.973$ kN/m

Unfactored self-weight of wet concrete (with ponding effect) (refer to deflection check below for more details)

$W_c' = 3.398$ kN/m

factored self-weight of wet concrete (with ponding effect)

$Q_{cf} = W_{cf}' = 4.587$ kN/m

Since 2.8m < 3m, the whole span is considered as working area, thus $Q_{cc} + Q_{ca}$ is applied across whole span

Action 1 is not considered since whole span is considered as working area.
Q_{cc}, Q_{cf} and Q_{ca} are applied across the entire span

Deflection check (SS EN 1994-1-1, Clause 9.6)

Deflection is caused by the unfactored load of wet concrete and decking, and such load is uniformly distributed across the whole span of decking.

Ponding effect is considered regardlessly. Deflection is calculated as below:

δ = k / 185 x (w_d + $w_{c'}$) x L^4 / EI

where K = 1.37 for double span

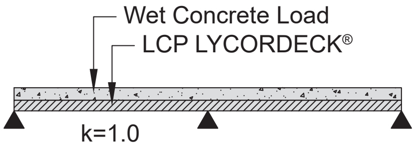
and $w_{c'}$ is the self-weight of concrete inclusive of ponding effect and it's a function of deflection, When ponding effect is considered, it provides an allowance for the extra mass of concrete due to panel deflection. It is obtained by assuming an additional depth of concrete equal to 70% of the deflection. Several iterations are needed to obtain panel deflection. The detailed iteration procedure is neglected here.

The actual deflection is calculated as: (SS EN 1994-1-1, Clause 9.3.2 (2))

w_d + $w_{c'}$ = 3.33 kN/m

δ = 11.01 mm < 30 mm

< 21.54 mm (L/130)

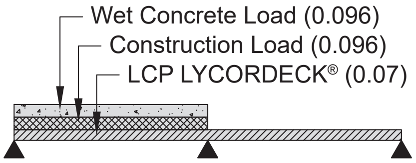


Positive bending moment check (assume maximum deflection)

M^+_{Ed} = kwl^2

= 0.07 x W_{df} x L^2 + 0.096 x (W_f + $W_{cf'}$) x L^2

= 4.39 kNm < $M^+_{c,Rd}$ **= 8.00 kNm** **OK**



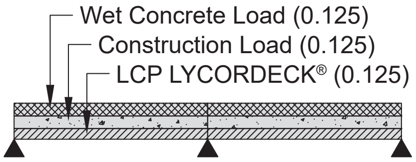
Negative bending moment check (assume maximum deflection)

M^-_{Ed} = kwl^2

= 0.125 x (W_{df} + W_f + $W_{cf'}$) x L^2

= 0.125 x (0.131 +2.25 + 3.899) x 2.564^2

= 5.16 kNm < $M^-_{c,Rd}$ **= 9.00 kNm** **OK**

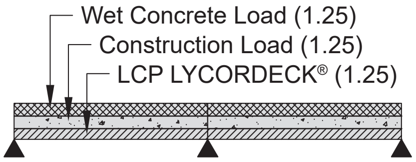


Local web transverse resistance check (assume maximum deflection)

F_{Ed} = kwl

= 1.25 x (W_{df} + W_f + $W_{cf'}$) x L

= 20.60 kN < $R_{w,Rd}$ **= 99.3 kN** **OK**

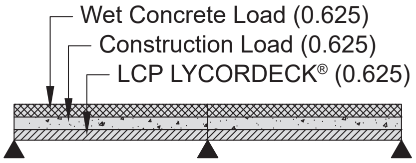


Ultimated shear capactiy check (assume maximum deflection)

V_{Ed} = kwl

= 0.625 x (W_{df} + W_f + $W_{cf'}$) x L

= 10.30 kN < $R_{w,Rd}$ **= 80.1 kN** **OK**



Combined stresses check (SS EN 1993-1-3, Clause 6.1.11(1)

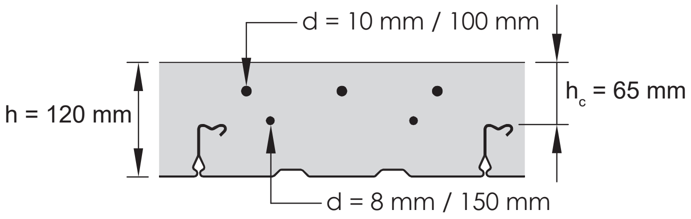
Combined bending and local web transerve resistance

$M^-_{Ed}/M^-_{c,Rd}$ +$F_{Ed}/R_{w,Rd}$ = **0.78** < **1.25** **OK**

Composite Slab Design Examples

BACKGROUND INFORMATION

Decking information



slab width		$b =$	1000	mm
Span		$L =$	2.8	m
Type			Double Span	
Effective area of cross-section		$A_p =$	1620	mm²/m
Slab depth above steel decking		$h_c =$	65	mm
Depth of decking		$h_p =$	55	mm
Overall depth of decking		$h =$	120	mm
Height to neutral axis		$e =$	15.41	mm
Effective depth		$d_p = h - e =$	104.6	mm
Characteristic yield strength		$f_{yp,k} =$	550	N/mm²
		$\gamma_{M0} =$	1.0	
Sagging bending resistance		$M^+_{pa,k} =$	7.83	kNm/m
Hogging bending resistance		$M^-_{pa,k} =$	9.11	kNm/m
Characteristic resistance to longitudinal shear (based on tests)		$\tau_u =$	0.379	N/mm²
		$\gamma_{VS} =$	1.25	
		$m =$	152.5	N/mm²
		$k =$	0.180	N/mm²
Reinforcement Properties				
Top mesh	Main rebar	$d_1 =$	10	mm
		$s_1 =$	100	mm
	Transverse	$d_2 =$	10	mm
		$s_2 =$	200	mm
Nominal cover		$a_0 =$	25	mm
Fire Reinforcement			8	mm
			150	mm
Consider fire reinforcement in composite stage			NO	
Nominal cover for fire reinforcement (from bottom)		$x =$	55	mm
Area of mesh (hogging moment resistance)		$A_s =$	785.4	mm²
Characteristic yield strength		$f_{sk} =$	400	MPa
Design yield strength		$f_{sd} =$	347.83	MPa
		$\gamma_s =$	1.15	
Second moment of area of steel core		$I_p =$	4.87×10^5	mm⁴/m
Design value of modulus of elasticity		$E_p =$	2.10×10^5	N/mm²
Concrete Properties				
Characteristic concrete strength		$f_{ck} =$	30	MPa
Design value of compressive strength		$f_{cd} =$	20.00	MPa
		$\gamma_c =$	1.50	
Secant modulus of elasticity		$E_{cm} =$	32836	MPa

Internal forces (SS EN 1991-1-1, 6.3.1.1, table 6.1, 6.2)

Imposed live load,	$q_k =$	5	kN/m
Floor finish + ceiling + services		2	kN/m
Slab self weight, (refer to working examples for construction stage)	$W_f + W_{cf'} =$	3.53	kN/m
Total dead load,	$w_G =$	5.53	kN/m

Design load (Load arrangement follow construction stage design example)

Maximum sagging bending moment:

$M^{+}_{Ed} = kwl^2$ $\qquad k_1 = 0.070$

$= (k_1 \times 1.35 \times w_G + k_2 \times 1.5 \times q_k) \times L^2$ $\qquad K_2 = 0.096$

$= 9.74$ kNm

Maximum hogging bending moment:

$M^{-}_{Ed} = kwl^2$ $\qquad k = 0.125$

$= k \times (1.35 \times w_G + 1.5 \times q_k) \times L^2$

$= 14.66$ kNm

Maximum shear

$V_{Ed} = kwl$ $\qquad k = 1.250$

$= k \times (1.35 \times w_G + 1.5 \times q_k) \times L$

$= 5.24$ kN

Maximum deflection

Average value of the modular ratio (SS EN 1994-1-1, 9.8.2(5))

$$n = E_p/E'_{cm} = E_p / (0.5*(E_{cm}+E_{cm}/3)) = 9.593$$

Second moment of area for the cracked section in sagging region

The depth of neutral axis (counted from the top of slab):

$$x_c = \frac{nA_p}{b}\left[\sqrt{1 + \frac{2bd_p}{nA_p}} - 1\right] = 43.6 \text{ mm}$$

The second moment of area for the cracked section is:

$$I_{cc} = \frac{bx_p^3}{3n} + A_p(d_p - x_c)^2 + I_p = 9.37 \times 10^6 \text{ mm}^4$$

Second moment of area for the un-cracked section

The depth of neutral axis (counted from the top of slab):

$$x_u = \frac{\sum A_i z_i}{\sum A_i} = \frac{bh_c^2\, l\, 2 + b_c h_p d_p + nA_p d_p}{bh_c + b_c h_p + nA_p} = 67.1 \text{ mm}$$

The second moment of area for the un-cracked section is:

$$I_{cu} = \frac{bh_c^3}{12n} = \frac{bh_c\,(x_u - h_c\, l\, 2)^2}{n} + \frac{b_c h_p^3}{12n} + \frac{b_c h_p}{n}\left[h_t - x_u - \frac{h_p}{n}\right]^2 + A_p\,(d_p - x_u)^2 + I_p$$

$$= 1.74 \times 10^7 \text{ mm}^4$$

with

$h_c = 65$ mm		$h_p = 55$ mm
$b_c = 806.7$ mm		$h_t = 120$ mm
$d_p = 104.60$		$A_p = 1620$ mm

Average I_c of the cracked and un-cracked section

$$I_c = (I_{cc} + I_{cu}) / 2 = 1.34 \times 10^7 \text{ mm}^4$$

Thus, the deflection is to determined as below:

$\delta = k/185 \times w \times L^4 / EI$ $\qquad k = 1$

$= k/185 \times (w_G + q_k) \times L^4 /EI$

$=1.77$ mm

ULTIMATE LIMIT STATE CHECK

The design values of internal forces shall not exceed the design values of resistance for the relevant ultimate limit states. (SS EN 1994-1-1, Clause 9.7.1(1))

Sagging moment resistance check (SS EN1994-1-1, Clause 9.7.2, (5)(6))

1. Assuming full connection

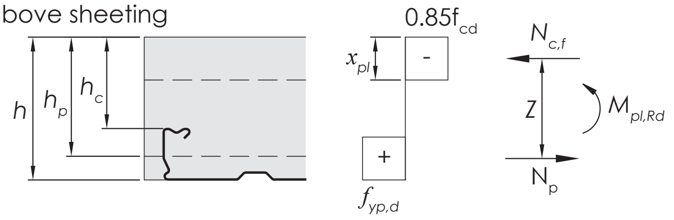
$N_p = A_{pe} f_{yp,d} = 891000$ N

$N_{c,f} = 0.85 f_{cd}\, bx = N_{pa}$

$N_p = N_{cf}$

$x_p = N_{cf} / (0.85 f_{cd}\, b) = 52.4\text{mm} < h_c = 65.0$ mm

Thus, the neutral axis is above sheeting



$M^+_{pl,Rd} = N_{cf}\,(d_p - 0.5x_{pl})$ = **69.85 kNm** > M^+_{Ed} = **9.74 kNm** OK

2. Assuming partial shear connection (SS EN1994-1-1, Clause 9.7.3(8))

Assume composite slab satisfies ductile longitudinal shear behaviour.

$\tau_{u,Rd} = \tau_u / \gamma_{Vs} = 0.30$ N/mm^2 b = 1000 mm

$M_{pa+} = 7.83$ kNm $L = 2800$ mm

e_p = 1mm from the bottom of the decking

L_x (mm)	$N_c(N) = t_{u,Rd} \times b \times Lx$	x_{pl} (mm) $N_c / (0.85 \times b \times f_{cd})$	z (mm) = $h - 0.5x_{pl} - e_p + (e_p - e) \times N_c / (A_{pe} \times f_{yp,d})$	Mpr (kNm) = $1.25 \times M_{pa} \times (1 - N_c/N_p)$	Mpl,Rd (kNm) = $M_{pr} + N_c \times z$
0	0	0	119.0	7.83	7.8
350.0	106120	6.24	114.2	7.83	17.8
700.0	212240	12.48	109.3	7.46	26.9
1050.0	318360	18.73	104.5	6.29	34.8
1400.0	424480	24.97	99.7	5.12	42.3 Mid-Span

$M^+_{pl,Rd}$ = **42.27 kNm** > M^+_{Ed} = **9.74 kNm** OK

Hogging moment resistance check (SS EN 1994-1-1, Clause 9.7.2(7))

Rebar concrete cover	$e_s = 30$ mm
Area of mesh	$d_s = h - e_s = 90$ mm
	$As = 785.40$ mm2
Tensile force	$N_s = A_s f_{sd} = 273182$ N
Depth of the compressive stress block	$x_{pl} = N_s / 0.85 \times b \times f_{cd} = 16.07$ mm
Lever arm from the bottom of decking	$z = d_s - x_{pl}/2 = 82.0$ mm

Design resistance to hogging bending is:

$M^-_{pl,Rd}$ = **22.39 kNm** > M^-_{Ed} = **14.66 kNm** OK

Vertical shear resistance check

Design vertical shear resistance is: (SS EN 1992-1-1, 6.2.2)

$C_{Rd,c} = 0.18/\gamma_c = 0.12$

$d_p = 104.60$ mm

$\rho_l = 0.0192$

$k = 2.0$

$V^{l}_{v,Rd} = C_{Rd,c} k\,(100\,\rho_l f_{ck})^{1/3}\, b_w d_p = 78.2$ kN/m

The recommended value for minimum value (υ_{min}) is:

$\upsilon_{min} = 0.035 \times k^{3/2} \times f_{ck}^{1/2} = 0.54$ N/mm^2

Minimum of shear resistance

$V_{vRd,min} = b_w d_p v_{min} = 45.8$ kN

The design resistance to vertical shear is:

$V_{v,Rd} = \max\,(V'_{v,Rd}\,;\,V_{v,Rd,min}) =$ **78.21 kN** > $V_{Ed} =$ **5.24 kN** OK

Longitudinal shear check

m-k method (SS EN 199-1-1, Clause 9.7.3 (4))

The design shear resistance is:

$b = 1.00$ m

$L = 2800$ mm

$L_s = L/4 = 0.07$ m (for uniform load applied to entire span)

$m = 152.5$ N/mm^2

$d_p = 104.60$ mm

$A_p = 1620$ mm^2

$k = 0.180$ N/mm^2

$V_{l,Rd} = bd_p\,[mA_p\,/\,(bL_s) + k]\,/\,\gamma_{vs} =$ **44.63 kN** > V_{Ed} = **5.24 kN** OK

Punching shear check (SS EN 1994-1-1, 9.7.6)

Neglected, only when the composite slab is subjected to concentrated loads

SERVICEABILITY LIMIT STATE

Control of cracking of concrete (SS EN1994-1-1, 9.8.1 (2))

As the slab is designed as simply supported, only anti-crack reinforcement is needed. The cross-sectional area of the reinforcement above the ribs should be not less than 0.2% for un-propped construction.

min $A_s = 0.002 \times b \times h_c = 130$ mm^2/m

Check $A_s =$ **785 mm²/m > 130 mm²/m** OK

Deflection (SS EN1994-1-1, 9.8.2)

Maximum deflection $\delta_{max} = 1.8$ mm

The allowable deflection is:

$[\,\delta\,] = 1/250 * L =$ **11.2** > δ = **1.77** OK

Note: *All design checks are OK at both the ultimate limit state and the serviceability limit state.*

Fire Design Working Examples

GENERAL INFORMATION

Slab thickness: 120 mm

Type of concrete: Normal

Decking thickness t = 1mm

Area of bottom deck A_{btm_deck} = 1000.5 mm^2

Area of the rib A_{rib} = 162 mm^2

Area of the flange A_{flange} = 82.5 mm^2

Area of bottom mesh (fire reinforcement)

Rebar size 8 mm @ 150 mm

Cover 55 mm

A_{btm_bar} = 335.1 mm^2

Possition x_4 = 59 mm from bottom of the decking

Area of anticrack mesh (top mesh)

Main rebar size 10 mm @ 100 mm

Cover 25 mm

A_{crk_mesh} = 785.4 mm^2

Possition x_3 = 30 mm from top of the decking

Strength of material

Design yield strength of decking $f_{y,\ decking}$ = 550 N/mm^2 $\gamma_{M,fi,s} = 1$

Design yield strength of mesh rebar $f_{yk,\ mesh}$ = 400 N/mm^2 $\gamma_{M,fi,s} = 1$

Compressive design strength of concrete f_{ck} = 30 N/mm^2 $\gamma_{M,fi,s} = 1$

DESIGN LOAD

Imposed live load, q_k = 5 kN/m (Follow example from composite design)

Dead load, w_G = 5.53 kN/m

Load factor for fire limit state:

$\gamma_{qk} = 1$

$\psi_1 = \gamma_{wG} = 0.8$ (NA to SS EN 1990, Table NA.A1.1)

Material factors for fire limit state

$\gamma_s = \gamma_c = 1$

$\eta = (w_G + \psi_1 q_k)/(1.35w_G + 1.5q_k) = 0.64$ (SS EN 1994-1-2, 2.4.2(2)(3))

Sagging moment under fire limit state

$M^{+'}_{Ed} = \eta \times M^{+}_{Ed} = 6.20$ kNm

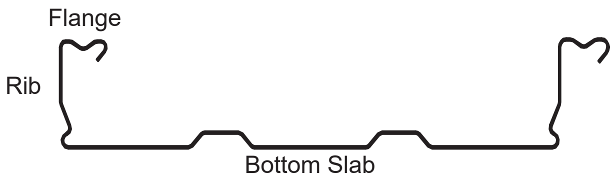
Hogging moment under fire limit state

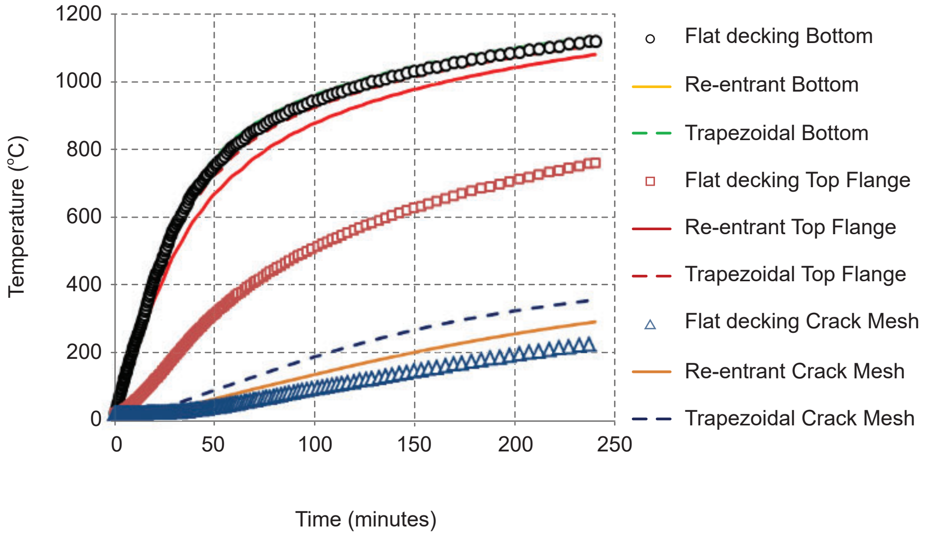
$M^{-'}_{Ed} = \eta \times M^{-}_{Ed} = 9.34$ kNm

DETERMINE TEMPERATURE OF STEEL COMPONENTS

Determine temperature at t = 90 minutes

Calculating temperature of steel component





Temperature of bottom slab

$$\theta_{s,btm\_deck} = -0.0166 \times t^2 + 6.7422 \times t + 417.03 = 922.34\ °C$$

Temperature of middle rib

$$\theta_{s,rib} = -0.0126 \times t^2 + 6.4596 \times t + 233.06 = 749.30\ °C$$

Temperature of flange

$$\theta_{s,flange} = -0.0086 \times t^2 + 6.177 \times t + 49.08 = 586.27\ °C$$

Temperature profile test result

Factors for anti-crack mesh				**Factors for bottom mesh**			
Rating (minutes)	a	b	c	Rating (minutes)	a	b	c
30	0.009	-1.9	127.00	30	0.08	-13	600
60	0.007	-1.6	170.75	60	0.23	-25	850
90	0.006	-2.05	243.25	90	0.23	-25.5	950
120	0.005	-2.25	290.25	120	0.21	-25	1030
150	0.003	-2.65	355.00	150	0.20	-24	1070
180	0.001	-2.85	434.50	180	0.18	-22	1100
210	0.001	-2.95	451.75	210	0.17	-21.5	1120
240	0.001	-3.15	494.13	240	0.17	-21	1150

$T_{c,below\_rib\_height} = a \times x^2 = b \times x + c$

$T_{c,above\_rib\_height} = a \times (x - 5)^2 + b \times (x - 55) + c$

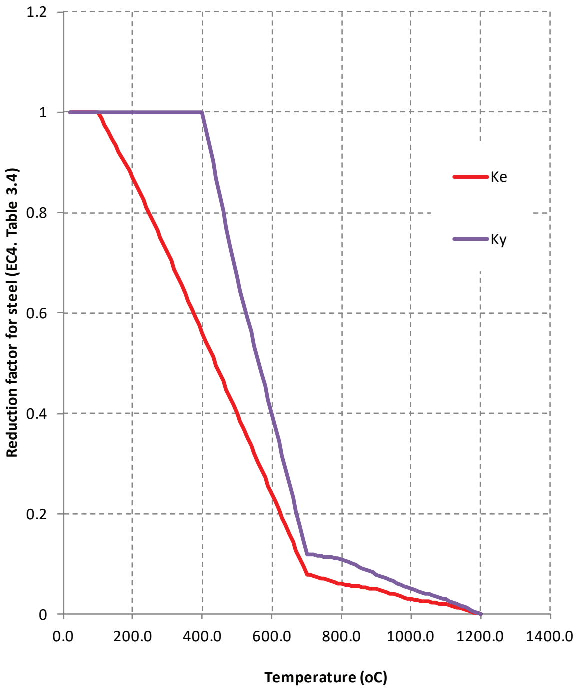
Temperature of bottom mesh

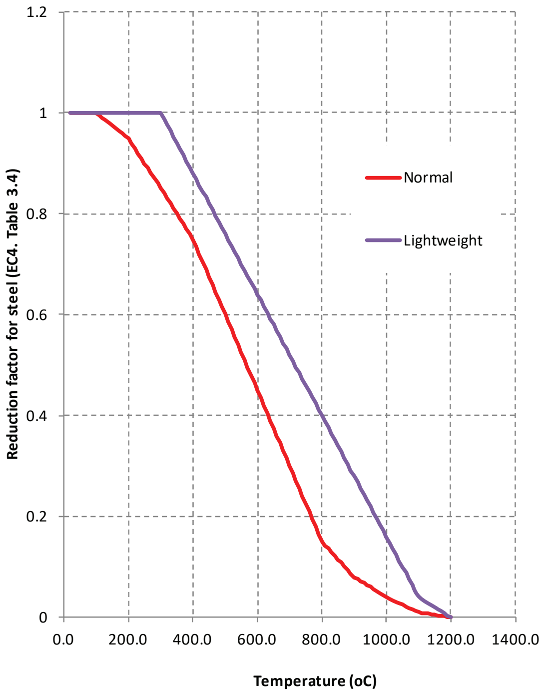
$$\theta_{s,btm\_mesh} = 0.23 \text{ x } x_4^2 - 25.5 \text{ x } x_4 + 950 = 246.13\ ^\circ C$$

Temperature of anti crack mesh

$$\theta_{s,crk\_mesh} = 0.006 \text{ x } (120 - x_3 - 55)^2 - 2.05 \text{ x } (120 - x_3 - 55) + 243.25 = 178.9\ ^\circ C$$

Note: *For factors apply to other timing, kindly consult LCP Building Products technical department.*





Calculating reduction factor of Yield Strength of steel component

(SS EN 1994-1-2, Table 3.3 & 3.4)

Reduction factor of bottom slab	$k_{y,\theta,btm\_deck} = 0.074$
Reduction factor of middle rib	$k_{y,\theta,rib} = 0.116$
Reduction factor of flange	$k_{y,\theta,\ flange} = 0.454$
Reduction factor of bottom mesh	$k_{y,\theta,btm\_mesh} = 1.0$
Reduction factor of crack mesh	$k_{y,\theta,crk\_mesh} = 1.0$
Reduction factor of concrete	$k_{c,\theta} = 0.965$

Calculating component forces

Only steel components are considered	$T = k_{y,\theta} \text{ x } f_y \text{ x } A$
Bottom decking force	$T_{s,\ btm\_deck} = 40.72$ kN
Middle rib force	$T_{s,\ rib} = 10.34$ kN
Flange force	$T_{s,\ flange} = 20.60$ kN
Bottom mesh force	$T_{s,btm\_mesh} = 134.04$ kN
Anti-crack mesh force	$T_{s,crk\_mesh} = 314.16$ kN

CALCULATING SAGGING MOMENT

Assume neutral asis is between top cover and anti-crack mesh

$x < x_3 = 30$ mm from top of the slab

Concrete temperature is taken at anti-crack mesh level

Total tension forces are: $T = T_{s,btm\_deck} + T_{s,rib} + T_{s,flange} + T_{s,btm\_mesh} + T_{s,crk\_mesh}$

$= 519.86$ kN

Neutral axis is $x = T / (0.85 \text{ x } k_{c,\theta} \text{ x } f_{ck} \text{ x } b) = 21.13 \text{ mm} < 30 \text{ mm}$

Thus the assumption is satisfied

Determine distance to neutral axis of each component

Concrete $x_c = x/2 =$ 10.56 mm

Bottom deck $x_{btm\_deck} = 120 - x =$ 98.87 mm

Middle rib $x_{rib} = 120 - x - 55/2 =$ 71.37 mm

Flange $x_{flange} = 120 - x - 55 =$ 43.87 mm

Bottom mesh $x_{btm\_bar} = 120 - x - x_4 =$ 39.87 mm

Crack mesh $x_{crk\_mesh} = x_3 - x =$ 8.87 mm

Compression force of concrete $T_c = T =$ 519.86 kN

Sagging moment $M_{sag} = x_c \times T_c + x_{btm\_deck} \times T_{s,btm\_deck} + x_{rib} \times T_{s,rib} + x_{flange} \times T_{s,flange} + x_{btm\_bar} \times T_{s,btm\_mesh} + x_{crk\_mesh} \times T_{s,crk\_mesh}$

19.29 kNm > 6.20 kNm **OK**

CALCULATING HOGGING MOMENT

Concrete slab is divided into n layers. Each layer has an identical thickness of 5mm. The concrete layers are numbered from the bottom of decking towards the top of slab.

Bottom concrete layer and add-up force for the balance of hogging moment are tabulated as below table of layers

Layer Number	Layer Thickness (mm)	Distance from center of layer to the bottom	Temperature of the layer	Reduction factor	Reduction stress of each layer	Compression force of each layer (kN)	Accumulate compression force from bottom (kN)	Moment of each layer (kNm)	Accumulate moment from bottom	Distance from center of layer to Neutral Axis
1	5	2.5	887.69	0.09	2.82	11.99	11.90	0.39	0.39	32.5
2	5	7.5	771.69	0.20	5.85	24.86	36.85	0.68	1.07	27.5
3	5	12.5	667.19	0.36	10.80	45.90	82.75	1.03	2.11	22.5
4	5	17.5	574.19	0.50	14.85	63.11	145.86	1.10	3.21	17.5
5	5	22.5	492.69	0.62	18.45	78.41	224.27	0.98	4.19	12.5
6	5	27.5	422.69	0.72	21.60	91.80	316.07	0.69	4.88	7.5
7	5	32.5	364.19	0.79	23.70	100.73	416.80	0.25	5.13	2.5
8	5	37.5	317.19	0.84	25.20	107.10	523.90	-0.27	4.86	-2.5
9	5	42.5	281.69	0.87	26.10	110.93	634.82	-0.83	4.03	-7.5
10	5	47.5	257.69	0.90	27.00	114.75	749.57	-1.43	2.60	-12.5
11	5	52.5	245.19	0.91	27.30	116.03	865.60	-2.03	0.57	-17.5
12	5	57.5	145.21	0.98	29.40	124.95	990.55	-2.81	-2.24	-22.5
13	5	62.5	138.56	0.99	29.55	125.59	1116.14	-3.45	-5.70	-27.5
14	5	67.5	132.21	0.99	29.55	125.59	1241.72	-4.08	-9.78	-32.5
15	5	72.5	126.16	0.99	29.70	126.23	1367.95	-4.73	-14.51	-37.5
16	5	77.5	120.41	0.99	29.70	126.23	1494.17	-5.36	-19.88	-42.5
17	5	82.5	114.96	1.00	29.85	126.86	1621.04	-6.03	-25.90	-47.5
18	5	87.5	109.81	1.00	30.00	127.50	1748.54	-6.69	-32.60	-52.5
19	5	92.5	104.96	1.00	30.00	127.50	1876.04	-7.33	-39.93	-57.5
20	5	97.5	100.41	1.00	30.00	127.50	2003.54	-7.97	-47.90	-62.5
21	5	102.5	96.16	1.00	30.00	127.50	2131.04	-8.61	-56.50	-67.5

Distance from centre of each layer to the bottom and corresponding temperature can be determined. Reduction factor will then be determined as well as compensating compression force. Accumulated compensating compression force and moments of first i layers of concrete shall be tabulated for easy reference on the right side of the table. For detailed information, consult **LCP Building Products** technical department.

Assume neutral axis is below half of the rib, 55/2

$z < 27.5$ mm

Total tension force $T = T_{s,rib} + T_{s,flange} + T_{s,btm\_mesh} + T_{s,crk\_mesh}$

$= 479.14$ kN

Steel under compression $C_t = T_{s,btm\_deck} = 40.72$ kN

Balance force for concrete $C_c = T - C_t = 438.42$ kN

Check for layer i $i = 7$ (first 7 layers accumulates 416.8 kN compression force)

Neutral axis is $z = 35.0$ mm > 27.5 mm

Thus the assumption is not satisfied

Assume the neutral axis is within upper part of the rib : 55 > neutral asis > 55/2

$27.5 \text{ mm} < z < 55$ mm

Total tension force $T = T_{s,flange} + T_{s,btm\_mesh} + T_{s,crk\_mesh}$

$= 468.80$ kN

Steel under compression $C_t = T_{s,btm\_deck} + T_{s,rib} = 51.06$ kN

Balance force for concrete $C_c = T - C_t = 417.74$ kN

Check for layer i $i = 7$ (first 7 layers accumulates 416.8 kN compression force)

Neutral axis is $z = 35.0$ mm > 27.5 mm

Thus the assumption is satisfied

Determine distance to neutral axis of each component

Bottom deck $z_{btm\_deck} = z = 35$ mm

Middle rib $z_{rib} = z - 55/2 = 7.5$ mm

Flange $z_{flange} = 55 - z = 20$ mm

Bottom mesh $z_{btm\_mesh} = x_4 - z = 24$ mm

Crack mesh $z_{crk\_mesh} = 120 - x_3 - z = 55$ kNm

Accumulate concrete moment $M_{c,acc} = 5.13$ mm

Hogging moment $M_{hog} = z_{btm\_deck} \text{ x } T_{s,btm\_deck} + z_{rib} \text{ x } T_{s,\ rib} + z_{flange} \text{ x } T_{s,flange} + z_{btm\_bar} \text{ x } T_{s,btm\_mesh} + z_{crk\_mesh} \text{ x } T_{s,crk\_mesh} + M_{c,ass}$

$=$ **27.54 kNm** > **9.34 kNm** **OK**

Both sagging moment and hogging moment check are OK in fire limit design.

PROJECT REFERENCE

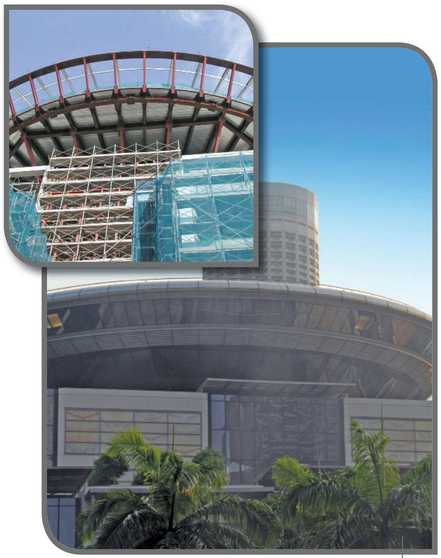
One Raffles Place, Singapore

International Finance Centre, Hong Kong

Marina Bay Sands IR, Singapore

ION Orchard, Singapore

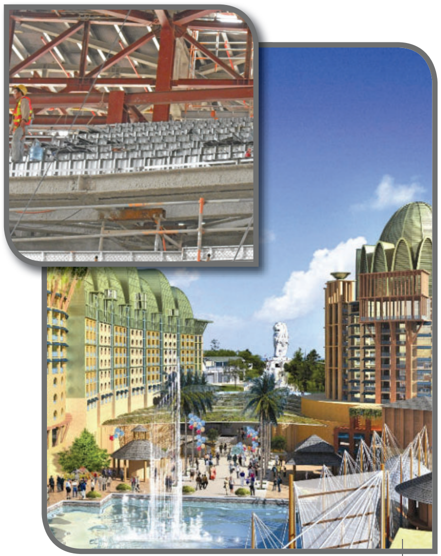
Times Square, Hong Kong



Supreme Court, Singapore

Changi Airport Terminal 3, Singapore

Naypyidaw Airport, Myanmar



Universal Studios, Singapore

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