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Introduction — *BS5950*

1 *Grade 50 more common than Grade 43 because composite beam stiffness often 3 to 4 times non composite beam, justifying use of higher working stresses.*

2 *Span to depth (overall beam and slab depth) ratios*
- *Simply supported UB 18 to 23*
- *Simply supported UC 22 to 29*
- *End span of continuous beam 22 to 25*
- *Internal span of continuous beam 25 to 30*

3 *The direction of the metal deck ribs matters as it can only span 3.0 to 3.5m.*
Hence usually decking spans to secondary beams (ribs perpendicular to secondary beam).
Typical unpropped composite slab span for a (4 + 1) kPa live loading and 1.7 kPa allowance for slab, services and ceiling is presented.

Decking gauge	Slab depth (mm)	Lightweight concrete		Normal Weight Concrete	
		Simply Supported	Continuous	Simply Supported	Continuous
0.9 (A142 mesh)	130 150	2.95 2.88	3.11 3.22	2.78 2.66	3.03 3.00
1.2 (A193 mesh)	130 150	3.20 3.08	3.73 3.62	3.02 2.89	3.55 3.41

Design assumes 60 minute fire resistance, provided that the slab is continious (decking need not be)

4 *Typical values of modular ratio for office buildings are 10 NWC and 15 LWC.*

5 *In final state, the slab provides LTB restraint to both the primary and secondary beams.*
In construction stage, parallel decking provides no LTB restraint to the primary beam but the perpendicular decking provides LTB restraint to the secondary beam.
But although no LTB restraint is provided to the primary beams by the metal decking in the contruction stage, the secondary beams provide the LTB restraint to primary beams.

6 *Note the overall utilisation does not include cross section classification or shear buckling.*
If the section is not ***at least compact*** *, then the equations within the sheet are NOT valid!*
If the section classification or shear buckling utilisations is violated, the overall utilisation is set at 999%.

7 *Capacity of composite section typically 1.6 to 2.0 times that of non-composite section.*

Typical starting point

Overall concrete depth 130mm (Grade 30)
Depth of profiled decking 60mm
Size beam with Z = (Z for non-composite beam) x F where F = 1.6 - 2.0

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Input Parameters			*BS5950*
Primary beam spacing (= secondary beam span) =	13.000	m	
Primary beam span =	8.500	m	
Secondary beam spacing (usually 3.0 - 3.6m) =	2.833	m	
Support condition for primary beam =	Simply Supported		
Support condition for secondary beam =	Simply Supported		
Redistribution of hogging moment (where applicable) =	30	%	
Steel grade =	S275 (43)		
Beam to be checked, i.e. secondary or primary beam =	Secondary Beam		
Suggested depth if simply supported =	565mm < UB < 722mm; 448mm < UC < 591mm		
Primary beam =	UB 686x254x152		
Secondary beam =	UB 533x210x92		
Mass per area of primary beam, m_p = mass per metre / spacing =	11.7	kg/m^2	
Mass per area of secondary beam, m_s = mass per metre / spacing =	32.5	kg/m^2	
Mass per area of structural steelwork = $m_p + m_s$ =	**44.2**	kg/m^2	
Comp strength of concrete, f_{cu} (affects stud cap, ULS cap, SLS stress criteria; ≤ 60N/mm² as H	35	N/mm^2	**OK**
Type of concrete (affects stud capacity, deflection calcs, density) =	Normal Weight		
Deck type =	CORUS PMF COMFLOOR 46		
Depth of profile decking, D_p (usually 60mm) =	46	mm	
Depth of slab to bottom of decking troughs, D_s (usually 130mm) =	130	mm	
Shear stud dimensions (usually ϕ = 19mm and h = 100mm) =	Dia. 19mm, Height 100mm		
No. of studs per section primary beam, N = 2 and secondary beam, N =	2	stud(s)	
Average trough width, b_a = 0.5 (t_c - crest width + trough width) (0.5t_c for symmetrical deck	132	mm	
Distance from first stud to mid level trough width, e_d =	40	mm	
Trough centres, t_c (usually 150 - 300mm, relevant for perpendicular decking) =	225	mm	
Along profile deck stud pitch (relevant for parallel decking) =	300	mm	
Decking, t_p = (0.86 - 1.50mm) = 1.00 mm and design strength, p_{yp} =	280	N/mm^2	
Live load (including partitions), LL =	5.00	kPa	
Steel deck =	0.15	kPa	
Flooring =	0.00	kPa	
Floor topping (including insulation) =	1.20	kPa	
Services =	1.50	kPa	
Ceiling =	0.00	kPa	
Internal or external facade primary beam (from load on elevation) =	0.0	kN/m	
Internal or external facade secondary beam (from load on elevation) =	0.0	kN/m	
Construction loading (for construction stage checks, >=0.5 kPa) =	1.50	kPa	**OK**
Method of construction (affects deflection and all construction effects) =	Unpropped Construction		
Percentage of dead and superimposed dead load deflection precamber, %pcam =	0.0	%	
Internal or edge beam (primary) (affects eff width and loading tributary) =	Internal Beam		
Internal or edge beam (secondary) (affects eff width and loading tributary) =	Internal Beam		

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BS5950

Cover =	25	mm
Yield strength of longitudinal steel, f_y =	460	N/mm^2
Primary beam hogging steel reinforcement diameter, ϕ_h =	None	mm
Primary beam hogging steel reinforcement pitch =	200	mm
Primary beam hogging steel area provided, $A_{s,prov,h}$ =	0	mm^2/m
Secondary beam hogging steel reinforcement diameter, ϕ_h =	None	mm
Secondary beam hogging steel reinforcement pitch =	200	mm
Secondary beam hogging steel area provided, $A_{s,prov,h}$ =	0	mm^2/m

Transverse rebars of ϕ_t = 8 mm at s_t = 200 mm and f_y = 460 N/mm^2

British Standard Fabric Reference		Longitudinal Wires: Nominal wire size mm	Pitch mm	Area mm^2	Cross Wires: Nominal wire size mm	Pitch mm	Area mm^2	Nominal Mass kg/m^2
Square Mesh	A 393	10	200	393	10	200	393	6.16
	A 252	8	200	252	8	200	252	3.95
	A 193	7	200	193	7	200	193	3.02
	A 142	6	200	142	6	200	142	2.22
	A 98	5	200	98	5	200	98	1.54

Additional transverse reinforcement (transverse to primary beam), $area_{add}$ =	389	mm^2/m
Additional transverse reinforcement (transverse to secondary beam), $area_{add}$ =	192	mm^2/m

Utilisation Summary

Utilisation Checks			
ULS Shear Stud Parameters	64%	OK	91%
ULS Cross Section Classification	67%	OK	
ULS Shear Buckling	67%	OK	
ULS Shear Capacity	34%	OK	
ULS Minimum Shear Connection Degree (Sagging Moment)	64%	OK	
ULS Sagging Moment Capacity	90%	OK	
ULS Hogging Moment Capacity	N/A	N/A	
SLS Live Load Deflection	54%	OK	
SLS Load Deflection	91%	OK	
SLS Concrete Stress	25%	OK	
SLS Steel Stress	87%	OK	
ULS Construction Shear Capacity	23%	OK	
ULS Construction Sagging Moment Capacity	63%	OK	
ULS Construction Hogging Moment Capacity	N/A	N/A	
ULS Transverse Reinforcement	33%	OK	

Dead and superimposed dead load deflection precamber, DL+SDL precamber = 0.0 mm

Primary beam utilisation summary	Design Floor !	98%	98%	%
Secondary beam utilisation summary		91%		

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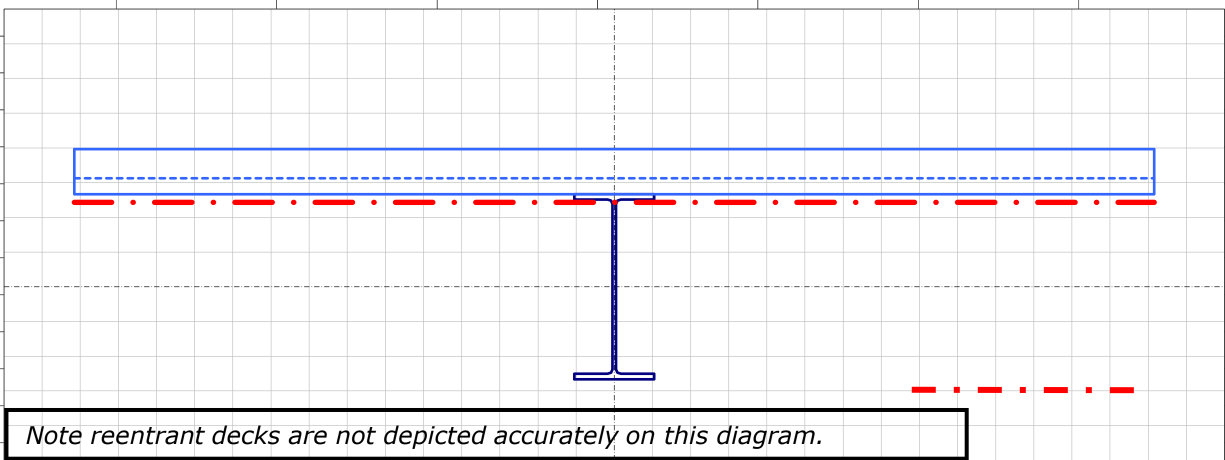
Steel Beam Section			*BS5950*
Section description =	UB 533x210x92		
Section mass =	92.1	kg/m	
Steel grade =	S275 (43)		
Strength (function of steel grade and plate thickness), p_y =	275	N/mm^2	
Depth of web, d =	476.5	mm	
Depth of section, D =	533.1	mm	
Flange width, B =	209.3	mm	
Web thickness, t =	10.1	mm	
Flange thickness, T =	15.6	mm	
Web slenderness, d/t =	47.2		
Flange slenderness, b/T =	6.7		
Area of section, A =	117.0	cm^2	
Second moment of area, I_x =	55227	cm^4	
Elastic modulus about x-x axis, Z_x =	2072	cm^3	
Plastic modulus about x-x axis, s_x =	2360	cm^3	
Radius of gyration about y-y axis, r_y =	4.5	cm	
Buckling parameter, u =	0.872		
Torsional index, x =	36.5		
$\varepsilon = \sqrt{(275/p_y)}$ =	1.00		
Modulus of elasticity, E =	2.05E+05	N/mm^2	
Length of beam span, L =	13000	mm	
(affects effective width, deflection estimates and criteria, vibration estimates and construction case deflection estimates and criteria)			
LTB effective length for construction case sagging, $L_{LTB,SAG}$ =	14066	mm	
(1.0 x secondary beam span if secondary beam + 2D, 1.0 x secondary beam spacing if primary beam + 2D)			
LTB effective length for construction case hogging, $L_{LTB,HOG}$ =	12116	mm	
(1.0 x 0.85 x secondary beam span if secondary beam + 2D, 1.0 x 0.85 x secondary beam spacing if primary beam + 2D)			
Beam spacing =	2833	mm	



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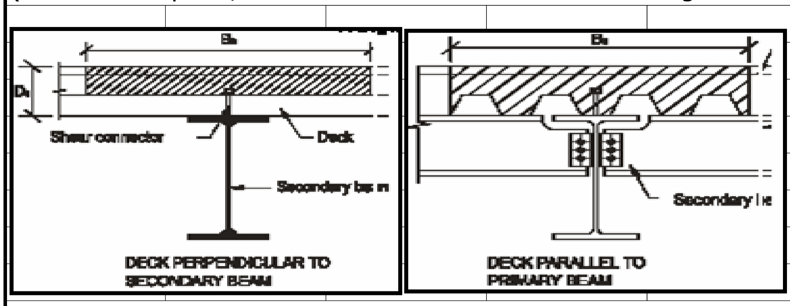
Slab Parameters — *BS5950*

Compressive strength of concrete, f_{cu} =	35.0	N/mm^2
Type of concrete =	Normal Weight	
Concrete density, ρ_c =	24.0	kN/m^3
Direction of profile sheeting =	Perpendicular	

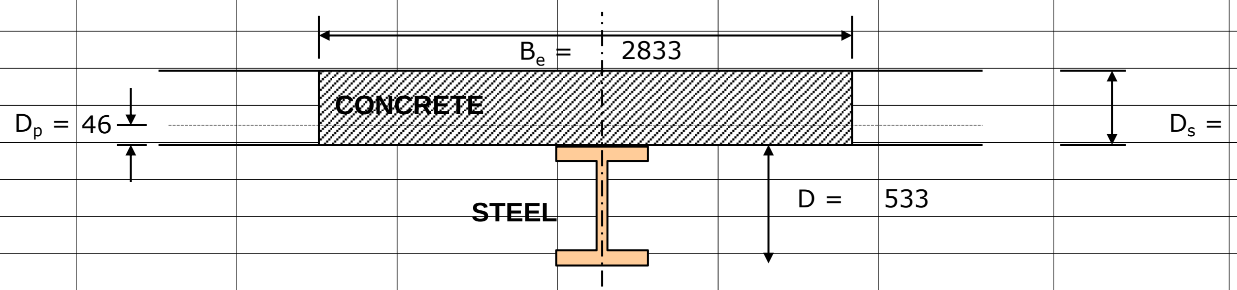
(perpendicular if secondary beam, parallel if primary beam)
(affects stud pitch, effective width and construction stage checks)



Effective width, B_e and $B_{e,hog}$		
	secondary	primary
simply supported	MIN (L/4, spacing)	MIN (L/4, 0.8spacing)
continuous sagging	MIN (0.7L/4, spacing)	MIN (0.7L/4, 0.8spacing)
continuous hogging	MIN (0.5L/4, spacing)	MIN (0.5L/4, 0.8spacing)

(Note that these effective width values are halved if edge beam instead of internal beam)

Depth of profile decking, D_p =	46	mm
Depth of slab to bottom of decking troughs, D_s =	130	mm
Effective width for sagging moment, B_e =	2833	mm
Effective width for hogging moment, $B_{e,hog}$ =	N/A	mm



LTB Restraint

	Decking Parallel	Decking Perpendicular
Design sag	No LTB	No LTB
Construction sag	$L_{LTB,SAG}$	No LTB
Design hog	No LTB	No LTB
Construction hog	$L_{LTB,HOG}$	$L_{LTB,HOG}$

(Note that in the design hog situation, torsional restraint is provided by the web and the concrete slab)

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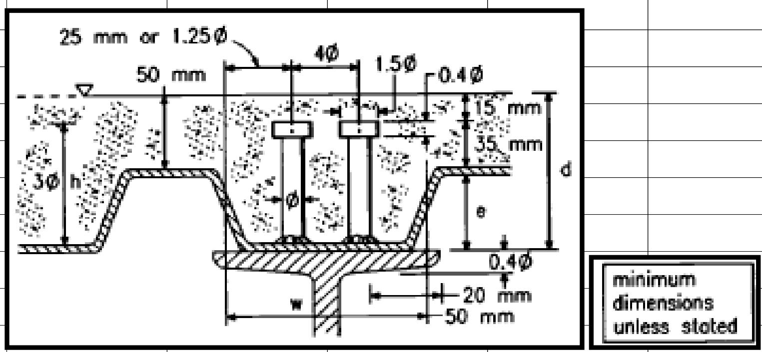
Shear Stud Parameters				*BS5950*
Capacity of 1 shear stud based on property table (ϕ, h, f_{cu}) =		104	kN	
Stud height, h =		100	mm	
Stud diameter, ϕ =		19	mm	
Shear stud parameters max utilisation =		**64%**		**OK**



Number of studs per trough, N =		2		
Number of studs per trough utilisation, N (<=2) =		**100%**		**OK**
Height of stud above decking profile, h-D_p =		54	mm	
Height of stud above decking profile utilisation, h-D_p (>=35mm) =		**65%**		**OK**
Stud height, h =		100	mm	
Stud height utilisation, h (>=3ϕ) =		**57%**		**OK**
Depth of profile decking, D_p =		46	mm	
Depth of profile decking utilisation, D_p (>=35mm, <=80mm) =		**76%**		**OK**
Depth of slab excluding profile decking, D_s - D_p =		84	mm	
Depth of slab excluding profile decking utilisation, D_s - D_p (>=50mm) =		**60%**		**OK**
Depth of slab above shear stud = D_s - h =		30	mm	
Depth of slab above shear stud utilisation = D_s - h (>=15mm) =		**50%**		**OK**
Average trough width, b_a =		132	mm	
Average trough width utilisation, b_a (>=100mm) =		**76%**		**OK**
Steel beam flange thickness utilisation, T >= ϕ/2.5 for through stud welding =		**49%**		**OK**
Average trough width, b_a =		132	mm	
Trough centres, t_c (relevant for s_l when decking perpendicular to beam) =		225	mm	
Along profile deck stud pitch (relevant for s_l when decking parallel to beam) =		300	mm	
Longitudinal (with respect to beam) stud pitch, s_l =		225	mm	
Longitudinal stud pitch utilisation, s_l (>=5ϕ, >=100mm, <=600mm, <=4D_s) =		**44%**		**OK**
Distance from first stud to mid level trough width, e_d =		40	mm	
Distance from first stud to mid level trough width utilisation, e_d (>25mm, >1.25ϕ) =		**63%**		**OK**
Transverse (with respect to beam) stud pitch, s_t = (B-2e_d)/(N-1) =		129	mm	
Transverse (with respect to beam) stud pitch utilisation, s_t (>=4ϕ) =		**59%**		**OK**
Distance from stud to edge of flange = (B - (N-1).s_t - ϕ)/2 =		31	mm	
Distance from stud to edge of flange utilisation (>=20mm) =		**66%**		**OK**

Applied Loading and Associated Effects *BS5950*

Type of support condition =	Simply Supported	
Tributary width i.e. beam spacing (divided by 2 if edge beam), t_w =	2.833	m
Live load (including partitions), LL =	5.00	kPa
Super dead load (from plan loading), SDL = tiles + floor topping + ceiling + services =	2.70	kPa
Flooring =	0.00	kPa
Floor topping (including insulation) =	1.20	kPa
Services =	1.50	kPa
Ceiling =	0.00	kPa
Super dead load (from elevation loading), SDL_{elev} =	0.0	kN/m
Dead load, DL = concrete weight + steel weight + steel deck =	3.13	kPa
Concrete weight = $[(D_s - D_p) + (b_a/t_c)D_p] . \rho_c$ =	2.66	kPa
Steel weight = m_s . g if secondary $(m_p + m_s)$. g if primary =	0.32	kPa
Steel deck =	0.15	kPa

Load	Factor	Load (kPa)	Factored load (kPa)	ω_{SLS} (kN/m)	ω_{ULS} (kN/m)
LL	1.6	5.0	8.0	14.2	22.7
SDL	1.4	2.7	3.8	7.7	10.7
DL	1.4	3.1	4.4	8.9	12.4
Total		10.8	16.2	**30.7**	**45.8**

ULS and SLS Bending Moment (Factors Not Shown)

	Enveloped Moment SLS	ULS
Simply Supported		
M_{HOG}=0.0=	0	0
$M_{SAG}=[0.125(\omega_{DL}+\omega_{SDL}+\omega_{LL})]L^2$=	648	967
Continuous 2 Span		
$M_{HOG}=[0.125(\omega_{DL}+\omega_{SDL})+0.125\omega_{LL}]L^2$=	648	967
$M_{SAG}=[0.070(\omega_{DL}+\omega_{SDL})+0.096\omega_{LL}]L^2$=	425	641
Continuous 3 Span (End Span)		
$M_{HOG}=[0.100(\omega_{DL}+\omega_{SDL})+0.117\omega_{LL}]L^2$=	559	839
$M_{SAG}=[0.080(\omega_{DL}+\omega_{SDL})+0.101\omega_{LL}]L^2$=	465	700
Continuous 3 Span (Interior Span)		
$M_{HOG}=[0.100(\omega_{DL}+\omega_{SDL})+0.117\omega_{LL}]L^2$=	559	839
$M_{SAG}=[0.025(\omega_{DL}+\omega_{SDL})+0.075\omega_{LL}]L^2$=	249	385
Continuous 4 or More Span (End Span)		
$M_{HOG}=[0.107(\omega_{DL}+\omega_{SDL})+0.121\omega_{LL}]L^2$=	588	882
$M_{SAG}=[0.077(\omega_{DL}+\omega_{SDL})+0.100\omega_{LL}]L^2$=	454	684
Continuous 4 or More Span (Interior Span)		
$M_{HOG}=[0.107(\omega_{DL}+\omega_{SDL})+0.121\omega_{LL}]L^2$=	588	882
$M_{SAG}=[0.036(\omega_{DL}+\omega_{SDL})+0.081\omega_{LL}]L^2$=	294	451

(Note for udl loads (DL and SDL) uniform loading considered)

(Note for udl loads (LL) patch loading considered)

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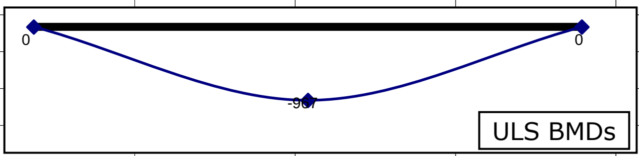
ULS hogging bending moment, $M_{ULS,HOG,Elastic}$ =	0	kNm	
ULS sagging bending moment, $M_{ULS,SAG,Elastic}$ =	967	kNm	
Redistribution of hogging moment for continuous beams, RD =	30.0	%	
ULS hogging bending moment, $M_{ULS,HOG}$ = $(1-RD)M_{ULS,HOG,Elastic}$ =	**0**	kNm	
ULS sagging bending moment, $M_{ULS,SAG}$ = $M_{ULS,SAG,Elastic} + RD.M_{ULS,HOG,Elastic}$ =	**967**	kNm	



SLS hogging bending moment, $M_{SLS,HOG}$ =	**0**	kNm	
SLS sagging bending moment, $M_{SLS,SAG}$ =	**648**	kNm	

ULS Shear Force (Factors Not Shown)		**Enveloped Shear**
Simply Supported		**ULS**
	$V=[0.500(\omega_{DL}+\omega_{SDL}+\omega_{LL})]L=$	298
Continuous 2 Span		
	$V=[0.625(\omega_{DL}+\omega_{SDL})+0.625\omega_{LL}]L=$	372
Continuous 3 Span (End Span)		
	$V=[0.600(\omega_{DL}+\omega_{SDL})+0.617\omega_{LL}]L=$	362
Continuous 3 Span (Interior Span)		
	$V=[0.500(\omega_{DL}+\omega_{SDL})+0.583\omega_{LL}]L=$	322
Continuous 4 or More Span (End Span)		
	$V=[0.607(\omega_{DL}+\omega_{SDL})+0.620\omega_{LL}]L=$	365
Continuous 4 or More Span (Interior Span)		
	$V=[0.536(\omega_{DL}+\omega_{SDL})+0.603\omega_{LL}]L=$	339

ULS shear force, V_{ULS} =	**298**	kN

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Unfactored Loads

Live load (unfactored), ω_{LL} =	**14.2**	kN/m
Superimposed dead load (unfactored), ω_{SDL} =	**7.7**	kN/m
Dead load of slab, steel beam and decking (unfactored), ω_{DL} =	**8.9**	kN/m
SLS load, ω_{SLS} =	**30.7**	kN/m

Live Load Bending Moment for Continuous Beam Deflection Calculations

$M_0=0.125\omega_{LL}L^2=$		299	kNm
	M_1	**M_2**	
Simply Supported			
$M_1=0.0=$	0		kNm
$M_2=0.0=$		0	kNm
Continuous 2 Span			
$M_1=0.0=$	0		kNm
$M_2=0.063\omega_{LL}L^2=$		151	kNm
Continuous 3 Span (End Span)			
$M_1=0.0=$	0		kNm
$M_2=0.050\omega_{LL}L^2=$		120	kNm
Continuous 3 Span (Interior Span)			
$M_1=0.050\omega_{LL}L^2=$	120		kNm
$M_2=0.050\omega_{LL}L^2=$		120	kNm
Continuous 4 or More Span (End Span)			
$M_1=0.0=$	0		kNm
$M_2=0.054\omega_{LL}L^2=$		129	kNm
Continuous 4 or More Span (Interior Span)			
$M_2=0.036\omega_{LL}L^2=$	86		kNm
$M_2=0.054\omega_{LL}L^2=$		129	kNm

(Note patch loading that produces MINIMUM support moments whilst span fully uniformly loaded have been adopted for conservatism in the deflection calculations)

M_0 =	**299**	kNm	**M_1 =**	**0**	kNm	**M_2 =**	**0**	kNm
Redistribution of hogging moment for continuous beams, RD =							30.0	%
M_0 =	**299**	kNm	**M_1 =**	**0**	kNm	**M_2 =**	**0**	kNm

BS5950

ULS Construction Loading

Construction loading kPa (for construction stage checks) =	1.5	kPa
UDL of construction load, $\omega_{construct}$ = construction loading kPa . t_w =	4.3	kN/m
Factored UDL of construction load, $1.6\omega_{construct}$ =	6.8	kN/m
Factored DL, $1.4\omega_{DL}$ =	12.4	kN/m
UDL of construction ULS, $\omega_{ULS,construct} = 1.4\omega_{DL} + 1.6\omega_{construct}$ =	19.2	kN/m
Method of construction =	Unpropped Construction	

(Note propped construction will not produce any construction effects, and vice versa)

	Shear (kN)	Sag (kNm)	Hog (kNm)
Simply Supported	125	406	0
Continuous 2 Span	156	257	406
Continuous 3 Span (End Span)	151	284	344
Continuous 3 Span (Interior Span)	132	139	344
Continuous 4 or More Span (End Span)	153	276	364
Continuous 4 or More Span (Interior Span)	140	169	364

(Note calculations based on previous formulae but utilising construction loadings)

ULS construction hogging moment, $M_{ULS,construct,HOG}$ =	**0**	kNm
ULS construction sagging moment, $M_{ULS,construct,SAG}$ =	**406**	kNm
Redistribution of hogging moment for continuous beams, RD =	30.0	%
ULS construction hogging moment, $M_{ULS,construct,HOG} = (1\text{-}RD)M_{ULS,construct,HOG}$ =	**0**	kNm
ULS construction sag moment, $M_{ULS,construct,SAG} = M_{ULS,construct,SAG} + RD.M_{ULS,construct,HOG}$ =	**406**	kNm
ULS construction shear force, $V_{ULS,construct}$ =	**125**	kN

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ULS Steel Beam Cross Section Classification					*BS5950*
(At Least Compact Section)					
Web, d/t (compact 100ε) =	47.2 <	100.0	**47%**		**OK**
Flange, b/T (compact <= 10ε rolled, 9ε welded) =	6.7 <	10.0	**67%**		**OK**
Section classification utilisation =			**67%**		**OK**
(Note the beam section must be at least compact for plastic composite beam equations to apply)					
ULS Shear Capacity					
(With Low or High Shear Force)					
Rolled I Shear X Area, A_v = tD =			5384	mm^2	
Welded I Shear X Area, A_v = t(D-2T) =			N/A	mm^2	
$P_v = 0.6p_yA_v$ =			**888**	kN	
Shear capacity utilisation = V_x / P_v			**34%**		**OK**
Shear buckling (<= 70ε rolled, 62ε welded), d/t =		47.2 <	70.0		
Shear buckling utilisation = (d/t) / (70ε or 62ε) =			**67%**		**OK**

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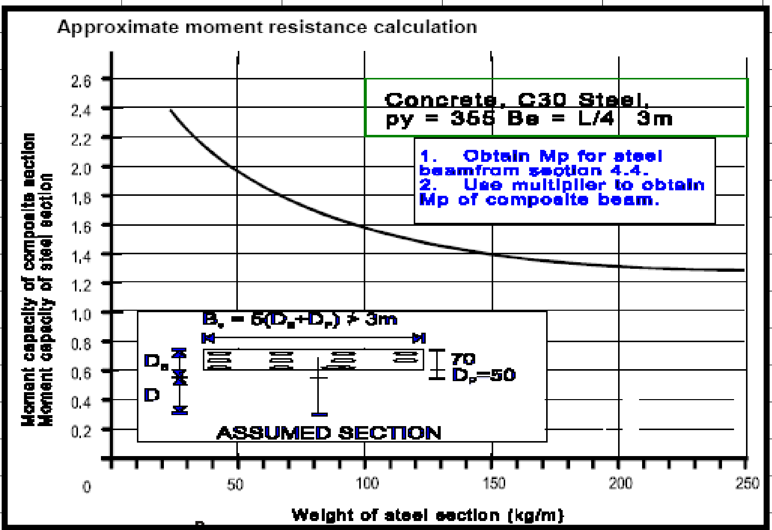
Member Design - Steel Composite Beam		Made by XX	Date 21/11/2021	Chd.

ULS Sagging Moment Capacity

(With Low or High Shear Force; At Least Compact Section)

Compression capacity of concrete effective slab, $R_c = (D_s\text{-}D_p) \times B_e \times 0.45 \times f_{cu}$=		3749	kN
Tensile capacity of steel, $R_s = p_yA_s$ =		3218	kN
Tensile capacity of one steel flange, $R_f = p_yA_f$ =		898	kN
Tensile capacity of overall web depth, $R_w = (R_s\text{-}2R_f)$ =		1422	kN
Tensile capacity of clear web depth, $R_v = dtp_y$ =		1323	kN
Shear stud capacity between zero and max sagging, $R_q = N_a.P_d$ =		2134	kN
Profile reduction, r = – for one stud per trough $k = 0.63\,(b_r/D_p)\{(h/D_p) - 1\}$ but ≤ 0.82; – for two studs per trough $k = 0.34\,(b_r/D_p)\{(h/D_p) - 1\}$ but ≤ 0.45		0.45	
(Note r limits for perpendicular deck; 0.60 used for parallel)			
Number of studs per section, N =		2	
Stud height, h = MIN (h, $2D_p$) =		92	mm
Average trough width, b_a =		132	mm
Depth of profile decking, D_p =		46	mm
Number of studs provided, $N_a = [N.(L/s_l)]/2$ s/s and $[N.(0.7L/s_l)]/2$ continuous		57	
Capacity of 1 shear stud based on prop table (ϕ, h, f_{cu}), P_c =		104	kN
Design capacity of 1 shear stud in sagging, $0.8P_c$ =		83	kN
Design capacity of 1 shear stud in sagging, P_d =		37	kN
(for LWC P_d=0.9r(0.8P_c), NWC P_d=1.0r(0.8P_c))			
Plastic moment capacity of steel alone, $M_s = s_x.p_y <= 1.2Z_x.p_y$ =		**649**	kNm
Plastic moment capacity of composite section, M_{pc} or M_c =	**Case 4**	**1079**	kNm
Plastic moment capacity of composite section (high shear force), M_{cv} =		**1079**	kNm
Applicability of high shear force (if $F_v > 0.5P_v$)		**Low Shear**	
$M_{cv} = M_c - (M_c - M_f)\,(2F_v/P_v - 1)^2$	F_v = 0.0 at midspan =	0	kN
	P_v =	888	kN
Moment capacity of steel minus web area, $M_f = BT(D\text{-}T)p_y$ =		465	kNm
Plastic moment capacity utilisation = $M_{ULS,SAG} / M_{cv}$ =		**90%**	**OK**



M_s =	649	kNm
Mass =	92.1	kg/m

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		jXXX	13	
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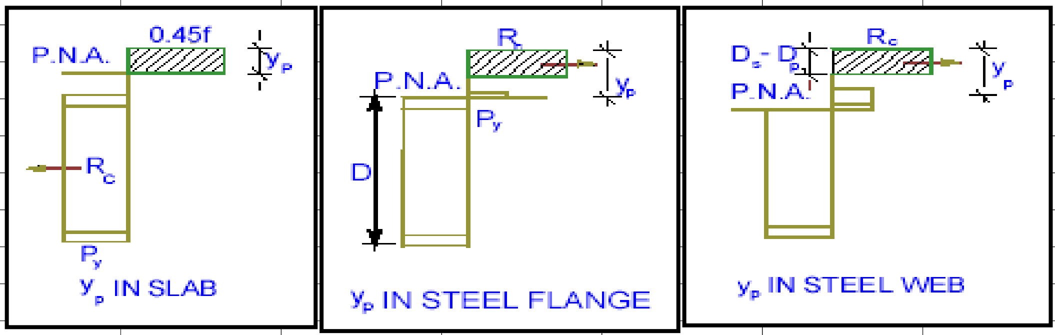
BS5950



Case 1: $R_c > R_s$ (plastic neutral axis lies in concrete slab):
(and full shear connection)

$$M_{pc} = R_s \left[\frac{D}{2} + D_s - \frac{R_s}{R_c} \left(\frac{D_s - D_p}{2} \right) \right]$$

INVALID **N/A** kNm

Case 2: $R_s > R_c > R_w$ (plastic neutral axis lies in steel flange):
(and full shear connection)

$$M_{pc} = R_s \frac{D}{2} + R_c \left(\frac{D_s + D_p}{2} \right) - \frac{(R_s - R_c)^2}{R_f} \frac{T}{4}$$

INVALID **N/A** kNm

Case 3: $R_c < R_w$ (plastic neutral axis lies in web):
(and full shear connection)

$$M_{pc} = M_s + R_c \left(\frac{D_s + D_p + D}{2} \right) - \frac{R_c^2}{R_w} \frac{D}{4}$$

INVALID **N/A** kNm

Degree of shear connection achieved **66% Partial Shear Connection Achieved**

R_q	<	R_c
R_q	<	R_s

(Note that either R_c or R_s need to be less than R_q for full shear connection)

Degree of shear connection achieved, K = R_q/MIN(R_s, R_c) =	66.3%	
Minimum allowable K_{MIN} = MAX[1-(355/p_y)(0.80-0.03L), 0.4] =	47.1%	
Minimum shear connection utilisation = 1-(K-K_{MIN})/(1-K_{MIN}) =	**64%**	**OK**

Case 4: $R_q > R_w$ (plastic neutral axis lies in flange):

$$M_c = R_s \frac{D}{2} + R_q \left[D_s - \frac{R_q}{R_c} \left(\frac{D_s - D_p}{2} \right) \right] - \frac{(R_s - R_q)^2}{R_f} \frac{T}{4}$$

NB the last term in this expression is generally small.

VALID **1079** kNm

Case 5: $R_q < R_w$ (plastic neutral axis lies in web):

$$M_c = M_s + R_q \left[\frac{D}{2} + D_s - \frac{R_q}{R_c} \left(\frac{D_s - D_p}{2} \right) \right] - \frac{R_q^2}{R_w} \frac{D}{4}$$

INVALID **N/A** kNm

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ULS Hogging Moment Capacity				BS5950
(With Low or High Shear Force; At Least Compact Section)				
Effective width for hogging moment, $B_{e,hog}$ =		N/A	mm	
Tensile capacity of the reinforcement over width $B_{e,hog}$, $R_r = A_{s,prov,h}.B_{e,hog}.f_y$ =		N/A	kN	
Height of reinforcement above top of beam, $D_r = D_s$ - cover =		105	mm	
Shear stud capacity between zero and max hogging, $R_q = N_a.P_{d,hog}$ =		786	kN	
Number of studs per section, N =		2		
Number of studs provided, $N_a = [N.(0.5L/s_l)]/2$ =		28		
Design capacity of 1 shear stud in sagging, P_d =		37	kN	
Design capacity of 1 shear stud in hogging, $P_{d,hog} = (.6/.8).P_d$ =		28	kN	
Plastic moment capacity of steel alone, $M_s = s_x.p_y <= 1.2Z_x.p_y$ =		**649**	kNm	
Plastic moment capacity of composite section, M_{pc} or M_c =	**N/A**	**N/A**	kNm	
Plastic moment capacity of composite section (high shear force), M_{cv} =		**N/A**	kNm	
Applicability of high shear force (if $F_v > 0.5P_v$)		**Low Shear**		
$M_{cv} = M_c - (M_c - M_f)(2F_v/P_v - 1)^2$ — $F_v = V_{ULS}$ at supports =		298	kN	
P_v =		888	kN	
Moment capacity of steel minus web area, $M_f = BT(D-T)p_y$ =		465	kNm	
Plastic moment capacity utilisation = $M_{ULS,HOG} / M_{cv}$ =		**N/A**		**N/A**

Case 1: $R_r < R_w$ (plastic neutral axis lies in web):

$M_{nc} = M_s + R_s\left(\frac{D}{2} + D_r\right) - \frac{R_q^2}{R_w}\frac{D}{4}$	**N/A**	**N/A**	kNm

Case 2: $R_r > R_w$ (plastic neutral axis lies in flange):

$M_{nc} = R_s\frac{D}{2} + R_r D_r - \frac{(R_s - R_r)^2}{R_f}\frac{T}{4}$	**N/A**	**N/A**	kNm

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		Member/Location	
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Member Design - Steel Composite Beam		Made by **XX**	Date **21/11/2021**	Chd.

SLS Deflection *BS5950*

At Construction

Dead load of slab, steel beam and decking (unfactored), ω_{DL} =		8.9	kN/m
Deflection of steel $\delta_{s,construct,dl} = 5\omega_{DL}L^4/(384EI_x).(1-0.6(M_1+M_2)/M_0)$ =	(Unpropped)	**29.1**	mm

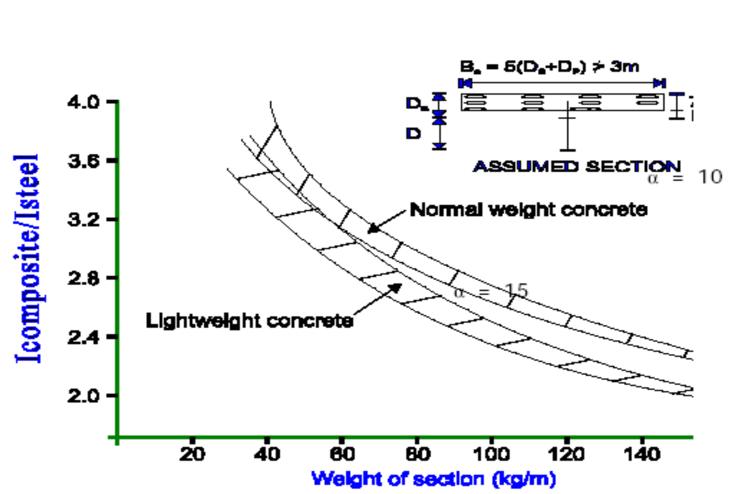
At Service

Live load (unfactored), ω_{LL} =		14.2	kN/m
Superimposed dead load (unfactored), ω_{SDL} =		7.7	kN/m
$\omega_{LL} + \omega_{SDL}$ =		21.8	kN/m
Proportion of imposed $\omega_{LL} + \omega_{SDL}$ that is permanent (i.e. ω_{SDL}), pl = $\omega_{SDL}/(\omega_{LL}+\omega_{SDL})$ x 100%		35.1	%
Short-term modular ratio, α_s (6 if NWC and 10 if LWC) =		6.0	
Long-term modular ratio, α_l (18 if NWC and 25 if LWC) =		18.0	
Combined modular ratio, $\alpha_e = \alpha_s + pl(\alpha_l - \alpha_s)$ =		10.2	
$r = A/[(D_s - D_p)B_e]$	=	0.045	

(Note concrete flange uncracked if $x_e > D_s - D_p$ and cracked if $x_e < D_s - D_p$)

Uncracked NA	$x_e = \dfrac{\dfrac{D_s - D_p}{2} + \alpha_e r\left(\dfrac{D}{2} + D_s\right)}{(1 + \alpha_e r)}$	**VALID**	153	mm
Uncracked Ic	$I_c = \dfrac{A(D + D_s + D_p)^2}{4(1 + \alpha_e r)} + \dfrac{B_e(D_s - D_p)^3}{12\,\alpha_e} + I$	**VALID**	1574607347	mm^4
Cracked NA	$x_e = [D+2D_s]/[1+(1+B_e(D+2D_s)/A\alpha_e)^{0.5}]$ =	**INVALID**	145	mm
Cracked Ic	$I_c = I_x + (B_e x_e^3)/(3\alpha_e) + A(D/2+D_s-x_e)^2$ =	**INVALID**	1574667982	mm^4
	Hence valid neutral axis depth, x_e =		153	mm
	Hence valid composite second moment of area, I_c =		**1574607347**	mm^4

Approximate ratio of second moment of area of composite section to that of the steel section.



I_x =	552270000	mm^4
Mass =	92.1	kg/m

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Section modulus for steel in tension	$Z_t = I_c/(D + D_s - x_c)$ =	3089305	mm^3
Section modulus for concrete in compression	$Z_c = I_c\ \alpha_c/x_c$ =	104777527	mm^3
Type of beam support conditions =		Simply Supported	

Live Load Deflection

Deflection fully composite section s/s beam, $\delta_{c,f,ll} = 5\omega_{LL}L^4/(384EI_c)$ =		16.3	mm
Deflection steel section s/s beam, $\delta_{s,ll} = 5\omega_{LL}L^4/(384EI_x)$ =		46.5	mm
Degree of shear connection achieved, K =		66.3%	
Deflection partially composite s/s beam, $\delta_{c,p,ll}$ =		19.4	mm
Propped construction $\delta_{c,p,ll} = \delta_{c,f,ll} + 0.5(1 - K)(\delta_{s,ll} - \delta_{c,f,ll})$			
Unpropped construction $\delta_{c,p,ll} = \delta_{c,f,ll} + 0.3(1 - K)(\delta_{s,ll} - \delta_{c,f,ll})$			
Deflection partially composite continuous beam, $\delta_{c,p,ct,ll} = \delta_{c,p,ll}$. $(1\text{-}0.6(M_1+M_2)/M_0)$ =		**19.4**	mm
(Equation reduces to that for s/s if s/s)			
Moment for simply supported beam, M_0 =		299.3	kNm
Moment at support 1, M_1 =		0.0	kNm
Moment for support 2, M_2 =		0.0	kNm
Live load deflection utilisation = $\delta_{c,p,ct,ll}$ / (L/360) =		**54%**	

SLS Load Deflection

Percentage of dead and superimposed dead load deflection precamber, %pcam =		0.0	%
Deflection partially composite continuous beam, $\delta_{c,p,ct,sls}$ =		**59.0**	mm
Deflection, $\delta_{c,p,ct,sls} = \delta_{c,p,ct,ll}$. ((1-%pcam). $\omega_{DL+SDL} + \omega_{LL}$) / ω_{LL} *for propped construction*			
Deflection, $\delta_{c,p,ct,sls}$ = (1-%pcam). $\delta_{s,construct,dl} + \delta_{c,p,ct,ll}$. ((1-%pcam). $\omega_{SDL} + \omega_{LL}$) / ω_{LL} *for unpropped construc*			
SLS load deflection utilisation = $\delta_{c,p,ct,sls}$ / (L/200) =		**91%**	
Dead and superimposed dead load deflection precamber, DL+SDL precamber =		**0.0**	mm
DL+SDL precamber = $\delta_{c,p,ct,ll}$. (%pcam. ω_{DL+SDL}) / ω_{LL} *for propped construction*			
DL+SDL precamber = %pcam. $\delta_{s,construct,dl} + \delta_{c,p,ct,ll}$. (%pcam. ω_{SDL}) / ω_{LL} *for unpropped construction*			

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SLS Steel and Concrete Stresses

At Construction

Dead load of slab, steel beam and decking (unfactored), ω_{DL} =		8.9	kN/m	
Moment due to dead load, M_{DL} =		187	kNm	
Simply Supported	$M_{DL}=0.125\omega_{DL}L^2=$	187	kNm	
Continuous 2 Span	$M_{DL}=0.070\omega_{DL}L^2=$	105	kNm	
Continuous 3 Span (End Span)	$M_{DL}=0.080\omega_{DL}L^2=$	120	kNm	
Continuous 3 Span (Interior Span)	$M_{DL}=0.025\omega_{DL}L^2=$	37	kNm	
Continuous 4 or More Span (End Span)	$M_{DL}=0.077\omega_{DL}L^2=$	115	kNm	
Continuous 4 or More Span (Interior Span)	$M_{DL}=0.036\omega_{DL}L^2=$	54	kNm	
(Note propped construction will not produce any construction effects, and vice versa)				
Stress in steel section, $\sigma_{s1} = M_{DL}/Z_x$ =		90	N/mm^2	

At Service

SLS load excluding DL (for unpropped) = $\omega_{SLS} - \omega_{DL}$ =		21.8	kN/m	
SLS load (for propped), ω_{SLS} =		30.7	kN/m	
Moment due to SLS load, M_{SLS} =		461	kNm	
Simply Supported	$M_{SLS}=0.125\omega L^2=$	461	kNm	
Continuous 2 Span	$M_{SLS}=0.070\omega L^2=$	258	kNm	
Continuous 3 Span (End Span)	$M_{SLS}=0.080\omega L^2=$	295	kNm	
Continuous 3 Span (Interior Span)	$M_{SLS}=0.025\omega L^2=$	92	kNm	
Continuous 4 or More Span (End Span)	$M_{SLS}=0.077\omega L^2=$	284	kNm	
Continuous 4 or More Span (Interior Span)	$M_{SLS}=0.036\omega L^2=$	133	kNm	
Additional stress in steel section, $\sigma_{s2} = M_{SLS}/Z_t$ =		149	N/mm^2	
Final stress in steel section = $\sigma_{s1} + \sigma_{s2}$ =		**240**	N/mm^2	
Final stress in steel section utilisation = $(\sigma_{s1} + \sigma_{s2})/p_y$ =		**87%**		**OK**
Stress in concrete section, $\sigma_c = M_{SLS}/Z_c$ =		**4.4**	N/mm^2	
Stress in concrete section utilisation = σ_c / $(0.5f_{cu})$ =		**25%**		**OK**

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ULS Construction Shear Capacity (1.4 x DL + 1.6 x Construction Loading)

(With Low Shear Force)

Rolled I shear X area, A_v = tD =	5384	mm^2	
Welded I shear X area, A_v = t(D-2T) =	N/A	mm^2	
$P_v = 0.6 p_y A_v$ =	**888**	kN	
ULS construction shear force, $V_{ULS,construct}$ =	125	kN	
Construction shear capacity utilisation = $V_{ULS,construct}$ / $(0.6 P_v)$ =	**23%**		**OK**

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Member Design - Steel Composite Beam		Made by XX	Date 21/11/2021	Chd.	

ULS Construction Sagging Moment Capacity (1.4 x DL + 1.6 x Construction Loading)			*BS5950*
(With Low Shear Force; At Least Compact Section)			
LTB effective length, $L_{LTB,SAG}$ =	14.1	m	
Minor axis slenderness, $\lambda = L_{LTB,SAG}/r_y$ =	311.9		
Taking β_w = 1 for plastic and compact sections =	1.0		
Equivalent slenderness, $\lambda_{LT} = uv\lambda(\beta_w)^{0.5}$ =	185.2		
Buckling parameter, u =	0.872		
Torsional index, x =	36.5		
λ / x =	8.54		
Slenderness factor, ν =	0.681		
Bending strength, p_b =	46	N/mm²	
λ_{LT} =	185.2		
Euler stress, p_E =	59	N/mm²	
p_y =	275	N/mm²	
ϕ_{LT} =	198	N/mm²	
Limiting equivalent slenderness, λ_{L0} =	34.3		
Robertson constant, a_{LT} =	7.0		
Perry factor, η_{LT} =	1.056		
Plastic modulus, s_x (but <= $1.2Z_x$) =	2360	cm³	
Equivalent uniform moment factor for LTB, m_{LT} =	1.0		*T.18*
Buckling resistance, $M_b/m_{LT} = s_x p_b/m_{LT}$ =	**109**	kNm	
LTB restraint provided by decking =	Decking perpendicular, comp flange restrained		
Moment capacity, $M_{cap,construct} = p_y s_x$ (restrained) or M_b/m_{LT} (unrestrained) =	**649**	kNm	
Construction sagging bending moment, $M_{ULS,construct,SAG}$ =	406	kNm	
Construction moment capacity utilisation = $M_{ULS,construct,SAG}$ / $M_{cap,construct}$ =	**63%**		**OK**

$$\nu = \frac{1}{[1 + 0.05(\lambda/x)^2]^{0.25}}$$

$$p_b = \frac{p_E p_y}{\phi_{LT} + (\phi_{LT}^2 - p_E p_y)^{0.5}}$$

$$p_E = (\pi^2 E/\lambda_{LT}^2)$$

$$\phi_{LT} = \frac{p_y + (\eta_{LT} + 1)p_E}{2}$$

$$\lambda_{L0} = 0.4(\pi^2 E/p_y)^{0.5}$$

The Perry factor η_{LT} should be taken as follows:

a) for rolled sections:

$\eta_{LT} = \alpha_{LT}(\lambda_{LT} - \lambda_{L0})/1\,000$ but $\eta_{LT} \geq 0$

b) for welded sections:

— if $\lambda_{LT} \leq \lambda_{L0}$: $\eta_{LT} = 0$
— if $\lambda_{L0} < \lambda_{LT} < 2\lambda_{L0}$: $\eta_{LT} = 2\alpha_{LT}(\lambda_{LT} - \lambda_{L0})/1\,000$
— if $2\lambda_{L0} \leq \lambda_{LT} \leq 3\lambda_{L0}$: $\eta_{LT} = 2\alpha_{LT}\lambda_{L0}/1\,000$
— if $\lambda_{LT} > 3\lambda_{L0}$: $\eta_{LT} = \alpha_{LT}(\lambda_{LT} - \lambda_{L0})/1\,000$

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		Member/Location		
Job Title	Member Design - Steel Composite Beam BS5950 v2015.02.xlsm	Drg.		
Member Design - Steel Composite Beam		Made by **XX**	Date **21/11/2021**	Chd.

ULS Construction Hogging Moment Capacity (1.4 x DL + 1.6 x Construction Loading)			*BS5950*
(With Low Shear Force; At Least Compact Section)			
LTB effective length, $L_{LTB,HOG}$ =	12.116	m	
Minor axis slenderness, $\lambda = L_{LTB,HOG}/r_y$ =	268.7		
Taking β_w = 1 for plastic and compact sections =	1.0		
Equivalent slenderness (unrestrained tension flange), $\lambda_{LT} = uv\lambda(\beta_w)^{0.5}$ =	N/A		
Equivalent slenderness (restrained tension flange) $\lambda_{TB} = n_t u v_t \lambda$	152.7		
Slenderness correction factor, n_t =	1.00		G.4.3
Buckling parameter, u =	0.872		
Torsional index, x =	36.5		
λ / x =	7.4		
Slenderness factor, ν or ν_t =	0.652		
Restraint above beam shear centre, a = d/2 =	238	mm	
Clear web depth, h_s = d =	477	mm	
Decking perpendicular, tension flange restrained			

$$\nu = \frac{1}{[1+0.05(\lambda/x)^2]^{0.25}}$$

Unrestrained tension flange

$$\nu_t = \left[\frac{4a/h_s}{1+(2a/h_s)^2+0.05(\lambda/x)^2}\right]^{0.5}$$

Restrained tension flange

Bending strength, p_b =	65	N/mm²	

$$p_b = \frac{p_E p_y}{\phi_{LT}+(\phi_{LT}^2-p_E p_y)^{0.5}}$$

$$p_E = (\pi^2 E/\lambda_{LT}^2)$$

$$\phi_{LT} = \frac{p_y+(\eta_{LT}+1)p_E}{2}$$

λ_{LT} or λ_{TB} =	152.7		
Euler stress, p_E =	87	N/mm²	
p_y =	275	N/mm²	
ϕ_{LT} =	217	N/mm²	
Limiting equivalent slenderness, λ_{L0} = $0.4(\pi^2 E/p_y)^{0.5}$	34.3		
Robertson constant, a_{LT} =	7.0		
Perry factor, η_{LT} =	0.829		

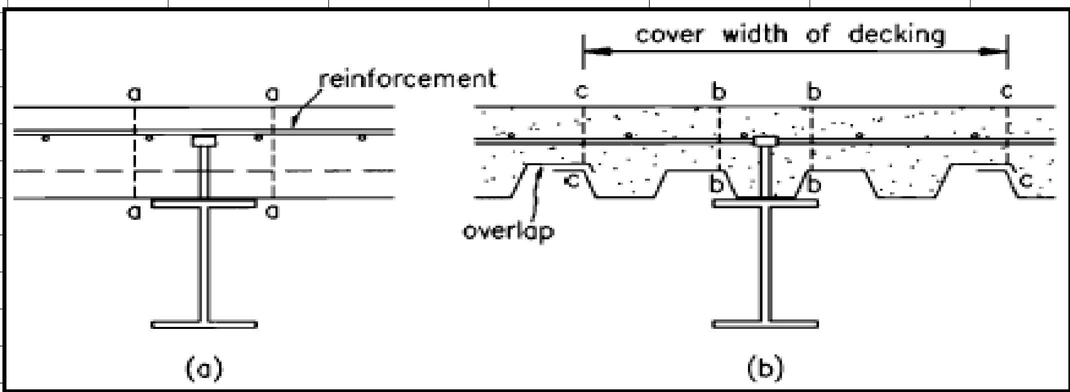
The Perry factor η_{LT} should be taken as follows:
a) for rolled sections:
$\eta_{LT} = \alpha_{LT}(\lambda_{LT}-\lambda_{L0})/1\,000$ but $\eta_{LT} \geq 0$

b) for welded sections:
- if $\lambda_{LT} \leq \lambda_{L0}$: $\eta_{LT} = 0$
- if $\lambda_{L0} < \lambda_{LT} < 2\lambda_{L0}$: $\eta_{LT} = 2\alpha_{LT}(\lambda_{LT}-\lambda_{L0})/1\,000$
- if $2\lambda_{L0} \leq \lambda_{LT} \leq 3\lambda_{L0}$: $\eta_{LT} = 2\alpha_{LT}\lambda_{L0}/1\,000$
- if $\lambda_{LT} > 3\lambda_{L0}$: $\eta_{LT} = \alpha_{LT}(\lambda_{LT}-\lambda_{L0})/1\,000$

Plastic modulus, s_x (but <= $1.2Z_x$) =	2360	cm³	
Equivalent uniform moment factor for LTB, m_{LT} or m_T =	1.0		*T.18 or G.4.2*
Buckling resistance, $M_{cap,construct} = M_b/(m_{LT}$ or $m_T) = s_x p_b/(m_{LT}$ or $m_T)$ =	**153**	kNm	
Construction hogging bending moment, $M_{ULS,construct,HOG}$ =	0	kNm	
Construction moment capacity utilisation = $M_{ULS,construct,SAG}$ / $M_{cap,construct}$ =	**N/A**		**N/A**

ULS Transverse Reinforcement *BS5950*

Longitudinal shear force per unit length, $\nu = NP_d/s_l$ =	333	kN/m	
Number of studs per trough, N =	2		
Shear stud design capacity, P_d =	37	kN	
Longitudinal (with respect to beam) stud pitch, s_l =	225	mm	
Longitudinal shear force per unit length per shear plane, $\nu/2$ =	**166**	kN/m	
Shear resistance, $\nu_r = 0.7A_{sv}f_y + 0.03\eta A_{cv}f_{cu} + \nu_p$ (but < $0.8\eta A_{cv}(f_{cu})^{0.5}$) =	**506**	kN/m	
Area of transverse steel per length of beam, $A_{sv} = (\pi\phi_t^2/4)/s_t + area_{add}$ =	**444**	mm^2/m	
Min required reinforcement area = 0.13% . (D_s-D_p) . 1000 =	**109**	mm^2/m	
Strength of rebars, f_y =	460	N/mm^2	
Factor, η = 1.0 for NWC and 0.8 for LWC =	1.0		
Mean area of concrete flange, $A_{cv} = (2D_s-D_p)/2$. 1000 =	107000	mm^2/m	
Compressive strength of concrete, f_{cu} =	35.0	N/mm^2	
Contribution of steel decking, $\nu_p = t_p p_{yp}$ =	280	kN/m	
(Only if decking is perpendicular, otherwise 0.0)			
Thickness of steel decking, t_p =	1.00	mm	
Design strength of steel decking, p_{yp} =	280	N/mm^2	
Transverse steel utilisation = MAX $(1-(A_{sv}$-min area$)/A_{sv}, \nu/(\nu_r/2))$ =	**33%**		**OK**



ULS Connection Force — *BS5950*

Shear force at either end of beam = V_{ULS} =	**298**	kN	
Moment at either end of beam = M_{ULS} =	**0**	kNm	