ECHOLLOWSLAB Precast Concrete Hollowcore Slab Design	**Job :** Precast Concrete Hollow Core Slab 6 _ v1
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1.0 INTRODUCTION

This calculation report presents the design of a precast hollow core slab for the input parameters defined in section 2.0. The report is auto generated from the cloud software www.ecplusdesign.com.

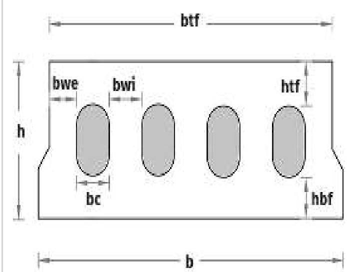
2.0 INPUT

3.0 INPUT

3.1 Design Options

Design Code **European Standard (EN 1992 : 1 - 1 : 2004)**

Unit **SI Unit**



3.2 Geometry

Effective Span	L_e	=	**8500** mm
Bearing Width	L_b	=	**85** mm

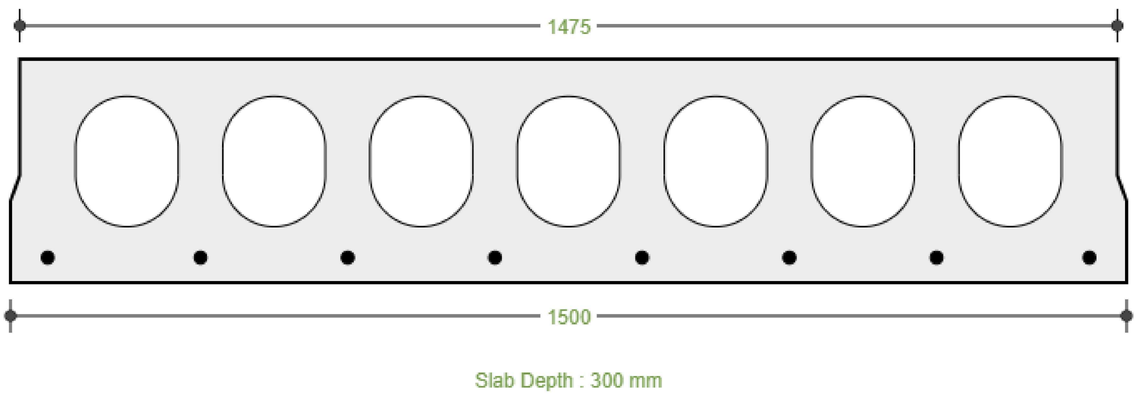
3.3 Slab Details

Width of Bottom Flange	b	=	**1500** mm
Width of Top Flange	b_{tf}	=	**1475** mm
Slab Depth	h	=	**300** mm
Top Flange Thickness	h_{tf}	=	**50** mm
Inner Rib Width	b_{wi}	=	**60** mm
End Rib Width	b_{we}	=	**75** mm
Number of Cores	N	=	**7**

3.4 Section Properties

User Defined

Cross Section Area	A_c	=	**251000** mm^2
Height to neutral axis from bottom	h_{NA}	=	**149.4** mm
First Moment of Area	S_C	=	**11800000** mm^3
Moment of Inertia	I_c	=	**2700000000** mm^4



HOLLOW CORE SLAB SECTION

3.5 Strand Layout Details

7.0 Φ Strands	No	=	**8**
Cover to Center of Strand	C_s	=	**33.5** mm
Max. Nos at a web	MNo	=	**1**

3.6 Loads and Factors

3.6.1 Load Factors

Partial Factor for Permanent Loads	γ_G	=	**1.35**
Partial Factor for Variable Loads	γ_Q	=	**1.5**
Quasi-Permanent Variable Load Factor	Ψ	=	**0.3**

3.6.2 Loads

Live Load	F_{live}	=	**5.0** kN/m²
Partitions	F_{part}	=	**2.0** kN/m²
Finishes	F_{fin}	=	**1.0** kN/m²

3.7 National Annex

Nation		=	**Malaysia**

3.8 Reinforced Concrete Properties (BS EN 1992-1-1)

Density of Concrete	γ_{conc}	=	**25** kN/m³
Specified Compressive Cylinder Strength	f_{ck}	=	**70** N/mm²
Maximum Aggregate Size	h_{agg}	=	**30** mm
Aggregate Type		=	**Basalt**
Cement Class		=	**N**

3.9 Prestressing Strand Data

National Standard		=	**BS5896-1980**
Strand Type/Grade	Type	=	**Stabilised (Wire)**
Strand Class		=	**1**
Bond Condition	Cond.	=	**Good**
Characteristic Strain at Maximum Load	ε_{uk}	=	**0.022**

Modulus of Elasticity	E_p	= **204** kN/mm²

3.10 Tendon Release Data

Release Type	R	= **Gradual**
Installation Time	Inst.	= **Two(2) Months**
Loading Time	Loading	= **Six(6) Months**
Tendon Release	t_0	= **72** hours

3.11 Deflection Limits

Initial Camber at Time of Storing	= **Span/300**
Camber after Installation	= **Span/360**
Long Term Deflection due to Quasi-Permanent	= **Span/360**

3.12 Relative Humidity

Exposed Faces		= **Bottom Face Only**
Relative Humidity at Release	R_{Hr}	= **65** %
Ambient Relative Humidity	R_{Ha}	= **45** %

4.0 OUTPUT

Ref: EN 1992:1-1-2004 + National Annex*

** Marked references indicate the factors and provisions from the relevant national annex.*

Width of the core	b_c	$= (b_{tf} - 2 * b_{we} - (N - 1) * b_{wi}) / N =$ **137.9** mm
Total Width of Ribs	b_{wt}	$= (N-1) * b_{wi} + 2 * b_{we} =$ **510** mm
Self Weight	F_{swt}	$= A_c * \gamma_{conc} / b =$ **4.18** kN/m²

4.1 Concrete Properties at 28 Days

Partial Factor - Concrete γ_C = **1.5** *Cl:2.4.2.4(1)*

Partial Factor - Prestressing Steel γ_S = **1.15** *Cl:2.4.2.4(1)*

Allowable characteristic compressive cylinder strength for shear

f_{ckv} = min (50 , f_{ck}) = **50** N/mm² *Cl:3.1.2(2)**

Strength coefficient for Flexure and Axial Loading due to long term and unfavourable effects

α_{cc} = **0.85** *Cl:3.1.6(1)**

Design Compressive Strength for Flexure and Axial Loading

$f_{cd} = \alpha_{cc} * f_{ck} / \gamma_C$ = **39.67** N/mm² *Table 2.1*

Strength coefficient for Shear due to long term and unfavourable effects

α_{ccv} = **1.0** *Cl:3.1.6(1)**

Design Compressive Strength for Shear

$f_{cdv} = \alpha_{ccv} * f_{ckv} / \gamma_C$ = **33.33** N/mm² *Cl:3.1.6(1)*

Mean Value of Concrete Cylinder Compressive Strength

$f_{cm} = f_{ck} + 8$ = **78** N/mm²

for shear $f_{cmv} = f_{ckv} + 8$ = **58** N/mm²

Mean Value of Axial Tensile Strength $f_{ctm} = 2.12 * \ln(1 + f_{cm}/10)$ = **4.61** N/mm²

for shear $f_{ctmv} = 0.3 * f_{ckv}^{2/3}$ = **4.07** N/mm²

Secant Modulus of Elasticity for the **Basalt** aggregate type

	E_{cm}	$= 1.2 * 22 * (f_{cm} / 10)^{0.3}$ = **48891.4** N/mm²	
Characteristic Axial Tensile Strength - 5% Fractile			
	f_{ctk}	$= 0.7 * f_{ctmv}$ = **2.85** N/mm²	
Tensile Strength coefficient	α_{ct}	= **1.0**	*Cl:3.1.6(2)*
Design Tensile Strength	f_{ctd}	$= \alpha_{ct} * f_{ctk} / \gamma_C$ = **1.9** N/mm²	*Cl:3.1.6(2)*
Ultimate Compressive Strain	ε_{cu3}	$= (2.6 + 35 * ((90 - f_{ck}) /100)^4)/1000$ = **0.00266**	

4.2 Concrete Properties at Release (After 72 hours)

Cement type coefficient	s	= **0.25**	*cl.3.1.2(6)*
Time Dependent Compressive Strength coefficient			
	β_{cct}	$= e^{(s * (1 - (28 / t_0)^{0.5}))}$ = **0.60**	*exp. 3.2*
Mean Value of Compressive Strength	f_{cmt}	$= \beta_{cct} * f_{cm}$ = **46.66** N/mm²	*exp.3.1*
Mean Value of Axial Tensile Strength	f_{ctmt}	$= \beta_{cct} * f_{ctm}$ = **2.76** N/mm²	*exp.3.4*
Characteristic Axial Tensile Strength - 5% Fractile			
	$f_{ctk, 0.05t}$	$= 0.7 * f_{ctmt}$ = **1.93** N/mm²	
Mean value of axial tensile strength for shear			
	f_{ctmvt}	$= \beta_{cct} * f_{ctmv}$ = **2.44** N/mm²	
Characteristic Compressive Cylinder Strength			
	f_{ckt}	$= f_{cmt} - 8$ = **38.66** N/mm²	*cl.3.1.2(5)*
Secant Modulus of Elasticity	E_{cmt}	$= (f_{cmt} / f_{cm})^{0.3} * E_{cm}$ = **41907.8** N/mm²	*exp.3.5*

4.3 Initial Prestressing Force

Strand - 7.0 Φ (dia)			
Area per Strand	A_{ps}	= **38.5** mm²	
Nominal Tensile Strength	f_{pks}	= **1860** N/mm²	
Characteristic 0.1% Proof Load	$F_{p0.1s1}$	= **53** kN	
Total Area of Prestressing Strands	A_p	$= No * A_{ps}$ = **308**mm²	
Strand dia	Φ_{s1}	= dia = **7** mm	
Height to Steel Centroid	h_{cp}	$= c_s$ = **33.5** mm	
Eccentricity of Prestressing Strands	Z_{cp}	$= h_{NA} - h_{cp}$ = **115.9** mm	
Average Characteristic Tensile Strength	f_{pk}	$= f_{pks}$ = **1860** N/mm²	
Characteristic 0.1% Proof - Stress	$f_{p0.1k}$	$= No * F_{p0.1s1} / A_p$ = **1376.6** N/mm²	
Maximum Stress Factors	k_1	= **0.8**	*cl.5.10.2.1(1)*
	k_2	= **0.9**	
Max. Stress Applied to the Tendon	σ_{pmax}	$= \min(k_1 * f_{pk}, k_2 * f_{p0.1k})$ = **1239.0** N/mm²	*cl.5.10.2.1(1)*
Force Applied to Tendons	P_{max}	$= A_p * \sigma_{pmax}$ = **381.6** kN	*exp.5.41*
Limiting Prestressing Force	P_{lim}	$= 0.7 * f_{pk} * A_p$ = **401.0** kN	*cl.3.3.2(5)*
Absolute Value of Initial Prestress	σ_{pi}	$= \min(P_{max}, P_{lim}) / A_p$ = **1239.0** N/mm²	

4.4 Net Prestressing Force after Losses

4.4.1 Initial Losses

4.4.1.1 Short Term Relaxation Loss

Tensor Release Time	time	= **72** hours

Relaxation Percentage Loss at 1000 Hours after Prestressing

	ρ_{1000}	= **8** %	*cl.3.3.2(6)*
Stress Ratio	μ	= σ_{pi} / f_{pk} =**0.666**	

Absolute Value of the Relaxation Losses of the Prestress for class 1

	$\Delta_{\sigma pr}$	= σ_{pi} * 5.39 * ρ_{1000} * $e^{(6.7 * \mu)}$ * $(time/1000)^{0.75*(1-\mu)}$*$10^{-5}$ = **24.0** N/mm²	*exp.3.29*
Prestress Just Before Release	σ_{pr}	= σ_{pi} - $\Delta_{\sigma pr}$ = **1215.0** N/mm²	

4.4.1.2 Elastic Deformation Loss due to Prestress

Force in Tendons	P	= σ_{pr} * A_p = **374.2** kN	
Stress in Concrete at Tendons	f_c	= P / A_c + P * Z_{cp}^2 / I_c = **3.35** N/mm²	
Elastic Deformation Loss due to Prestress			
	Δ_{Pel}	= E_p / E_{cmt} * f_c = **16.3** N/mm²	

4.4.2 Total of Initial Losses

Prestress after Initial Losses	σ_{pmo}	= σ_{pi} - $\Delta_{\sigma pr}$ - Δ_{Pel} = **1198.7** N/mm²	
Tendon Stress Factors	k_7	= **0.75**	*cl.5.10.3(2)*
	k_8	= **0.85**	
Maximum Value of Prestress after Initial Losses			
	$\sigma_{pmo, max}$	= min(k_7 * f_{pk}, k_8 * $f_{p0.1k}$) = **1170.1** N/mm²	*cl.5.10.3(2)*
Prestressing Force at Release	P_{m0}	= min(σ_{pmo}, $\sigma_{pmo, max}$) * A_p = **360.4** kN	*cl.5.10.3(2)*

4.4.3 Time Dependent Losses

Concrete Stress at Tendons	$\sigma_{c, QP}$	= P_{m0} / A_c + P_{m0} * Z_{cp}^2 / I_c = **3.23** N/mm²	

4.4.3.1 Loss due to Creep

Perimeter in Contact with Atmosphere			
	u	= b = **1500** mm	*Annex B.1(1)*
Notional Size of Member	h_0	= 2 * A_c / u = **334.7** mm	*exp.B.6*
Concrete Strength Coefficients	α_1	= (35 / f_{cm} $)^{0.7}$ = **0.571**	*exp.B.8c*
	α_2	= (35 / f_{cm} $)^{0.2}$ = **0.852**	
	α_3	= (35 / f_{cm} $)^{0.5}$ = **0.67**	
Relative Humidity Factor	Φ_1	= (1 + (1 - R_{Hr} / 100) / (0.1 * $h_0^{1/3}$) * α_1) * α_2 = **1.097**	*exp.B.3b*
Relative Humidity and Size coefficient			
	$\beta_{H, rel}$	= min(1.5 * (1 + (0.012 * $R_{Hr})^{18}$) * h_0 + 250 * α_3,1500 * α_3) = **675.199**	*exp.B.8b*
Relative Humidity Factor	Φ_2	= (1 + (1 - R_{Ha} / 100) / (0.1 * $h_0^{1/3}$) * α_1) * α_2 = **1.237**	*exp.B.3b*
Relative Humidity and Size coefficient			
	$\beta_{H, final}$	= min(1.5 * (1 + (0.012 * $R_{Ha})^{18}$) * h_0 + 250 * α_3, 1500 * α_3) = **669.474**	*exp.B.8b*
Concrete Strength Factor	β_{fcm}	= 16.8 / √f_{cm} = **1.902**	*exp.B.4*
Concrete Age Factor	$\beta_{t0, rel}$	= 1 / (0.1 + $t_0^{0.2}$) = **0.743**	*exp.B.5*
Notional Creep Coefficients	$\Phi_{0, rel}$	= Φ_1 * β_{fcm} * $\beta_{t0, rel}$ = **1.551**	*exp.B.2*
Final Time	t_f	= **28** days	

Concrete Age Factor	$\beta_{t0, final}$	$= 1 / (0.1 + t_f^{0.2}) =$ **0.488**	*exp.B.5*
Notional Creep Coefficients	$\Phi_{0, final}$	$= \Phi_2 * \beta_{fcm} * \beta_{t0, final} =$ **1.149**	*exp.B.2*
Loss due to Creep	$\Delta_{\sigma p, c}$	$= ((E_p / E_{cm}) * \Phi_{0, rel} * \sigma_{c, QP}) / (1 + (E_p * A_p / (E_{cm} * A_c)) * (1 + A_c / I_c * Z_{cp}^2) * (1 + 0.8 * \Phi_{0, rel}))$ = **20.37** N/mm²	

4.4.3.2 Loss due to Shrinkage

Relative Humidity	R_{H0}	= **100** %	
Relative Humidity Ratio	β_{RH}	$= -1.55 * (1 - (R_{Ha} / R_{H0})^3) =$ **-1.409**	*exp.B.12*
Compressive Strength	f_{cmo}	= **10** N/mm²	*exp.B.12*
Cement Type Coefficients	α_{ds1}	= **4.0**	*Appendix B.2*
	α_{ds2}	= **0.12**	
Basic Drying Shrinkage Strain	ε_{cd0}	$= 0.85 * ((220 + 110 * \alpha_{ds1}) * e^{(-\alpha_{ds2} * f_{cm} / f_{cmo})}) * 10^{-6} * \beta_{RH} =$ **-0.00031**	*exp.B.11*
Notional Size coefficient	k_h	= **0.741**	*Table 3.3*
Drying Shrinkage Strain at Infinite Time			
	$\beta_{ds, t, ts}$	$= ((t - t_f) / ((t - t_f) + 0.04 * \sqrt{(h_0^3)})) =$ **1.0**	*exp.3.10*
	ε_{cdt}	$= \beta_{ds, t, ts} * k_h * \varepsilon_{cd0} =$ **-0.00023**	*exp.3.9*
Autogenous Shrinkage Strain at Infinite Time			
	$\varepsilon_{ca, inf}$	$= 2.5 * (f_{ck} - 10) * 10^{-6} =$ **0.00015**	*exp.3.12*
	$\beta_{as, t}$	$= 1 - e^{(-0.2 * t^{0.5})} =$ **1.0**	*exp.3.13*
Autogenous Shrinkage Strain	$\varepsilon_{ca, t}$	$= \beta_{as, t} * \varepsilon_{ca, inf} =$ **0.00015**	*exp.3.11*
Total Shrinkage Strain	ε_{cs}	$= -\varepsilon_{cdt} + \varepsilon_{cat} =$ **0.00038**	*exp.3.8*
Loss due to Shrinkage	$\Delta_{\sigma p, s}$	$= \varepsilon_{cs} * E_p / (1 + E_p * A_p / (E_{cm} * A_c) * (1 + A_c * Z_{cp}^2 / I_c) * (1 + 0.8 * \Phi_{0, rel})) =$ **75.48** N/mm²	

4.4.3.3 Loss due to Relaxation

Maximum Tensile Stress Minus Immediate Losses			
	$\sigma_{pi, r}$	$= \sigma_{pmo} =$ **1198.7** N/mm²	*cl.5.10.4(1)*
Initial Prestress Ratio	μ_r	$= \sigma_{pir} / f_{pk} =$ **0.644**	*cl.3.3.2(7)*
Time for Long Term Relaxation Losses (Hours)			
	t	= **500000** hours	*cl.3.3.2(8)*
Absolute Value of the Relaxation Losses of the Prestress for class 1			
	$\Delta_{\sigma pr, r}$	$= \sigma_{pir} * 5.39 * \rho_{1000} * e^{(6.7 * \mu_r)} * (t/1000)^{(0.75 * (1 - \mu_r))} * 10^{-5} =$ **203.4** N/mm²	
Loss due to Relaxation	$\Delta_{\sigma p, rr}$	$= 0.8 * \Delta_{\sigma pr, r} / (1 + E_p * A_p / (E_{cm} * A_c) * (1 + A_c * Z_{cp}^2 / I_c) * (1 + 0.8 * \Phi_{0, rel})) =$ **158.6** N/mm²	*exp.3.29*

4.4.3.4 Total losses

Total of Time Dependent Losses	$\Delta_{\sigma p,c,s,r}$	$= \Delta_{\sigma p, c} + \Delta_{\sigma p, s} + \Delta_{\sigma p, rr} =$ **254.5** N/mm²	
Prestress after Final Losses	σ_{p0}	$= \sigma_{pmo} - \Delta_{\sigma p,c,s,r} =$ **944.2** N/mm²	
Final Prestressing Force	P_{p0}	$= \sigma_{p0} * A_p =$ **290.8** kN	

4.5 Flexural Stresses at Service Stage

Stress in Bottom Fibre	f_{bot}	$= P_{p0} / A_c + P_{p0} * Z_{cp} * h_{NA} / I_c =$ **3.02** N/mm²	
Stress in Top Fibre	f_{top}	$= P_{p0} / A_c - P_{p0} * Z_{cp} * (h - h_{NA}) / I_c =$ **-0.72** N/mm²	

Quasi-Permanent Stress Factor	$k_{2,1}$	= **0.45**	*cl.7.2(3)*
Maximum Permissible Compressive Stress			
	$\sigma_{c,max}$	= $k_{2,1} * f_{ck}$ = **31.5** N/mm²	*cl.7.2(3)*
Section Modulus at Top	Z_{top}	= $I_c / (h - h_{NA})$ = **17928286.9** mm³	
Resistance Moment at Top	$M_{R,top}$	= $(k_{2,1} * f_{ck} - f_{top}) * Z_{top}$ = **577.7** kN.m	
Section Modulus at Bottom	Z_{bot}	= I_c / h_{NA} = **18072289.2** mm³	
Resistance Moment at Bottom	$M_{R,bot}$	= $(f_{ctm} + f_{bot}) * Z_{bot}$ = **138.0** kN.m	
Distributed Load at Service	F_{sls}	= $F_{swt} + F_{fin} + F_{live} + F_{part}$ = **12.18** kN/m²	
Serviceability Bending Moment	M_{sls}	= $F_{sls} * b * L_e^2 / 8$ = **165.0** kN.m	
Utilisation	Util	= $M_{sls} / \min(M_{R,bot}, M_{R,top})$ = **1.196**	

4.6 Ultimate Moment of Resistance

Characteristic Strain of Prestressing Steel at Maximum Load			
Strain Limit	ε_{ud}	= $0.9 * \varepsilon_{uk}$ = **0.0198**	*cl.3.3.6(7)*
Strain due to Prestressing	ε_{p0}	= σ_{p0} / E_p = **0.00463**	*cl.3.3.6(7)*
Design Tensile Strength of Prestressing Steel			
	f_{pd}	= $f_{p0.1k} / \gamma_S$ = **1197.1** N/mm²	*cl.3.3.6(6)*
Strain at Elastic Limit	ε_{el}	= f_{pd} / E_p = **0.00587**	*Fig 3.10*
Stress at Maximum Load	$f_{pd,uk}$	= f_{pk} / γ_S = **1617.4** N/mm²	*Fig 3.10*
Stress at Limiting Strain	$f_{p,max}$	= $f_{pd} + (f_{pd,uk} - f_{pd}) * (\varepsilon_{ud} - \varepsilon_{el}) / (\varepsilon_{uk} - \varepsilon_{el})$	
		= **1560.1** N/mm²	*Fig 3.10*
Depth to Prestressing Steel	d	= $h - h_{cp}$ = **266.5** mm	
Stress Distribution Factor	λ	= **0.75**	*exp.3.19*
Stress Block Factor	η	= **0.9**	*exp.3.21*
Depth of Neutral Axis (by iteration)	x	= **12.2** mm	
Depth to Centroid of Concrete in Compression			
	d_n	= $0.5 * \lambda * x$ = **4.6** mm	
Change in Strain	$\Delta_{\varepsilon,p}$	= $\varepsilon_{cu3} * (h - h_{cp}) / x - \varepsilon_{cu3}$ = **0.0560**	
Final Strain in Tendons	ε_p	= $\Delta_{\varepsilon,p} + \varepsilon_{p0}$ = **0.06000**	
Final Stress in Tendons	$f_{p,1}$	= $\min(f_{pd} + (f_{pd,uk} - f_{pd}) * (\varepsilon_p - \varepsilon_{el}) / (\varepsilon_{uk} - \varepsilon_{el}),$	
		$f_{p,max})$ = **1560.1** N/mm²	
Force in Tendons	f_p	= $f_{p,1} * A_p$ = **480.5** kN	
Area of Concrete	$A_{c,tf}$	= $b_{tf} * \lambda * x$ = **13459.4** mm²	
Force in Concrete	$f_{c,1}$	= $A_{c,tf} * \eta * f_{cd}$ = **480.5** kN	
Ultimate Moment of Resistance	MR	= $F_{c,1} * (d - d_n)$ = **125.9** kN.m	
Ultimate Design Distributed Load	F_{uls}	= $F_{swt} * \gamma_G + F_{fin} * \gamma_G + F_{live} * \gamma_Q + F_{part} * \gamma_Q$	
		= **17.5** kN/m²	
Ultimate Bending Moment	M_{uls}	= $F_{uls} * b * L_e^2 / 8$ = **237.0** kN.m	
Utilisation		= M_{uls} / M_R = **1.883**	

4.7 Shear Resistance

4.7.1 Cracked Sections

Shear Stress Constant	$C_{Rd,c}$	= $0.18 / \gamma_c$ = **0.12**	*cl.6.2.2(1)*
Reinforcement Depth Factor	k	= $\min(1 + \sqrt{(200 / d)}, 2)$ = **1.866**	
Reinforcement Ratio	ρ_1	= $\min(A_p / (b_{wt} * d), 0.02)$ = **0.002**	

Axial Force in Cross-Section	N_{Ed}	$= A_p * \sigma_{p0} =$ **290.8** kN	
Stress in Concrete Section	σ_{cp}	$=$ min(N_{Ed} / A_c, 0.2 * f_{cdv}) = **1.16** N/mm²	
Minimum Shear Stress	v_{min}	$= 0.035 * k^{3/2} * f_{ckv}^{1/2} =$ **0.717** N/mm²	
Maximum Stress Factor	k_1	= **0.15**	
Shear Resistance for Cracked Section	$V_{Rdc, c}$	= (max ($C_{RD, c} * k * (100 * \rho_1 * f_{ckv})^{(1/3)}$, v_{min}) + $k_1 * \sigma_{cp}$) * b_{wt} * d = **121.1** kN	
Ultimate Shear Force at Support	V_{uls}	$= F_{uls} * b * L_e / 2 =$ **111.5** kN	
Moment at x from support	M_x	$= V_{uls} * x - F_{uls} * b * x^2 / 2$	
Shear at x from support	V_x	$= V_{uls} - F_{uls} * b * x$	
Bottom Fibre Stress at x from support	f_b	$= M_x / Z_{bot} + V_x * \mathrm{Cos}(45) / A_c - P_{p0} / A_c - P_{p0} * Z_{cp} / Z_{bot} + V_{uls} / (0.7 * A_c) + V_{uls} * h_{NA} / (0.7 * Z_{bot})$	

The location x1 for cracked section is where $f_b = f_{ctd}$

Cracked location	x_1	= **461.1** mm	
Moment at x_1	M_{x_x1}	= **48.6** kN.m	
Shear at x_1	V_{x_x1}	= **99.4** kN	
Bottom fibre stress at x1	f_{b_x1}	= **1.90** N/mm²	
$V_x / V_{RDc, c}$		= **0.821**	

4.7.2 Uncracked Sections

Distance of Section from Starting Point of Transmission Length			
	l_x	$= L_b + h_{NA} =$ **234.4** mm	*cl.6.2.2(2)*
Tendon Release Factor	α_{11}	= **1**	*cl.8.10.2.2(2)*
Cross-Section Factor	α_{22}	= **0.25**	*cl.8.10.2.2(2)*
Tendon coefficient	η_{p1}	= **2.7**	*cl.8.10.2.2(1)*
Bond Condition coefficient	η_1	= **1**	*cl.8.10.2.2(1)*
Design Value of Tensile Strength at Release			
	$f_{ctd, t}$	$= \alpha_{ct} * 0.7 * f_{ctmvt} / \gamma_C =$ **1.29** N/mm²	*cl.8.10.2.2(1)*
Bond Stress at Transfer	f_{bpt}	$= \eta_{p1} * \eta_1 * f_{ctd, t} =$ **3.48** N/mm²	*exp.8.15*
Basic Value of Transmission Length	l_{pt}	$= \alpha_{11} * \alpha_{22} * \phi_{s1} * \sigma_{pmo} / f_{bpt} =$ **603.6** mm	*exp.8.16*
Upper Value of Transmission Length			
	$l_{pt, 2}$	$= 1.2 * l_{pt} =$ **724.3** mm	*exp.8.18*
Length Ratio	α_1	$= l_x / l_{pt, 2} =$ **0.324**	*cl.6.2.2(2)*
Shear Resistance for Uncracked Section			
	V_{Rdcu}	$= (I_c * b_{wt} / S_c) * \sqrt{(f_{ctd}^2 + \alpha_1 * \sigma_{cp} * f_{ctd})}$	
		= **242.6** kN	*exp.6.4*
V_{uls} / V_{Rdcu}		= **0.46**	

4.8 Resistance to Spalling (Splitting)

EN 1168 cl.4.3.3.2.1

Section Modulus of Bottom Fibre	W_b	$= I_c / h_{NA} =$ **18072289.2** mm³	
Core Radius	K_r	$= W_b / A_c =$ **72** mm	
Eccentricity of Prestressing Steel	e_0	$= h_{NA} - c_s =$ **115.9** mm	
Alpha Factor	α_e	= max(($e_0 - k_r$) / h, 0) = **0.146**	
Initial Prestressing Force in a Single Web			
	P_0	$= \sigma_{pm0} * A_{ps} *$ MNo = **46.1** kN	
Basic Value of Transmission Length	l_{pts}	$= \alpha_{11} * \alpha_{22} * \phi_{s1} * \sigma_{pmo} / f_{bpt} =$ **603.6** mm	*exp.8.16*
Lower Value of Transmission Length			

	l_{ptls}	$= 0.8 * l_{pts} =$ **482.9** mm	
Spalling Stress	σ_{sp}	$= (P_0 / (b_{wi} * e_0)) * (15 * \alpha_e^{2.3} + 0.07) / (1 + (l_{ptls} / e_0)^{1.5} * (1.3 * \alpha_e + 0.1)) =$ **0.48** N/mm²	
$\sigma_{sp} / f_{ctk0.05t}$		= **0.248**	

4.9 Stress Limits

Max.Compressive Stress at Transfer	σ_c	$= 0.6 * f_{ckt} =$ **23.2** N/mm²	*exp.5.42*
Compressive Stress at Transfer	$f_{c, t}$	$= P / A_c + P * Z_{cp} / Z_{bot} =$ **3.89** N/mm²	*exp.5.42*
Maximum Tensile Stress at Transfer	σ_t	$= f_{ctm, t} =$ **2.76** N/mm²	
Self-Weight Moment	M_{swt}	$= F_{swt} * b * L_e^2 / 8 =$ **56.67** kN.m	
Tensile Stress at Transfer	$f_{t, t}$	$= \max(P * Z_{cp} / Z_{top} - P / A_c - M_{swt} / Z_{top}, 0)$ = **0** N/mm²	
	$f_{t, t} / \sigma_t$	= **0.0**	

Maximum Compressive Stress due to Characteristic Loads

	σ_{cc}	$= 0.45 * f_{ck} =$ **31.5** N/mm²	

Compressive Stress due to Characteristic Loads

	f_{cc}	$= f_{top} + M_{sls} / Z_{top} =$ **8.49** N/mm²	
	f_{cc} / σ_{cc}	$= f_{cc} / \sigma_{cc} =$ **0.269**	

Maximum Tensile Stress due to Characteristic Loads

	σ_{tc}	$= f_{ct,eff} = f_{ctm} =$ **4.61** N/mm²	*cl.7.3.2(4)*

Tensile Stress due to Characteristic Loads

	f_{tc}	$= \max(M_{sls} / Z_{bot} - f_{bot}, 0) =$ **6.11** N/mm²	
f_{tc} / σ_{tc}		= **1.325**	

4.10 Deflection

4.10.1 Initial Camber

Camber due to Prestress	δ_{0p}	$= A_p * \sigma_{pmo} * Z_{cp} * L_e^2 / (8 * E_{cmt} * I_c) =$ **3.4** mm	
Deflection due to Self Weight	δ_{0G}	$= 5 * F_{swt} * b * L_e^4 / (384 * E_{cmt} * I_c) =$ **3.8** mm	
Initial Camber	δ_0	$= \delta_{0p} - \delta_{0G} =$ **-0.4** mm	
Deflection Limit	$\delta_{0, lim}$	$= L_e / 300 =$ **28.3** mm	
$\delta_0 / \delta_{0, lim}$		= **-0.012**	

4.10.2 Camber after Installation

Initial Coefficient of Viscous Effect	α_{t0}	= **0.1**	
During installation	α_{t1}	= **0.5**	
	$\Phi_{tinf, t0}$	= **2.5**	

Concrete Viscosity coefficient between Time t_0 and t_1

	$\Phi_{t0, t1}$	$= \Phi_{tinf, t0} * (\alpha_{t11} - \delta_{t0}) =$ **1.0**	

Variation in Initial Camber due to Prestress Over Time

	δ_{1p}	$= \delta_{0p} * (1 + E_{cmt} * 2 / (E_{cmt} + E_{cm}) * \Phi_{t0, t1}) + (P_{p0} - P_{m0}) * Z_{cp} * L_e^2 / (8 * E_{cm} * I_c) =$ **6.0** mm	
Deflection due to Self-Weight	δ_{1G}	$= 5 * (F_{swt} + F_t) * b * L_e^4 / (384 * E_{cm} * I_c)$ = **3.2** mm	

Variation of Deflection due to Self-Weight Over Time

	$\delta_{1\Phi G}$	$= \delta_{0G} * (E_{cmt} * 2 / (E_{cmt} + E_{cm}) * \Phi_{t0, t1}) =$ **3.5** mm	

Camber after Installation δ_1 = $\delta_{1p} - \delta_{1G} - \delta_{1\Phi G}$ = **-0.7** mm

Deflection Limit $\delta_{1, lim}$ = L_e / 360 = **23.6** mm

$\delta_1 / \delta_{1, lim}$ = **-0.029**

4.10.3 Long Term Deflection

At installation α_{t1} = **0.5**

Application of Live Loads α_{t2} = **0.7**

Finally $\alpha_{t, inf, t0}$ = **1.0**

Concrete Viscosity coefficient between Time t_1 and t_2

$\Phi_{t2, t1}$ = $\Phi_{t, inf, t0} * (\alpha_{t2} - \alpha_{t1})$ = **0.5**

Concrete Viscosity coefficient between Time t_2 and t_{inf}

$\Phi_{tinf, t2}$ = $\Phi_{t, inf, t0} * (\alpha_{t, inf} - \alpha_{t2})$ = **0.75**

Concrete Viscosity coefficient between Time t_1 and t_{inf}

$\Phi_{tinf, t1}$ = $\Phi_{t, inf, t0} * (\alpha_{t, inf} - \alpha_{t1})$ = **1.25**

Concrete Aging coefficient p_c = **0.8**

Variation in Initial Camber due to Prestress between Time t_1, Installation and Time t_{inf}

$\delta_{inf, \Phi p}$ = $p_c * (\Phi_{tinft1} * A_p * \sigma_{p0} * Z_{cp} * L_e^2) / (8 * E_{cm} * I_c)$

= **2.306** mm

Viscous Effects of Self-Weight from Time t_1, Installation to Time t_2, Application of Live Loads

$\delta_{2, \Phi G, G1}$ = $5 * (F_{swt} + F_t) * b * L_e^4 * \Phi_{t2, t1} / (384 * E_{cm} * I_c)$

= **1.6** mm

Elastic Deflection for Permanent and Long-Term Variable Loads

$\delta_{2, Qp, Qi}$ = $5 * (F_{fin} + \Psi * (F_{part} + F_{live})) * b * L_e^4$

$/ (384 * E_{cm} * I_c)$ = **2.4** mm

Viscous Effects of All Permanent Loads from Time t_2, Application of Live Loads to Time t_{inf}

$\delta_{inf, \Phi G, Q}$ = $5 * b * (F_{swt} + F_t + F_{fin} + \Psi * (F_{part} + F_{live})) * L_e^4$

$* p_c * \Phi_{tinft2} / (384 * E_{cm} * I_c)$ = **3.4** mm

Long Term Deflection δ_{inf} = $\delta_{2, \Phi G, G1} + \delta_{2, Qp, Qi} + \delta_{inf, \Phi G, Q} - \delta_{inf, \Phi p}$

= **5.1** mm

Deflection Limit $\delta_{inf, lim}$ = L_e / 360 = **23.6** mm

abs(δ_{inf}) / $\delta_{inf, lim}$ = **0.215**

Final Deflection δ_{final} = $\delta_1 + \delta_{inf}$ = **4.4** mm

5.0 SUMMARY

5.1 Initial Stage

Description	Actual	Allowable	Status
Compressive Stress at Transfer (**N/mm²**)	3.89	23.2	**PASS**
Tensile Stress at Transfer (**N/mm²**)	0.0	2.76	**PASS**
Spalling/Splitting Resistance (**N/mm²**)	0.48	1.93	**PASS**
Initial Deflection (**mm**)	-0.35	28.33	**PASS**

5.2 Installation Stage

Description	Actual	Allowable	Status
Deflection after Installation (**mm**)	-0.7	23.6	**PASS**

5.3 Service Stage

Description	Actual	Allowable	Status
Serviceability Moment (**kN.m**)	165.0	138.0	**FAIL**
Ultimate Moment (**kN.m**)	237.0	125.9	**FAIL**
Shear - Cracked Section (**kN**)	99.4	121.1	**PASS**
Shear - Uncracked Section (**kN**)	111.5	242.6	**PASS**
Long Term Deflection (**mm**)	5.1	23.6	**PASS**