Reference: **Abutment Wall**

Early Thermal Cracking of Concrete

(Document Reference Notation: Eurocode , CIRIA Report C660)

	Type of Restraint =	Wall cast on	to a base			
	Restrained Section Length L =	11600	mm	Sectn 4.7 Restraint R =	0.58	
	Restrained Section Thickness T =	1000	mm		EN 1992-1-1:2 Cl. 3.1.2 & 3.1.3	
	Reinforcement Strength f_{yk} =	500	N/mm^2	Aggregate factor =	1	
	Concrete Strength f_{ck} =	30	N/mm^2	E_{cm} =	32.8	Gpa
	Binder Type =	Not Specified	Addition(%) = 0	f_{ctm} =	2.90	Mpa
	Course Aggregate Rock Group =	Not Specified		Curing Period =	3	days
	Formwork Type =	18mm plywood		3 day Ecm =	28.1	Gpa
	Formwork removal =	24	hrs	s =	0.25	(Class N)
	Placing time (24 hr clock: mid day =12) =	10	hrs	3 day fctm(t) =	1.73	Mpa
Sectn 4.9.1	Creep Coefficient K_1 =	0.65		E_s =	200	Gpa
Sectn 4.9.2	Sustained Loading Coefficient K_2 =	0.8		Modular Ratio $\alpha_{e(28)}$ =	6.1	
EN1992-2				Modular Ratio $\alpha_{e(t)}$ =	7.1	
Sectn 7.3.1	Allowable crack width = w_{max} =	0.3	mm			
Table 4.2	Binder Content =	340	kg/m^3			
	Specific Heat =	1.0	kJ/kg°C			
	Density of Concrete =	2500	kg/m^3			
	Wind speed =	4	m/s			
	Thermal conductance of surface G =	5.2	W/m^2K	Results from Numerical Model		
	Mean ambient temperature =	15	°C	Max. Temp. =	60.3	°C
	Placing temperature =	20	°C	at time =	29	hr
	Thermal conductivity of concrete =	1.8	W/mK	Max. diff. temp ΔT=	32.9	°C
				at time =	32	hr
				Temperature Drop T_1 from Fig's 4.5 to 4.8 =	46	°C
	Annual Temperature Change T_2 =	20	°C			
Table 4.4	Coefficient of thermal expansion α_c =	12	με / °C			
EN1992-1-1	Ultimate autogenous shrinkage ε_{ca} =	50	με			
Sectn 3.1.4	Autogenous shrinkage at 3 days =	15	με			
ε_{ca} values	Autogenous shrinkage at 28 days =	33	με			
	Early age restrained strain $\varepsilon_r = K_1[\alpha_c T_1+\varepsilon_{ca}]R$ =	214	με			
Table 4.11	$\varepsilon_{ctu} = (K_2/K_1)(f_{ctm}/E_{ctm})x10^6$ =	76	με	Crack inducing strain :		
				$\varepsilon_{cr} = \varepsilon_r - 0.5\varepsilon_{ctu}$ =	176	με
EN1992-1-1	**Minimum Reinforcement Area for Early-Age Cracking (ts = 3days)**					
Sectn 7.3.2	k_c =	1				
	k =	0.75				
	Depth of surface zone h_{ct} =	500	mm			
	A_{ct} = 1000 x h_{ct} =	500000	mm^2			
	$A_{s,min} = k_c\, k\, A_{ct}\, f_{ctm(t)} / f_{yk}$ =	1300	mm^2/m each face	(Based on 3 day strength)		
	Bar Dia =	**32**	mm^2	A_s =	**8042**	mm^2/m
	Spacing =	**100**	mm	As,min = 1300 < 8042 Hence OK		
	Cover to reinforcement c =	**100**	mm			
EN1992-1-1	Maximum crack width spacing $s_{r,max} = k_3c + k_1k_2k_4\phi / \rho_{p,eff}$			(Eqn. 7.11)		
	k_3 = 3.4 k_2 = 1.0 k_4 = 0.425	k_1 =	1.14			
	$h_{c,eff}$ =	290	mm			

$A_{c,eff}$ = 290000 mm^2

$\rho_{p,eff} = A_s / A_{c,eff}$ = 0.0277327

Maximum crack width spacing $s_{r,max}$ = 899 mm

Early age crack width = $w_k = s_{r,max}\ \varepsilon_{cr}$ = 0.16 mm

Minimum A_s to meet early age crack width = 1345 mm^2/m As = 1345 < 8042 Hence OK

EN1992-1-1 3.1.4(6) & Annex B

Long Term Effects

Ambient Relative Humidity RH = 85 % α_{ds1} = 4 (Class N)

$\beta_{RH} = 1.55[1-(RH/RH_0)^3]$ = 0.598 α_{ds2} = 0.12

f_{cm} = 38

f_{cmo} = 10

$\varepsilon_{cd,0} = 0.85[(220+110\cdot\alpha_{ds1})\cdot\exp(-\alpha d_{s2}\cdot f_{cm}/f_{cmo})]\cdot 10^{-6}\cdot\beta_{RH}$ = 213 $\mu\varepsilon$

Number of faces exposed to drying = 1

EN1992-1-1 Table 3.3

Approximate h_0 = 2000 mm

k_h = 0.700

Age of concrete considered for long term effects = 20000 days

$\beta_{ds}(t,t_s) = (t-t_s)/[(t-t_s)+0.04h_o^{3/2}]$ = 0.848

Drying shrikage $\varepsilon_{cd}(t) = \beta_{ds}(t,t_s)\cdot k_h\cdot\varepsilon_{cd,0}$ = 126 $\mu\varepsilon$

Table 4.11 $\varepsilon_{ctu} = (K_2/K_1)(f_{ctm}/E_{ctm})x10^6$ = 109 $\mu\varepsilon$

Total crack-inducing strain:

$\varepsilon_{cr} = K_1\{[\alpha_c T_1 + \varepsilon_{ca}]R_1 + \alpha_c T_2 R_2 + \varepsilon_{cd} R_3\} - 0.5\varepsilon_{ctu}$ = 304 $\mu\varepsilon$

Long-term crack width = $w_k = s_{r,max}\ \varepsilon_{cr}$ = 0.27 mm

Minimum A_s to meet long-term crack width = 6021 mm As = 6021 < 8042 Hence OK

$A_{s,min} = k_c\ k\ A_{ct}\ f_{ctm} / f_{yk}$ = 2172 mm^2/m each face (Based on 28 day strength)

As,min = 2172 < 8042 Hence OK

$A_{s,min}$ = 2172 mm^2/m each face

Height above base	R	$\varepsilon_{cr(early)}$	$\varepsilon_{cr(long)}$	$A_{s,Wk}$	A_s Required
H = 6.63m	0	0	0	0	**2172**
0.9H = 5.967m	0	0	0	0	**2172**
0.8H = 5.304m	0.07	0	0	0	**2172**
0.7H = 4.641m	0.12	6	20	12	**2172**
0.6H = 3.978m	0.17	25	51	82	**2172**
0.5H = 3.315m	0.22	43	82	228	**2172**
0.4H = 2.652m	0.29	69	125	592	**2172**
0.3H = 1.989m	0.35	91	162	1100	**2172**
0.2H = 1.326m	0.42	117	205	1992	**2172**
0.1H = 0.663m	0.5	146	255	3592	**3592**
0	0.58	176	304	6008	**6008**