Reference: Abutment Base Slab

Early Thermal Cracking of Concrete

(Document Reference Notation: Eurocode, CIRIA Report C660)

Type of Restraint = Massive pour cast on to blinding
Restrained Section Length L = 11600 mm
Restrained Section Thickness T = 1000 mm
Reinforcement Strength f_yk = 500 N/mm²
Concrete Strength f_ck = 30 N/mm²
Binder Type = Not Specified
Course Aggregate Rock Group = Not Specified
Formwork Type = 18mm plywood
Formwork removal = 24 hrs
Placing time (24 hr clock: mid day = 12) = 10 hrs
Creep Coefficient K1 = 0.65
Sustained Loading Coefficient K2 = 0.8

Allowable crack width = w_max = 0.3 mm

Table 4.2
Binder Content = 340 kg/m³
Specific Heat = 1.0 kJ/kg°C
Density of Concrete = 2500 kg/m³
Wind speed = 4 m/s
Thermal conductance of surface G = 5.2 W/m²K
Mean ambient temperature = 15 °C
Placing temperature = 20 °C
Thermal conductivity of concrete = 1.8 W/mK

Table 4.4
Coefficient of thermal expansion αc = 12 µε / °C
Ultimate autogenous shrinkage εca = 50 µε
Autogenous shrinkage at 3 days = 15 µε
Autogenous shrinkage at 28 days = 33 µε

Early age restrained strain ε_r = K1[αc(T1 + εca)]R = 74 µε

Table 4.11
ε_ctu = (K2/K1)(f_ctm/E_ctm)x10⁶ = 76 µε

EN1992-1-1 Minimum Reinforcement Area for Early-Age Cracking (ts = 3days)

Depth of surface zone h_c = 500 mm
A_c = 1000 x h_c = 500000 mm²
A_s_min = k_c x A_c x f(t)/f_yk = 1300 mm²/m each face (Based on 3 day strength)
Bar Dia = 25 mm²
Spacing = 200 mm
Cover to reinforcement c = 100 mm

EN1992-1-1 Maximum crack width spacing s_{r,max} = k_3c + k_1k_2k_4θ / ρ_{p,e} (Eqn. 7.11)

Results from Numerical Model

As,min = 1300 < 2454 Hence OK
\( A_{c,\text{eff}} = 281250 \text{ mm}^2 \)

\( \rho_{p,\text{eff}} = A_s / A_{c,\text{eff}} = 0.0087266 \)

Maximum crack width spacing \( s_{r,\text{max}} = 1728 \text{ mm} \)

Early age crack width = \( w_k = s_{r,\text{max}} \varepsilon_{cr} = 0.06 \text{ mm} \)

Minimum \( A_s \) to meet early age crack width = 73 \( \text{ mm}^2 / \text{m} \) \( \text{ As } = 73 \times 2454 \text{ Hence OK} \)

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**Long Term Effects**

En1992-1-1

3.1.4(6)

Ambient Relative Humidity RH = 85 \( \% \)

\( \alpha_{d_{s1}} = 4 \) (Class N)

& Annex B

\( \beta_{\text{RH}} = 1.55[1-(\text{RH}/\text{RH}_0)^3] = 0.598 \)

\( f_{\text{cm}} = 38 \)

\( f_{\text{cmo}} = 10 \)

\( \varepsilon_{cd,0} = 0.85\left[(220+110\alpha_{d_{s1}})\exp(-\alpha_{d_{s2}}\frac{f_{\text{cm}}}{f_{\text{cmo}}})\right]10^{-6}, \beta_{\text{RH}} = 213 \text{ \( \mu \varepsilon \)} \)

Number of faces exposed to drying = 2

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Table 3.3

Approximate \( h_0 = 1000 \text{ mm} \)

\( k_n = 0.700 \)

Age of concrete considered for long term effects = 20000 \( \text{ days} \)

\( \beta_{d_{s}(t,t_s)} = (t-t_s)/[(t-t_s)+0.04h_0^{3/2}] = 0.941 \)

Drying shrikage \( \varepsilon_{cd}(t) = \beta_{d_{s}(t,t_s)}k_n\varepsilon_{cd,0} = 140 \text{ \( \mu \varepsilon \)} \)

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Table 4.11

\( \varepsilon_{\text{ctu}} = (K_2/K_1)(f_{\text{ctm}}/E_{\text{ctm}})\times10^6 = 109 \text{ \( \mu \varepsilon \)} \)

Total crack-inducing strain:

\( \varepsilon_{cr} = K_1[\left(\alpha_{c_T1} + \varepsilon_{cd}\right)R_1 + \alpha_{c_T2}R_2 + \varepsilon_{cd}R_3] - 0.5\varepsilon_{\text{ctu}} = 71 \text{ \( \mu \varepsilon \)} \)

Long-term crack width = \( w_k = s_{r,\text{max}} \varepsilon_{cr} = 0.12 \text{ mm} \)

Minimum \( A_s \) to meet long-term crack width = 314 \( \text{ mm} \) \( \text{ As } = 314 \times 2454 \text{ Hence OK} \)

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

\( A_{s,\text{min}} = 2172 < 2454 \text{ Hence OK} \)