Creep Loss – AERB/SS/CSE-1

Creep is the increase in strain under stress. If service stress < 40% of the mean compressive strength of concrete, creep is linearly related to stress. At any age t, creep strain ε_{cc} of concrete member under constant stress applied at time t_0 may be calculated as:-

$$\varepsilon_{cc} = C_r(\sigma_c / E_c)$$

$$E_t = \frac{E_c}{(1 + C_r)}, \quad C_r = C_n \beta_c,$$

$$C_n = C_{RH} \beta(f_{cm}) \beta(t_o)$$

$$where \quad f_{cm} = (0.8 * f_{ck} + \Delta f), \Delta f = 8MPa$$

$$\beta(f_{cm}) = \frac{5.3}{(0.1 f_{cm})^{0.5}}, \quad \beta(t_0) = \frac{1}{\{0.1 + (t_0)^{0.2}\}}$$

$$with \quad C_{RH} = 1 + \frac{1 - \left(\frac{RH}{100}\right)}{0.46\left(\frac{h}{100}\right)^{\frac{1}{3}}}$$

$$= \left[\frac{(t - t_0)}{\{\beta_H + (t - t_0)\}}\right]^{0.3}$$

Creep Loss – CEB FIP

$$\varepsilon_{cc}(t-t_o)=\frac{\sigma_c(t_o)}{E_{ci}}\phi(t,t_o)$$

$$where,\quad \phi(t,t_o)=\phi_o\beta_c(t,t_o)$$

$$\phi_o=\phi_{RH}\beta(f_{cm})\beta_c(t_o)$$

$$\phi_{RH}=1\frac{1-\left(\frac{RH}{RH_o}\right)}{0.46\left(\frac{h}{h_o}\right)^{1/3}},\ where,\ RH_o=100\%,\ h_o=100mm$$

$$\beta(f_{cm})=\frac{5.3}{\left(\frac{f_{cm}}{f_{cmo}}\right)^{0.5}},\ where,\ f_{cm}=f_{ck}+\Delta f,\Delta f=8MPa;\quad f_{cmo}=10MPa$$

$$\beta_c(t_o)=\frac{1}{0.1+\left(\frac{t_o}{t_1}\right)^{0.2}},\ where,\quad t_1=1day$$

$$t_T=\sum_{i=1}^{n}\Delta t_i\exp\left[13.65-\frac{4000}{273+T(\Delta t_i)/T_o}\right],$$

$$where,\ T_o=1^oC,\quad T(\Delta t_i)=Temp.during\ period\ \Delta t_i$$

Creep Loss – CEB FIP (contd..)

$$Time\,Variation: \quad \beta_c(t-t_o)=\left[\frac{(t-t_o)/t_1}{\beta_H+(t-t_o)/t_1}\right]^{0.3}$$

$$\beta_H = 150\left\{1+\left(1.2\frac{RH}{RH_o}\right)^{18}\right\}\frac{h}{h_o}+250 \le 1500$$

$$t_o = t_{o,T}\left[\frac{9}{2+\left(\frac{t_{o,T}}{t_{1,T}}\right)^{1.2}}+1\right]^{\alpha} \quad \ge \quad 0.5\,days$$

$$where\ t_{o,T} = age\ of\ loading\ (days)\ adjusted\ according\ to$$

$$t_T = \sum_{i=1}^{n}\Delta t_i \exp\left[13.65-\frac{4000}{273+T(\Delta t_i)/T_o}\right],$$

$$where,\ T_o = 1^o C, \quad T(\Delta t_i) = Temp.\,during\ period\ \Delta t_i$$

Creep Loss – Euro Code E2

$$\phi(t,t_o)=\phi_o\beta_c(t-t_o)$$

$$\phi_o=\phi_{RH}\beta(f_{cm})\beta(t_o)$$

$$\phi_{RH}=1+\frac{1-\left(\frac{RH}{100}\right)}{0.10\sqrt[3]{h_o}},\quad \beta(f_{cm})=\frac{16.8}{\sqrt{f_{cm}}},\quad \beta(t_o)=\frac{1}{0.1+t_o^{0.2}},\quad h_o=2A_c/u$$

$$TimeVariation:\quad \beta_c(t-t_o)=\left[\frac{(t-t_o)}{\beta_H+(t-t_o)}\right]^{0.3}$$

$$\beta_H=1.5\left\{1+(0.012RH)^{18}\right\}h_o+250\quad\leq\quad 1500$$

$$t_o=t_{o,T}\left[\frac{9}{2+(t_{o,T})^{1.2}}+1\right]^{\alpha}\quad\geq\quad 0.5days$$

$$where\ t_{o,T}=age\ of\ loading\ (days)\ adjusted\ according\ to$$

$$t_T=\sum_{i=1}^{n}e^{-\left[\frac{4000}{273+T(\Delta t_i)}-13.65\right]}.\Delta t_i$$

$$where,\ T_o=1^oC,\quad T(\Delta t_i)=Temp.during\ period\ \Delta t_i$$

$$\alpha=-1\ for\ slowly\ hardening\ cement,S$$

$$\alpha=0\ for\ normal\ or\ rapid\ hardening\ cement,N,\ R$$

$$\alpha=1\ for\ rapid\ hardening\ high\ strength\ cement,RS$$

$$E_{c(28)}=1.05E_{cm},\quad E_{cm}=9.5(f_{ck}+8)^{(1/3)},\ E_{cm}\ in\ KN/mm^2,\ f_{ck}\ in\ N/mm^2$$

Creep Loss – IS: 1343 - 1980

Age at Loading (days)	**Creep Co-eff.**
7	**2.2**
28	**1.6**
365	**1.1**

Creep Loss – BPEL-91

Final loss due to effect of creep of concrete is

$$\Delta\sigma_{fl} = (\sigma_b + \sigma_M)*(E_p / E_{ij})$$

where, σ_b = Final stress in concrete at section

σ_M = Max. stress applied to the concrete in the section at the C.G. of the tendons

E_p = Young's Modulus of prestressing cable

E_{ij} = Young's Modulus of concrete = $11000(f_{cj})^{(1/3)}$

where, j = age of concrete when it is prestressed

If, $\sigma_M \leq 1.5\sigma_b$ it is desirable for simplicity to evaluate the final loss of tension due to creep of the concerete at :

$$\Delta\sigma_{fl} = 2.5\ \sigma_b\ (E_p / E_{ij})$$

Creep Loss – IRC – 18 : 2000

Maturity of Concrete at the time of stressing, as a percentage of its 28 days' specified strength (%)	Strain per 10 MPa
40	9.4E-04
50	8.3E-04
60	7.2E-04
70	6.1E-04
75	5.6E-04
80	5.1E-04
90	4.4E-04
100	4.0E-04
110	3.6E-04

Creep Loss – CANADIAN

In Line with ACI 209 – American Standard

$$C_t = \frac{t^{0.6}}{10 + t^{0.6}} C_u Q_{cr} \ldots\ldots\ldots\ldots (1.9)$$

where, t is the time in days after loading, and C_u is the ultimate creep co-efficient and varies between 1.30 and 4.15. In the absence of specific creep data for local aggregates and conditions, the average value suggested for C_u is 2.35.

The above equation was developed for sustained compressive stress not exceeding 50% of concrete strength. It consists of an expression for creep under standard conditions multiplied by the correction factor Q_{cr} to modify for non-standard conditions. The standard conditions and correction factor Q_{cr} are specified in Table 1.2 of the Code.

$$\mathbf{Q_{cr} = Q_a\ Q_h\ Q_f\ Q_r\ Q_s\ Q_v}$$

Creep Loss - ACI 209R

$k_a = 1.25(t_i)^{-0.118}$ – Time of Initial Loading

$k_h = 1.27 - 0.0067H$ – Thickness

$k_{th} = (2/3) * \{1.0 + 1.13*e^{(-0.0212*V/S)}\}$ – (V/S)

$k_s = 0.82 + 0.00264*S$ – Slump

$k_f = 0.88 + 0.0024*(A_f / A)$ – Fine to Total Aggeegate

$k_e = 0.46 + 0.09*a$ – Air Entrainment

$\phi_\infty(t,t_i) = C_u * k_t\ k_a\ k_h\ k_{th}\ k_s\ k_f\ k_e$

$$\phi(t, t_i) = \frac{(t - t_i)^{0.6}}{10 + (t - t_i)^{0.6}} \times \phi_\infty(t, t_0)$$