Shrinkage Loss – AERB/SS/CSE-1

Shrinkage strain, $\varepsilon_{st} = \varepsilon_n * \beta_s$

Notional Shrinkage Coeff, $\varepsilon_n = \varepsilon_s * \beta_{RH}$

$\varepsilon_s = [160 + 10\ \beta_{sc}\ (9 - 0.1\ f_{cm})]\ 10^{-6}$

where, $f_{cm} = 0.8 * f_{ck} + \Delta f$

$\beta_{sc} = 4$, for slow hardening cements,

5, for normal or rapid hardening cements,

8, for rapid hardening high-strength cements,

$\beta_{RH} = -1.55\ \beta_{sRH}$ (for 40% <= RH < 99%)

= 1.2152 + 0.25 , for RH >= 99%

$\beta_{sRH} = 1 - (RH/100)^3$

Time coefficient, $\beta_s = [(t - t_s)/\{350(h/100)^2 + (t - t_s)\}]^{(1/2)}$

Shrinkage Loss – CEB FIP

$$\varepsilon_{cs}(t,t_s) = \varepsilon_{cso}\,\beta_s(t-t_s)$$

$$where\ ,\quad \varepsilon_{cso} = \varepsilon_s(f_{cm})\beta_{RH}$$

$$\beta_{RH} = -1.55\,\beta_{SRH} \qquad -40\% \le RH < 99\%$$

$$\beta_{RH} = +0.25 \qquad RH \ge 99\%$$

$$\beta_{SRH} = 1 - \left(\frac{RH}{RH_o}\right)^3 \quad where\ ,\ RH_o = 100\,\%$$

$$\varepsilon_s(f_{cm}) = \left[160 + 10\,\beta_{sc}\left(9 - \frac{f_{cm}}{f_{cmo}}\right)\right] x\ 10^{-6}$$

$$\beta_{sc} = 4 \ \ for\ slowly\ hardening\ cements\ SL$$

$$\beta_{sc} = 5 \ \ for\ normal\ or\ rapid\ hardening\ cements\ N\ or\ R$$

$$\beta_{sc} = 8 \ \ for\ rapid\ hardening\ high\ strength\ cements\ RS$$

$$TimeVariat\ ion:\quad \beta_s(t-t_s) = \left[\frac{(t-t_s)/t_1}{350\left(h/h_o\right)^2 + (t-t_s)/t_1}\right]^{0.5}$$

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

Shrinkage Loss – Euro Code E2

$$\varepsilon_{cs}(t-t_s)=\varepsilon_{cso}\beta_s(t-t_s)$$

$$where, \quad \varepsilon_{cso}=\varepsilon_s(f_{cm})\beta_{RH}$$

$$\beta_{RH}=-1.55\beta_{SRH} \qquad -40\% \le RH < 99\% \; (sored \;\; in \;\; air)$$

$$\beta_{RH}=+0.25 \qquad RH \ge 99\% \; (immersed \; in \; water)$$

$$\beta_{SRH}=1-\left(\frac{RH}{100}\right)^3$$

$$\varepsilon_s(f_{cm})=\left[160+\beta_{sc}(90-f_{cm})\right]x\,10^{-6}$$

$$\beta_{sc}=4 \;\; for\ slowly\ hardening\ cements\ S$$

$$\beta_{sc}=5 \;\; for\ normal\ or\ rapid\ hardening\ cements\ N\ or\ R$$

$$\beta_{sc}=8 \;\; for\ rapid\ hardening\ high\ strength\ cements\ RS$$

$$TimeVariation: \quad \beta_s(t-t_s)=\left[\frac{(t-t_s)}{0.035h^2+(t-t_s)}\right]^{0.5}$$

Shrinkage Loss – IS: 1343 - 1980

$\varepsilon_s = 0.0002/(\log_{10}(t+2)$

t = age at loading (days)

Shrinkage Loss – BPEL-91

Final loss due to shrinkage, $\Delta\sigma_r = \varepsilon_r [\ 1 - r(j)\ ]\ E_p$

Where, $\varepsilon_r = \varepsilon_0 * K_s$

$$\varepsilon_0 = (100-\rho_h)*(6+80/(10+3r_m))*10^{-6}$$

ρ_h = relative humidity

r_m = mean thickness in cm

$K_s = 1.0 / (1.0 + 20\ \rho_s)$

where, ρ_s = reinforcement fraction = (A_s/B)

$$r(j) = j / (j + 9*r_m)$$

where, j = age of concrete at the time when it is prestressed

Shrinkage Loss – IRC – 18 : 2000

The loss in prestress in steel, due to shrinkage of concrete, shall be estimated from the values of strain due to residual shrinkage given in

Table 3 (1965), Table 5 (1985), TABLE 3 (IRC:18 - 2000)

Age of concrete at the time of stressing, in days	Strain due to residual shrinkage
3	4.3E-04
7	3.5E-04
10	3.0E-04
14	2.5E-04
21	2.0E-04
28	1.9E-04
90	1.5E-04

Note:

Values for intermediate figures for any age of concrete may be interpolated taking a linear variation between the values given above.

The above values are for Ordinary Portland Cement. (in IRC:18-1985)

Shrinkage Loss – Canadian Code

- In Line with ACI 209
  - With Different Values of Coefficients

Values are in given in Tabular Form

- Relative Humidity (P_h)
- Ratio of Fine to Total Aggregate (P_f)
- Volume to Exposed Surface Ratio (P_r)
- Slump Content (P_s)
- % Air Entrainment (P_v)
- Cement Content (P_c)

$$P_{sh} = P_h P_f P_r P_s P_v P_c$$

$$\varepsilon_{sh} = \frac{t}{C_s + t}\varepsilon_{shu} P_{sh}$$

C_s = 35 for moist cured concrete for 7 days

= 55 for steam cured concrete for 1-3 days

ε_{shu} = 0.00078 mm/mm – in absence of actual calculation

Shrinkage Loss – ACI 209R

$S_t = (t - t_o) / \{35+(t - t_o)\}$: for moist curing – Time Factor

$S_h = 1.4 - 0.01\ H$ – Humidity Factor

$S_{th} = 1.2\ e^{-0.00473(V/S)}$ – Size Factor

$S_s = 0.89 + 0.00264\ S$ – Slump Factor

$S_f = 0.3 + 0.014\ (A_f / A)$ – Fineness Factor

$S_e = 0.95 + 0.008\ a$ – Air Content Factor

$S_c = 0.75 + 0.00061\ C$ – Cement content Factor

$$\varepsilon_u = \varepsilon_t * S_{tf} * S_h * S_{th} * S_s * S_f * S_e * S_c \text{ , where } \varepsilon_t = 0.00078$$