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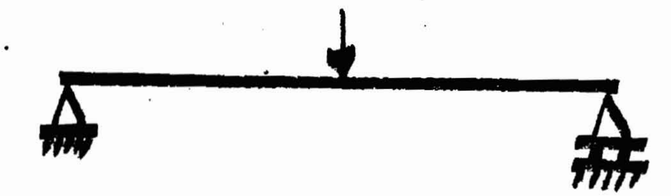
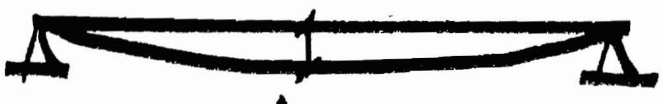
#12

Creep in Bending — الزحف في الانحناء



* يحدث زحف [ترخيم] للكمرات مثل ما يحدث في الأجسام المعرضة للشد نتيجة عامل الوقت.

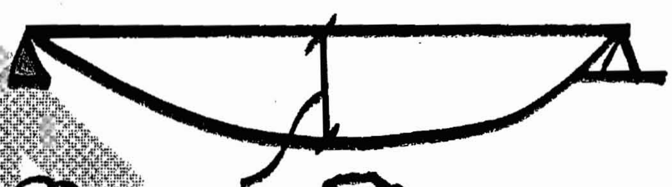


بعد التحميل

Δ_o

وبالتالي تتغير الإجهادات وتحسب من العلاقة:

$$\boxed{f_{cr} = f_e \cdot \left(\frac{2n+1}{3n}\right)}$$



بعد زمن

الترخيم بعد زمن (t): $y = \Delta_o + \Delta_{cr}$

دي بكام

ممكن إستبدال الثابت ($n \leftarrow K_q$) حسب العمل

والترخيم من العلاقة:

$$\boxed{\frac{d^2y}{dx^2} = \frac{t}{A} M_x^n} \qquad (1)$$

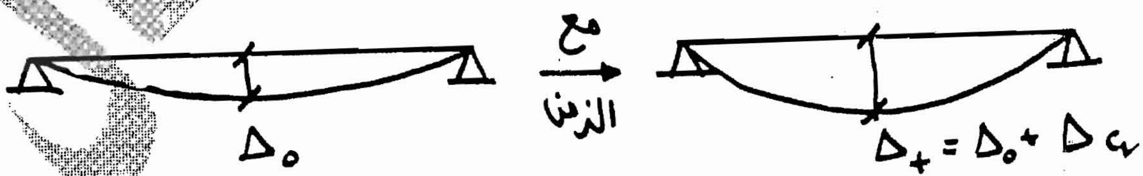
: t : time

: A : Const

: n = Const = K_q

Creep in Bending

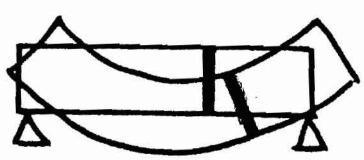
★ يحدث زحف للكمرات فيزداد الهبوط الناتج.



← للحكم على الزحف فى الإنحناء سيتم فرض مجموعة فروض :

→ Assumtion for mechanicsm of creep in Bending :

١. إهمال القص الناتج من الإنحناء.



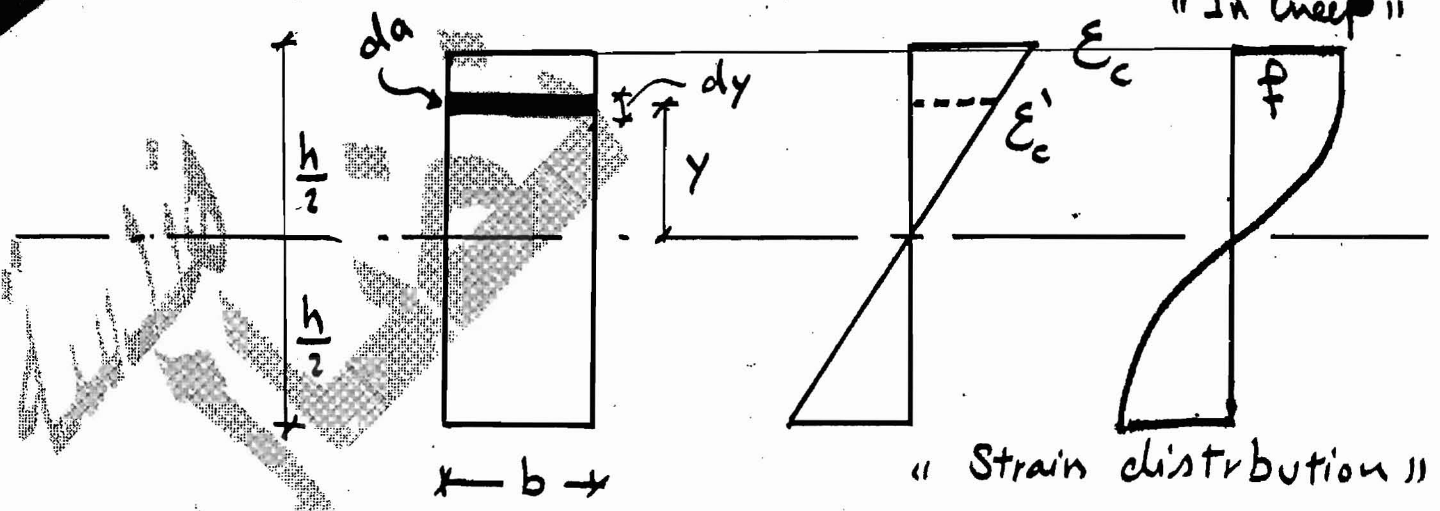
٢. المستويات تظل مستويات بعد التحميل.

٣. العلاقة المستنتجة بين الزحف و الإجهاد و الزمن فى الشد هى نفسها فى الضغط.

٤. عند أى قطاع فى الكمرة القوى الموجودة متكافئة

[شد = ضغط]

٥. العزوم الناتجة من الأحمال الخارجية = العزوم الناتجة من الإجهادات الداخلية



← من تشابه المثلثات :

$$\therefore \quad \frac{\mathcal{E}'_c}{\mathcal{E}_c} = \frac{y}{(h/2)} \longrightarrow ①$$

$$\because \quad \mathcal{E} = B \cdot f^n \cdot t$$

$$\therefore \quad \mathcal{E}'_c = B\,t\,f_{c'}^n \quad , \quad \mathcal{E}_c = B\,t\,f_c^n$$

بالتعويض من (١) :

$$\frac{\cancel{Bt}\,f_{c'}^n}{\cancel{Bt}\,f_c^n} = \frac{y}{(h/2)}$$

$$\therefore \quad f_{c'} = \left(\frac{y}{h/2}\right)^{1/n} f_c$$

Look

$$M = \int_{-h/2}^{+h/2} f'_c \cdot da \cdot y$$

عزم = قوة * مسافة

إجهاد * مساحة

$$da = b \cdot dy$$

$$= \int_{-h/2}^{+h/2} f_c \cdot \left(\frac{y}{h/2}\right)^{1/n} \cdot b \cdot dy \cdot y$$

$$= \int_{-h/2}^{+h/2} \frac{f_c \cdot b}{\left(\frac{h}{2}\right)^{1/n}} \cdot y \cdot y^{1/n} \cdot dy$$

$$\therefore \quad M = \int_{-h/2}^{+h/2} \frac{f_c \cdot b}{(h/2)^{1/n}} \cdot y \cdot y^{1/n} \cdot dy$$

$$= \frac{f_c \cdot b}{(h/2)^{1/n}} \cdot \int_{-h/2}^{+h/2} y^{(1+\frac{1}{n})} \cdot dy$$

$$= \frac{f_c \cdot b}{[h/2]^{1/n}} \cdot \left[\frac{y^{2+\frac{1}{n}}}{2+\frac{1}{n}} \right]_{-\frac{h}{2}}^{h/2}$$

$$\therefore \quad M = \frac{f_c \cdot b}{(h/2)^{1/n} \cdot (2 + 1/n)} \cdot (2) \cdot \left[h/2 \right]^{2+\frac{1}{n}}$$

$$\therefore \quad f_c = \frac{M \cdot (h/2)^{1/n} \cdot (2 + 1/n)}{2 \; b \; (h/2)^{2+\frac{1}{n}}} \cdot \left(\frac{h/6}{h/6} \right)$$

والإختصار

$$\therefore \quad f_c = \frac{M \cdot h}{I \cdot 2} \left(\frac{2n+1}{3n} \right)$$

$$\because I = \frac{bh^3}{12}$$

$$\therefore \quad f_c = f_{elastic} \cdot \left(\frac{2n+1}{3n} \right)$$

$$f_{elastic} = \frac{M}{I} \cdot \frac{h}{2}$$

$\because \; n > 1$

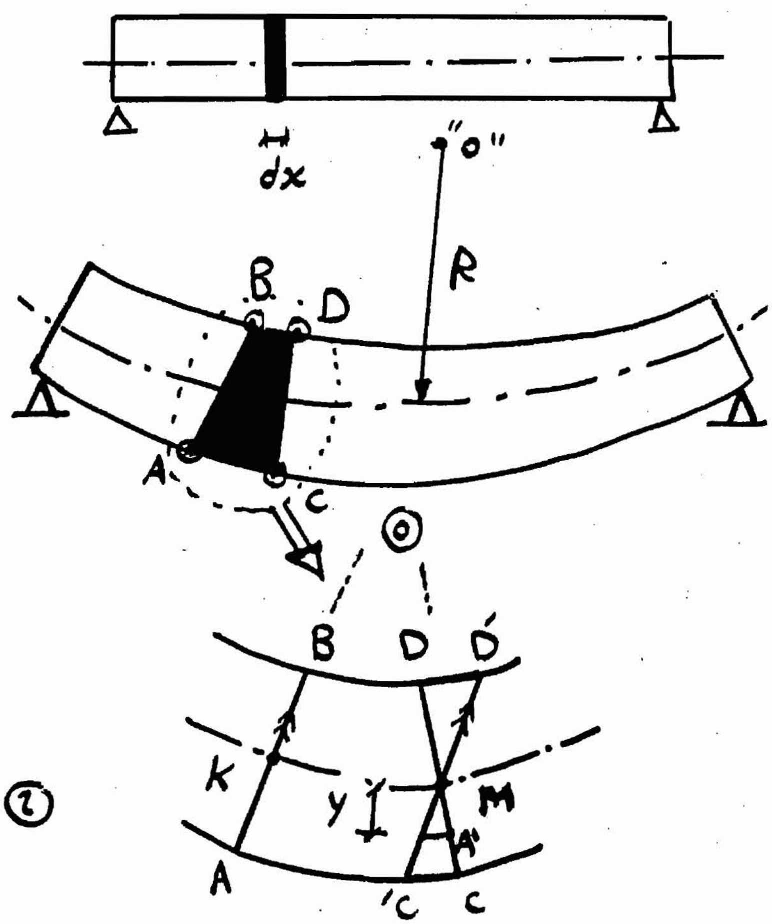
في المرونة $\leftarrow n = 1$

Look

* Creep Deflection : الترخيم الناتج من الزحف

from shape: $\Delta cc'm \sim \Delta Kmo$

$\because \dfrac{cc'}{Km} = \dfrac{c'm}{Ko}$



$\because Km = AC'$

$\therefore \dfrac{cc'}{AC'} = \dfrac{h/2}{R}$

$\because \varepsilon_A = \dfrac{h/2}{R}$

$\because \varepsilon'_A = \dfrac{y}{R} \rightarrow ①$

$\because \varepsilon'_A = B_t \cdot f_{A'}^{n} \rightarrow ②$

from ①, ② :

$\therefore \dfrac{y}{R} = B_t \cdot f_{A'}^{n}$

$\because f_{A'} = \left(\dfrac{y}{R \cdot B_t}\right)^{1/n}$

$\because M = \displaystyle\int_{-h/2}^{h/2} f_{A'} \cdot b \cdot dy \cdot y$ ⟸ من الشكل لحساب العزم :

$$M = \int_{-h/2}^{h/2} \sigma_A \cdot b \cdot dy \cdot y = \int_{-h/2}^{h/2} \left(\frac{y}{R \cdot B_t}\right)^{1/n} \cdot b \cdot dy \cdot y$$

$$= \frac{b}{(R B_t)^{1/n}} \cdot \int_{-h/2}^{h/2} y^{1+\frac{1}{n}} \cdot dy$$

$$= \frac{n \cdot b}{(2n+1)(R B_t)^{1/n}} \cdot \left[y^{\frac{2n+1}{n}} \right]_{-h/2}^{h/2}$$

$$= \frac{2b}{(\frac{1}{n}+2)(R \cdot B_t)^{1/n}} \cdot \left(\frac{h}{2}\right)^{\frac{1+2n}{n}}$$

$$\because \quad M = \frac{(2b)^n}{B_t \cdot (\frac{1}{n}+2)^n} \cdot \left(\frac{h}{2}\right)^{1+2n} \cdot \frac{1}{R}$$

$$\therefore \quad \frac{M}{IE} = 1/R$$

$$\boxed{\frac{M}{I} = \frac{\sigma}{y} = \frac{E}{R}}$$

hook

$$\because \quad \frac{d^2y}{dx^2} = \frac{-M}{EI}$$

Look

من الآخر هنستخدم ال vs

$$\boxed{\therefore \quad M^n = -D \cdot \frac{d^2y}{dx^2}}$$

لا علاقة بالزمن

D : Const

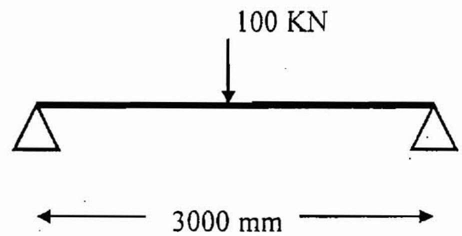
$$D = \frac{A}{t} \leftarrow \text{Const}$$

: y : Deflection الترخيم

x : distance from support المسافة من الركيزة

1- Simple beam (rectangular cross section with 120mm width and 200mm depth) subjected to concentrated load of 100KN as shown in fig (1).

Find the creep stress in beam and the total deformation at mid span after 10 years (K_4=8, A=6.8*10^{-23}).



1- Stress:

$$f_{cr} = f_e \cdot \left(\frac{2K_4+1}{K_4} \right)$$

$$\rightarrow f_e = \frac{M}{I} \cdot y$$

$$= \frac{P \cdot L}{4 \cdot \left(\frac{bh^3}{12}\right)} \cdot \frac{h}{2}$$

$$= \frac{(100 * 1000 * 3000)}{4\left(\frac{120 * (200)^3}{12}\right)} \cdot \frac{200}{2}$$

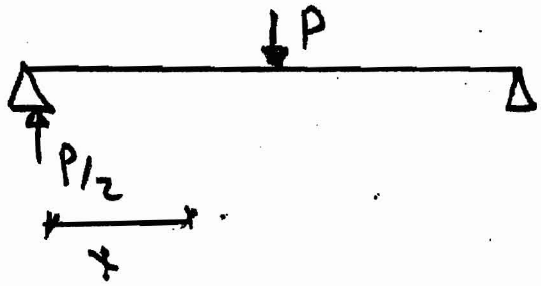
$$= 93.75 \ N/mm^2 = MPa$$

$$\therefore f_{cr} = 93.75 * \left(\frac{2*8+1}{3*8} \right) = \underline{66.4 \ MPa}$$

2- Deformation:

$$\frac{d^2y}{dx^2} = \frac{t}{A}\cdot\left(M_x^{k4}\right)$$

$$\therefore \frac{d^2y}{dx^2} = \frac{t}{A}\cdot\left(\frac{P}{2}x\right)^8$$



بالتكامل

$$\therefore \frac{dy}{dx} = \left(\frac{t}{A}\right)\int \frac{P^8}{(2)^8}X^8\,.dx \qquad M_x = \frac{P}{2}\cdot X$$

$$(0 \rightarrow L/2)$$

$$\frac{dy}{dx} = \frac{t}{A}\left(\frac{P}{2}\right)^8\cdot\frac{X^9}{9} + C_1 \rightarrow (1)$$

بالتكامل $\therefore$

$$y = \frac{t}{9A}\left(\frac{P}{2}\right)^8\frac{X^{10}}{10} + C_1X + C_2 \rightarrow (2)$$

الظروف
الشروط :

$$\frac{dy}{dx} = 0.0 \rightarrow X_{max} = L/2$$

$$\text{from } y = 0.0 \rightarrow X = 0.0$$

$$\therefore \text{from } (2) \quad C_2 = 0.0$$

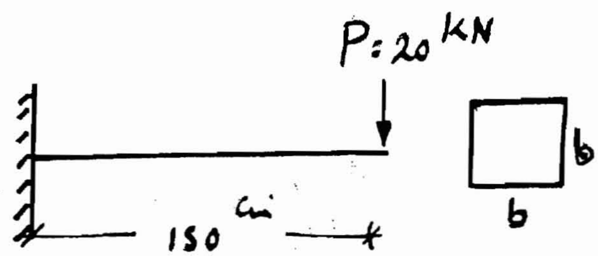
$$\text{from } (1) \quad C_1 = -\frac{t}{A}\left(\frac{P^8}{2}\right)\frac{(L/2)^9}{9}$$

$$\therefore Y = \frac{t}{9A}\left(\frac{P}{2}\right)^8\frac{X^{10}}{10} + \frac{-t}{A}\cdot\left(\frac{P}{2}\right)^8\cdot\frac{(L/2)^9}{9}$$

6) A cantilever beam of square cross section and length L = 150.0 cm is subjected to an end concentrated load P = 20 kN. Determine the cross sectional dimensions if a) the creep stress is not exceed 80.0 MPa and b) the creep deflection is to be less than 1/50 of the beam span in 10 years. Use the following equations:

$\sigma = \sigma_{elastic}\left(\frac{2n+1}{3n}\right)$, $D = \left(\frac{1}{\beta_t}\right)\left[\frac{(2b)^n \left(\frac{h}{2}\right)^{(2n+1)}}{\left(2+\frac{1}{n}\right)^n}\right]$, where b = width of beam, h = depth of beam, $D\frac{d^2y}{dx^2} = M^n$, n = 5, and $\beta_t = 8\,(10)^{-14}$ mm/mm per day.

a) $\because f_{cr} = 80$ MPa



$\because f_{cr} = f_{elastic} \cdot \left(\frac{2n+1}{3n}\right)$

$\because f_{elastic} = \frac{M}{I} \cdot y$

$= \frac{20 \cdot 150 \cdot 1000}{\frac{b \cdot b^3}{12}} \cdot \frac{b}{2} = \frac{18 \cdot 10^7}{b^3}$

$f = f_{elastic}\left(\frac{2n+1}{3n}\right)$

$\therefore 80 = \frac{18 \cdot 10^7}{b^3} \cdot \left(\frac{2 \cdot 5 + 1}{3 \cdot 5}\right)$

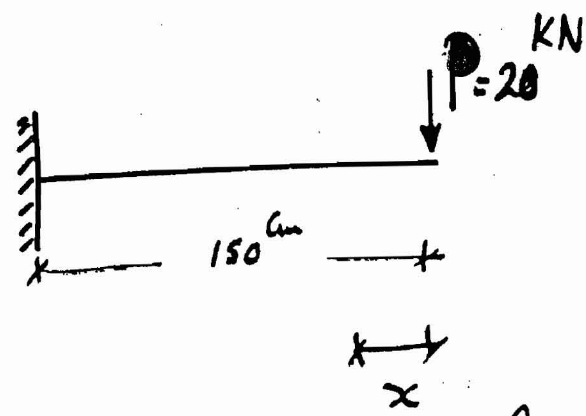
$\Rightarrow b = 118.2$ mm

$= 11.8$ cm

أقصى ترخيم

b) $Y_{max} = \frac{1}{50} \cdot 150^{cm}$

$= 3^{cm}$



$$\therefore \frac{d^2y}{dx^2} = \frac{1}{D} \cdot (M_x)^n$$

$$\boxed{M_x = P \cdot x}$$ Look

$$\therefore \frac{d^2y}{dx^2} = \frac{1}{D}(Px)^5 = \frac{1}{D}(P^5 \cdot x^5)$$

بالتكامل الثاني → $\frac{dy}{dx} = \frac{P^5 \cdot x^6}{6\,D} + C_1$

بالتكامل الأول → $\boxed{y = \frac{P^5 \cdot x^7}{6 \cdot 7 \cdot D} + C_1 \cdot x + C_2}$

Look

أقصى ترخيم يمكن حسابه من التفاضل الأول

Condition (1) → $\frac{dy}{dx} = \text{Zero}$ at → $x = L$

$$\therefore C_1 = -\frac{P^5 \cdot x^6}{6\,D} = \frac{-P^5 \cdot L^6}{6\,D} \rightarrow ①$$

Look خذ بالك

Condition (2) → $y = 0.0$ at → $x = L$

$$0.0 = \frac{P^5 \cdot L^7}{42\,D} + \frac{-P^5 \cdot L^6 \cdot L}{6\,D} + C_2$$

$$C_2 = \frac{P^5 \cdot L^7}{7\,D} \rightarrow ②$$

$$\therefore \quad y = \frac{P^5 \cdot x^7}{42\,D} - \frac{P^5 \cdot L^6}{6\,D}x + \frac{P^5 \cdot L^7}{7\,D}$$

$\because \; y = y_{max}$ at $\rightarrow x = 0.0$

عند الطرف

Look

$$\therefore \quad y_{max} = \frac{P^5 \cdot L^7}{7\,D}$$

$$y_{max} = 3\,cm = 30\,mm = \frac{(20 \times 1000)^5 \times (1500)^7}{7\,D}$$

Look

$\boxed{\text{Constant}} \rightarrow D = 2.6 \times 10^{41}$

from relation:

$$D = \frac{1}{B} \cdot \left[\frac{(2b)^n \cdot \left(\frac{h}{2}\right)^{2n+1}}{\left(2 + \frac{1}{n}\right)^n} \right]$$

$$\therefore \quad 2.6 \times 10^{41} = \frac{1}{8 \times 10^{-14}} \cdot \left[\frac{(2 \times b)^5 \times \left(b/2\right)^{2 \times 5+1}}{\left(2 + \frac{1}{5}\right)^5} \right]$$

$$\therefore \quad b = 100.6\,mm$$

Use $b = 11.8\,cm$

2- Design a vertical bar AB with length 2m subjected to 6 ton tensile load at 300° c after 10 years if :

1- Steel grade (24/36) and factor of safety = 4.

2- Allowable creep rate = 0.0012 at year.

Assume that the total instantaneous and primary elongation is 1.4 mm, $f^{\circ} = 72$ kg/cm², $k_4 = 8$, $k_3 = 5*10^{-12}$ cm/cm/day

Look

لو شه قال F.O.S بكام نأخذه
F.O.S = 2

(1) Grade (24/36)

$\therefore \quad f_y = 24 \text{ kg/mm}^2$

$\therefore \quad f_{all} = \dfrac{f_y}{F.O.S} = \dfrac{24}{4} = 6 \text{ kg/mm}^2$

$= 600 \text{ kg/cm}^2$

$\therefore \quad f_{all} = \dfrac{P}{A}$

$\therefore \quad \text{Area} = \dfrac{6000}{600}$

$= 10 \text{ cm}^2$

$\therefore \quad D = 3.57 \text{ cm}$

2) $C = 0.0012$ cm/cm/year

$\therefore C = K_3 * \left(\frac{f}{f_o}\right)^{K_4}$

$\therefore f_o = 72$ Kg/cm² & $K_4 = 8$

$K_3 = 5 * 10^{-12}$

$\therefore \left(0.0012 / 365\right) = 5 * 10^{-12} * \left(\frac{f}{72}\right)^8$

$\therefore f = 384.2$ Kg/cm²

$\therefore f = \frac{P}{A} = \frac{6000}{Area}$

$\therefore Area = \frac{6000}{384.2} = 15.6$ cm²

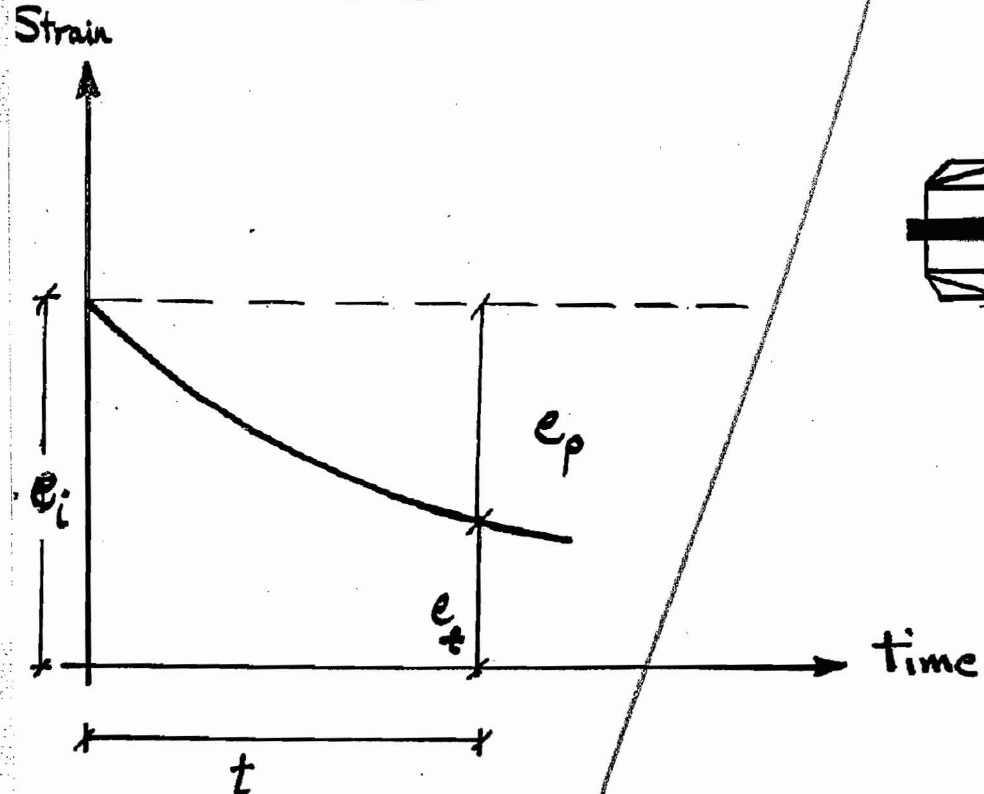
$\therefore D = 22.1$ cm

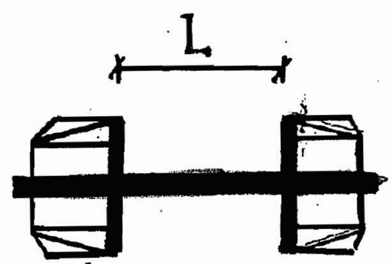
take $\underline{D = 22.1}$ cm

Stress Relaxation

إجهاد الإسترخاء

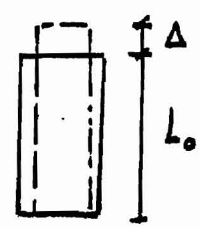
- عند ثبات الإنفعال يقل الإجهاد مع الزمن وتظهر هذه الظاهرة من المسامير والخرسانة سابقة الإجهاد.





« bolts »

→ After Loading : $e_i = \dfrac{f_i}{E}$



→ After any time :

$$e_i = e_t + e_{creep}$$

$$e_i = e_t + e_p$$

e_i : initial strain الإنفعال الإبتدائي

e_t : Strain at any time الإنفعال عند أي زمن

e_p : Creep strain إنفعال الزحف

$$(1) \quad \boxed{\frac{f_i}{E} = \frac{f_t}{E} + \beta \cdot f_t^{n} \cdot t}$$

f_i : الإجهاد الإبتدائي

f_t : الإجهاد عند الزمن المطلوب

$$(2) \quad \boxed{t = \frac{(f_o)^{k_4}}{E k_3 (k_4 - 1) f_t^{(k_4-1)}} \cdot \left(1 - \left(\frac{f_t}{f_i}\right)^{(k_4-1)}\right)}$$

يتم إستخدام المعادلة كل حسب المعطيات ملاحظة

4) A steel bolt is subjected to an axial tensile load fixed between two rigid plates so that the length of the bolt remains constant. What must be the initial stress to produce 65 percent of the initial stress after 10 years? Use the following equation: $\frac{\sigma_i}{E} = \frac{\sigma}{E} + \beta t \sigma^n$ and the constants n = 4 & $\beta = 4.6(10)^{-14}$ mm/mm/day and E = 200 GPa.

$f_t = 0.65\ f_i \longrightarrow 10$ years

$\beta = 4.6 \cdot 10^{-1}$ mm/mm/day , E = 200 GPa

$n = 4$

~~sol~~

$$\frac{f_i}{E} = \frac{f_t}{E} + \beta \cdot t \cdot f_t^n$$

$$\therefore \frac{f_i}{200} = \frac{0.65\ f_i}{200} + 4.6 \cdot 10^{-1} \cdot 10 \cdot 365 \cdot (0.65 \cdot f_i)^4$$

$$\therefore f_i = 0.0391 \text{ GPa}$$

$$\therefore f_t = 0.025 \text{ GPa}$$

5) For the steel bolt in problem (4), estimate the time intervals to be retightened again for both initial stress calculated in problem (4) and for initial stress of 100 MPa if the decreasing of stress should not be less than half of initial stress. Comment on your results

$f_i = 39.12$ MPa

$f_t = 0.5\, f_i$

$= 19.56$ MPa

$$\frac{f_i}{E} = \frac{f_t}{E} + B \cdot t \cdot f_t^n$$

$$\frac{39.12}{200 \cdot 10^3} = \frac{19.56}{200 \cdot 10^3} + 4.6 \cdot 10^{-14} \cdot t \cdot (0.5 \cdot 39.14)^4$$

$\therefore t = 14525$ day

$f_i = 100$ MPa

$f_t = 0.5\, f_i$

$= 50$ MPa

$$\frac{f_i}{E} = \frac{f_t}{E} + B \cdot t \cdot f_t^n$$

$$\frac{100}{200 \cdot 10^3} = \frac{50}{200 \cdot 10^3} + 4.6 \cdot 10^{-14} \cdot t \cdot (50)^4$$

$t = 869$ day

← بزيادة الإجهاد الابتدائي يزداد معدل الإسترخاء

ويقل الزمن اللازم

لفك

المسمار

Look

6- A steel bolt is subjected to an axial tensile load fixed between two rigid plates so that the length of the bolt remains constants. What must be the initial stress to produce 75 % of the initial stress after 3 years?

The constants: $f^o = 72$ kg/cm², $k_4 = 8$, $k_3 = 5*10^{-10}$ cm/cm/day, $E = 2*10^6$ kg/cm²

Sol

$$\therefore \quad t = \frac{(f_o)^{k_4}}{E\, k_3\, (k_4 - 1)\, f_t^{(k_4-1)}} \cdot \left(1 - \left(\frac{f_t}{f_i}\right)^{(k_4-1)}\right)$$

$$\therefore \quad \frac{f_t}{f_i} = \frac{75}{100} = 0.75$$

$$\therefore \quad 3 * 365 = \frac{(72)^8}{2*10^6 * 5*10^{-10}\,(8-1) \cdot f_t^{(8-1)}} \left(1 - (0.75)^{(8-1)}\right)$$

حل المعادلة

$$\therefore \quad f_t = 97.2 \text{ Kg/cm}^2$$

يعني الإجهاد بعد زمن ٢ سنين الموجود على المنشأ

Logic