บทที่ 3

วิธีการออกแบบและขั้นตอนการทำงานของโปรแกรมคอมพิวเตอร์

3.1 Slab Bridge

ออกแบบโดยวิธี Sevice Load Design Method โดยมีขั้นตอนของการออกแบบและการทำงานของโปรแกรมดังนี้

1> Design Conditions

1. Span Length	(L)	=	......	m.
2. Width of Bridge	(E)	=	......	m.
3. Number of Lane	(N1)	=	$\frac{W}{3.05}$	
4. Type of Loads		=	......	(1-4)
	1	=	H15-44	
	2	=	HS15-44	
	3	=	H20-44	
	4	=	HS20-44	

2> Materials (AASHTO 8.7.1)

(a). Concrete

1. Compressive strength of concrete (fc') = ... ksc.
2. Extreme fiber stress in compression (fc) = 0.4fc' ksc.
3. Modulus of elasticity of concrete (Ec) = $15,114\sqrt{fcs'}$ ksc.

(b). Reinforcing Steel

1. Yield strength of reinforcing steel (fy) = ... ksc.
2. allow.tensile stress reinforcing steel (fs) = ... ksc.
3. Modulus of elasticity of steel (Es) = 2.04×10^6 ksc.
4. Modular ratio of elasticity (n) = $Es/_{Ec}$
5. Compression block (k) = $\dfrac{1}{1 + fs/_{(nfc)}}$
6. Arm of moment factor (j) = $1 - k/_3$

3> Sectional Properties

1. Depth of slab (t) = ... m.
2. Minimum depth of slab = $\dfrac{L+3.047}{30}$ m.
3. Distance from extreme fiber to centroid of reinforcing Steel (d) = ... m.
4. Moment of Inertia (I) = $\dfrac{1}{12} E.t^3$ $m.^4$

4> Design Loads and Moment

(a). Dead Loads

1. Slab (Wb) = 2400 .t kg/m./m.
2. Maximum Moment due to dead loads (Md) = $\frac{1}{8}$ Wd.L^2 kg-m./m.

(b). Live Load

1. Live Load Moment for H20-44,HS20-44 Loading (AASHTO 3.24.3)

   for 0 < L <15.25 m. (Ml) = 408.24 L kg-m./m.

   for L >= 15.25 m. (Ml) = 453.60(1.3L-6.094) kg-m./m.

2. Live Load Moment for H15-44,HS15-44 Loading (AASHTO 3.24.3)

   for 0 < L <15.25 m. (Ml) = 306.18 L kg-m./m.

   for L >= 15.25 m. (Ml) = 340.20(1.3L-6.094) kg-m./m.

3. Impact loading (i) = $\frac{15.24}{L + 38}$ =< 0.30

4. LL.moment include impact (ML) = Ml.(1+i) kg.-m.

(c). Concrete

1. Maximum moment (M) = Md + (ML.Nl) kg-m.
2. Moment provided by concrete (Mc) = $1/_2$ fc.k.j.b.d^2 kg-m.

If Mc > M ok.

(d). Main reinforcement

1. Maximum moment (M) = Md + (ML.Nl) kg-m.
2. Diameter of reinforcing steel (ds) = ... mm.
3. Section area of reinforcing steel $(a_s) = \frac{(\pi.d^2)}{(4*100)}$ $cm.^2$
4. Area of steel requirement $(As) = \frac{M}{(fs.j.d)}$ $cm.^2$
5. Spacing of steel $(s) = \frac{as}{As}$ m.

(e). distribution reinforcement

1. Area of steel requirement $(A^*s) = 55.21/\sqrt{L}$ $cm.^2$
2. Diameter of reinforcing steel (d^*s)= ..... mm.
3. Section area of reinforcing steel $(a^*s) = \frac{(\pi.d^2)}{(4*100)}$ $cm.^2$
4. Spacing of steel $(s) = \frac{a^*s}{A^*s}$ m.

5> Edge Beams

(a). Dead Loads

1. Width of Beam (b) = ... m.
2. Depth of Beam (t1) = ... m.
3. Beam dead load (Wb) = 2400 bt kg/m./m.
4. Side walk & Rail (Wr) = ... kg/m.
5. Total of dead load (Wd) = Wb+Wr kg/m./m.
6. Maximum moment due to dead loads (Md) = $\frac{1}{8}$ Wd.L^2 kg-m./m.

(b). Live Load

1. Live Load Moment for HS20-44 Loading (AASHTO 3.24.8)

   = 0.1PS

   P = 14,515 kg.

   S = Span Length (m)

2. Live Load Moment for H15-44,HS15-44 Loading (AASHTO 3.24.3)

   = 0.1PS

   P = 14,515 kg.

   S = Span Length (m)

3. Impact loading (i) = $\frac{15.24}{L + 38}$ =< 0.30

4. LL.moment include impact (ML) = Ml.(1+i) kg.-m.

Check Shear

1.Shear force due to dead loads (Vd) = $\frac{Wb.L}{2}$ kg.

2.Permissible shear stress carried by concrete (AASHTO 8.15.2)

(vc) = $0.252\sqrt{fc'}$ ksc.

3.Shear carried by concrete (Vc) = vc.b.t1 kg.

4.Shear carried by steel (Vs) = Vd - Vc kg.

3.2 precast prestressed multibeam bridge

สำหรับการออกแบบ precast prestressed multibeam bridge ได้ออกแบบโปรแกรมโดยแบ่งตามลักษณะของหน้าตัดคาน ออกเป็น 3 ชนิด ดังต่อไปนี้

1. non-void rectangular beams
2. rectangular beams with circular void
3. box section beams

โดยมีทฤษฎี และขั้นตอนการออกแบบ ดังนี้

1> Design Conditions				
1. Span Length	(L)	=	......	m.
2. Width of Bridge	(E)	=	......	m.
3. Number of Lanes	(Nl)	=	......	
4. Type of Loads		=	......	(1–4)
	1	=	H15–44	
	2	=	HS15–44	
	3	=	H20–44	
	4	=	HS20–44	

2> Materials

(a). Precast Concrete

1.Compressive strength of concrete (fc') = ... ksc

2.Compressive strength of concrete at time of initial Prestress

(fci') = 0.8 fc' ksc

(AASHTO 9.15)

3.Modulus of elasticity of concrete (Ec) = $15{,}114\sqrt{fc'}$ ksc

(AASHTO 8.7.1)

(b). Cast-in-place Concrete

1.Compressive strength of concrete (fcs') = ... ksc

2.Modulus of elasticity of concrete (Ecs) = $15{,}114\sqrt{fcs'}$ ksc

(AASHTO 8.7.1)

(c).Prestressing Steel

1.Diameter of prestressing steel (d^*_s) = ... mm.

2.Ultimate strength of prestressing steel (f^*s') = ... ksc.

3.Section area of prestressing steel (a^*_s) $= \frac{\pi (d^*_s)^2}{4 \times (100)}$ cm.^{2}

(d).Reinforcement Steel

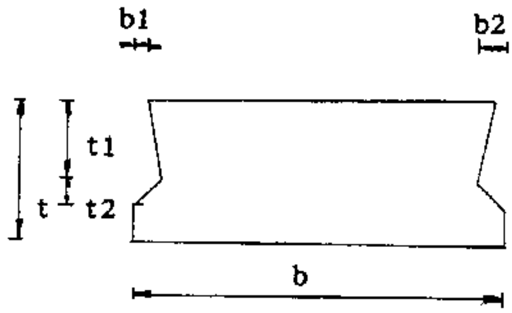
1.Diameter of reinforcing steel (d) = ... mm.

2.Ultimate strength of reinforcing steel (fs') = ... ksc.

3.Section area of reinforcing steel (a_s) = $\frac{\pi (d_s)^2}{4 \times (100)}$ cm.^{2}

3> Sectional Properties

Case 1# >> non-void rectangular beams



t = ... m.

$t1$ = ... m.

$t2$ = ... m.

b = ... m.

$b1$ = ... m.

$b2$ = ... m.

1. Number of beams

$$Ng = E/b$$

2. Gross area of concrete

$$Ac = (tb) - 2(b1t1) - t1(b2-b1) - (b2t2) \qquad m.^2$$

3. Distance from bottom fiber to the neutral axis

$$y_b = [\frac{tb^2}{2} - 2(b1t1)(t-\frac{t1}{2}) - t1(b2-b1)(t-\frac{t1}{3}) - 2(b2t2)(t-(t1+\frac{t2}{3})]/A_c$$

4. Distance from top fiber to the neutral axis

$$y_t = t - y_b \qquad m.$$

5. Moment of inertia of section

$$I = [\frac{1}{12}bt^3 + Ac(\frac{t}{2} - y_b)^2] - 2[\frac{1}{12}b1t1^3 + (b1t1)(y_t-\frac{t1}{2})^2]$$

$$-2[(b2-b1)\frac{t1^3}{4} + (y_b-t)^2(b2-b1)\frac{t1}{2}] - 2[(\underline{\ 1}b2t2^3)+(\underline{b2}t2)(yt-(t1+\frac{t2}{3}))]$$

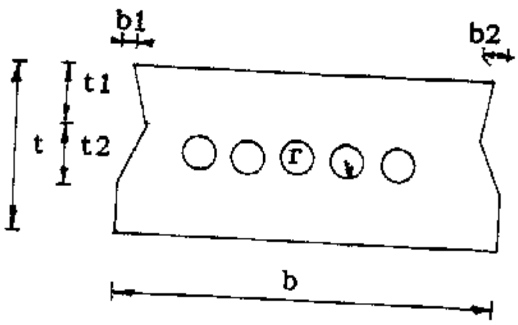
6. lower modulus of section

$$S_b = I/Y_b \qquad m.^3$$

7. upper modulus of section

$$S_t = I/Y_t \qquad m.^3$$

Case 2# >> rectangular beam with circular void



t = ... m.

t1 = ... m.

t2 = ... m.

b = ... m.

b1 = ... m.

b2 = ... m.

r = ... m.

n = ... no.of void

1. Number of beams

$$N_g = E/_b$$

2. Gross area of concrete

$$A_c = (tb) - 2(b1t1) - t1(b2-b1) - (t2b2) - \pi r^2 n \qquad m.^2$$

3. Distance from bottom fiber to the neutral axis

$$y_b = [\frac{tb^2}{2} - 2(b1t1)(t-\frac{t1}{2}) - t1(b2-b1)(t-\frac{t1}{3}) - 2(b2t2)(t-(t1+\underline{t2}) \pi r^2 \frac{t}{2}]/_{(Ac)}$$

4. Distance from top fiber to the neutral axis

$$y_t = t - y_b \qquad m.$$

5. Moment of inertia of section

$$I = [\frac{1}{12}bt^3 + Ac(\frac{t}{2}-y_b)^2] - 2[\frac{1}{12}b1t1^3 + (b1t1)(y_t-\frac{t1}{2})^2] - 2[(b2-b1)\frac{t1^3}{4}$$
$$+(y_b-t)^2(b2-b1)\frac{t1}{2}] - 2[(\frac{1}{12}b2t_2^3 + (\frac{b2}{2}t2)(yt-(t1+\frac{t2}{3}))^2] - [\frac{\pi r^4}{4} + (\pi r^2)(\frac{t}{2}-y_t)^2]$$

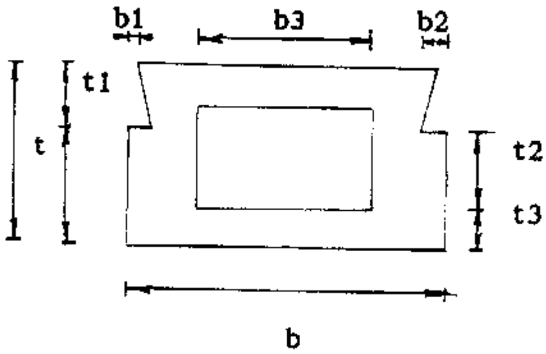
6. lower modulus of section

$$S_b = I/_{Yt} \qquad m.^3$$

7. upper modulus of section

$$S_t = I/_{Yb} \qquad m.^3$$

Case 3# >> box section beams



t = ... m.

t1 = ... m.

t2 = ... m.

t3 = ... m.

b = ... m.

b1 = ... m.

b2 = ... m.

b3 = ... m.

1. Number of beams

   $Ng = E/_{b}$

2. Gross area of concrete

   $Ac = (tb) - 2(b1t1) - t1(b2-b1) - (b3t2)$ $m.^2$

3. Distance from bottom fiber to the neutral axis (y_b)

$\left[\frac{tb^2}{2} - 2(b1t1)(t-\frac{t1}{2}) - t1(b2-b1)(t-\frac{t1}{3}) - 2(b2t2)(t-(t1+\frac{t2}{3})) - (b3t2)\frac{t}{2}\right] /_{(Ac)}$

4. Distance from top fiber to the neutral axis

   $y_t = t - y_b$ m.

5. Moment of inertia of section

$I = [\frac{1}{12}bt^3 + Ac(\frac{t}{2}-y_b)^2] - 2[\frac{1}{12}b1t1^3 + (b1t1)(y_t-\frac{t1}{2})^2] - 2[(b2-b1)\frac{t1^3}{4}$

$+y_b-t)^2(b2-b1)\frac{t1}{2}] - [\frac{1}{4}b3t2^3 + (t2b3)(\frac{t}{2}-y_t)] - 2[(\frac{1}{12}b2t2^3 + (\frac{b2}{2}t2)(yt-(t1+\frac{t2}{3}))^2]$

6. Lower modulus of section

   $S_b = I/_{Yb}$ $m.^3$

7. upper modulus of section

   $S_t = I/_{Yt}$ $m.^3$

4> Loads and Moment

(a). Dead Loads

1. Beam (Wb) = 2400 x Ac kg./m.
2. Side walk & Rail (Wr) = ... kg./m.
3. Topping (Wt) = ... kg./m.
4. Total Wd = Wb+Wr+Wt kg./m.
5. Moment Md = $\frac{Wd.L^2}{8}$ kg.-m.

(b). Live Load

1. Live load moment (Ml) = kg.-m.

The computer program search from the table of Maximum Moment

2. Value of (K)

   = 0.7 for non-void rectangular beams

   = 0.8 for rectangular beams with circular void

   = 1.0 for box section beams

3. Stiffness parameter (C) = $K\,(^{W}/_{L})$
4. $D = 5 + \frac{Nl}{10} + (3-\frac{2Nl}{7})(1-\frac{C}{3})^2$ for C =< 3
5. $D = 5 + Nl/_{10}$ for C =< 3
6. $S = 12\,\frac{Nl}{Ng} + 9$
7. Load fraction = $S/_{D}$
8. Impact load (i) = $\frac{15.24}{L + 38}$ =< 0.30
9. Moment due to live load (ML) = $Ml\,\frac{S}{D}\,(1+i)(0.5)$

5> Prestressing Strands

1. Bottom fiber stress due to loads (fb) = $(Md+ML)/_{Sb}$ ksc.
2. Allowable tensile stress (fct) = $1.591\sqrt{fc'}$ ksc.
3. Required prestress in bottom fiber (fbs) = fb − fct ksc.
4. Distance from bottom fiber to centroid of prestressing Steel (c) = ... m.
5. Strand eccentricity (e) = $S_b - c$ m.
6. Effective depth of beam (d) = t − c m.
7. Effective prestress force after loss (Pse) = $\frac{fbs.Ac.Sb}{(Sb + Ac.e)}$ kg.
8. Final prestress loss per strand
   :: Assuming (pl) = ... %
   :: Psf = $(a^*{}_s x0.7xf^*s')(1-pl)$ kg.
9. Number of strands required (n) = $\frac{Pse}{Psf}$

6> Flexural Strength

1. Factored moment (Mu) = 1.3(Md+1.67ML) kg.-m.
2. f^*su = $f^*s'(1-0.5p^*f^*s'/_{fc'})$ ksc.
3. p^* = $A^*s/_{bd}$
4. Mu = $A^*s.f^*su.d(1-0.6p^*f^*su/_{fc'})$ kg.-m.

   If Mu > Mu ...... OK.

7> Maximum and Minimum Steel Percentage

(a).Maximum Steel (AASHTO 9.18.1)

> Reinforcement Index $= \frac{p^{*}.f^{*}su}{fc'}$ < 0.3 .... OK

(b).Minimum Steel (AASHTO 9.18.2)

1. Average concrete stress at the c.g. of prestressing steel

   (fcr) = 1.9887√fc' ksc.

2. Moment causing flexural cracking at section due to externally applied loads (Mcr) $= Sb\left(\frac{Pse}{Ac} + \frac{Pse.e}{Sb} + fcr\right)$ kg.-m.

If $\frac{Mu}{Mcr}$ > 1.20 ...... OK.

8> Prestress Losses

(a).Shrinkage

> Relative humidity (RH) = ... %

> Loss of prestress due to concrete shrinkage

(SH) = 1,195 - 10.5 RH ksc.

(b).Elastic Shortening

1. Effective Prestress force after transfer (Assume ...% loss)

$$(Psi) = (1\text{-}loss)(0.7\ f^{*}s')\ n.a^{*}_{s} \quad kg.$$

2. Modulus of elasticity of concrete at time of initial prestress

$$(Eci) = 15{,}114\sqrt{fci'} \quad ksc.$$

3. Average concrete stress at the c.g. of prestressing steel at time of initial prestress

$$(fcir) = \frac{Psi}{Ac} + \frac{Pse.e^2}{I} - \frac{Md.e}{I} \quad ksc.$$

4. Modulus of elasticity of prestressing steel

$$(Es) = 2.04 \times 10^{6} \quad ksc.$$

5. Loss of prestress due to elastic shortening

$$(ES) = \frac{Es}{Eci}.\ fcir \quad ksc.$$

(c).Creep of Concrete

1. Concrete stress at level of prestressing steel due to supperimpose dead load

$$(fcds) = \frac{Md.e}{I} \quad kg.$$

2. Loss of prestress due to creep of concrete

$$(CRc) = 12\ fcir - 7\ fcds \quad ksc.$$

(d).Relaxation of Prestressing Steel

loss of prestress due to relaxation of prestressing steel

for stress-relieved strand $(CRs) = 1{,}406-0.4ES-0.2(SH+CRc)$ ksc.

for low-relaxation strand $(CRs) = 351.5-0.1ES-0.05(SH+CRc)$ ksc.

(e).Total Loss of Prestress

$$fs = SH + ES + CRc + Crs \quad ksc.$$

$$= \frac{fs}{(0.7f^{*}s')} \quad \%$$

9> Concrete Stress (AASHTO 9.15.2)

LOAD	Span end at Prestress Transfer P = Psi		Midspan at Service Load P = Pse	
	fb	ft	fb	ft
P/Ac P/S Md/S Ml/S				
Total Stress				
Allowable Stress	0.6fc'	1.9887√fc'	1.5909√fc'	0.4fc'

10> Shear Strength

1. Shear force due to unfactored dead loads

(Vd) = (Wd.L/2) kg.

2. Shear force due to truck load (Vl) = kg./lane

>> search from the table of Maximum Shear

3. Shear force due to truck Load include Impact

$$(VL) = (1+I)Vl.\frac{S}{D}(0.5) \quad kg./beam$$

4. Factored shear forced

$$(Vu) = 1.3\,(Vd + 1.67\,VL) \quad kg.$$

5. Reaction at the support

$$(R) = Vu.L/_2 \quad kg./beam$$

6. Maximum factored moment of section due to externally applied loads $(Mmax) = R.d/_2$ kg.

7. Moment causing flexural cracking at section due to externally applied loads $(Mcr) = \frac{I}{Yt}(1.591\sqrt{fc'}+fpe-fd)$ kg.-m.

8. Compressive stress in concrete due to effective prestress force only (after allowance for all prestress losses) at extreme fiber of section where tensile stress is caused by externally applied loads $(fpe) = \frac{Pse}{Ac} + \frac{Pse.e}{Sb}$ ksc.

9. Stress due to unfactored dead load at extreme fiber of section where tensile stress is caused by externally applied loads $(fd) = \frac{Md}{Sb}$ ksc.

10. Width of a web of a member (b')

$= b$ for case 1#

$= b-2nr$ for case 2#

$= b-b3$ for case 3#

11.factored shear force due to externally applied loads

$$(V_i) = 1.3(1.67VL) \quad \text{kg.}$$

12.Norminal Shear strength provided by concrete when diagonal cracking results from combined shear and moment

$$(V_{ci}) = 0.1591\sqrt{fc'}.b'.d + V_d + \frac{V_i.M_{cr}}{M_{max}} \quad \text{kg.}$$

13.Norminal shear strength provided by concrete when diagonal cracking results from excessive principal tensile stress in web

$$(V_{cw}) = (0.9281\sqrt{fc'} + 0.3f_{pc})b'.d + V_p \quad \text{kg.}$$

14.Shear provided by concrete

$$(V_c) = \quad \text{kg.}$$

Use the lesser of the value Vci or Vcw

15.Shear provided by steel

$$(V_s) = V_u - V_c \quad \text{kg.}$$

** Remark Vs shall not be taken greater than $2.121\sqrt{fc'}.b'.d$

16.Design diameter of web

$$(ds) = \ldots\ldots \quad \text{mm.}$$

$$(av) = \frac{\pi.ds^2(2)}{400} \quad \text{cm.}^2$$

17.Spacing of web

$$(s) = \frac{Av.fsy.d}{Vs} \quad \text{m.}$$

10> Deflection to be Considered		
Multipliers to be used as a guide in estimating Long-time Cambers and Deflections for typical members.		
Deflection to be Considered	Without Composite Topping	With Composite Topping
>> At erection		
(1) Deflection (downward) component - apply to the elastic deflection to the member weight at release of prestress	1.85	1.85
(2) Camber (upward) component - apply to the elastic camber due to prestress at the time of release of prestress	1.80	1.80
>> Final		
(3) Deflection (downward) component - apply to the elastic deflection due to the member weight at release of prestrees	2.70	2.40
(4) Camber (upward) component - apply to the elastic camber due to prestress at the time of release of prestress	2.45	2.20

(5) Deflection (downward) component - apply to the elastic deflection due to superimposed dead load only	3.00	3.00
(6) Deflection (downward) component - apply to the elastic deflection caused by the composite topping	-	2.30

(a).Prestress at transfer

$$yps = \frac{Psi.e.L^2}{8\ EI} \quad - \quad m.$$

(b).Beam dead load

$$yb = \frac{5Wb.L^4}{384EI} \quad + \quad m.$$

(c).Growth in storage

$$yg = 1.8\ (\ yps + yd\ ) \quad m.$$

(d).Superimpose dead loads

$$ysd = \frac{5Wd.L^4}{384EI} \quad m.$$

(e).Net long term after construction

$$ynl = yg + ysd \quad m.$$

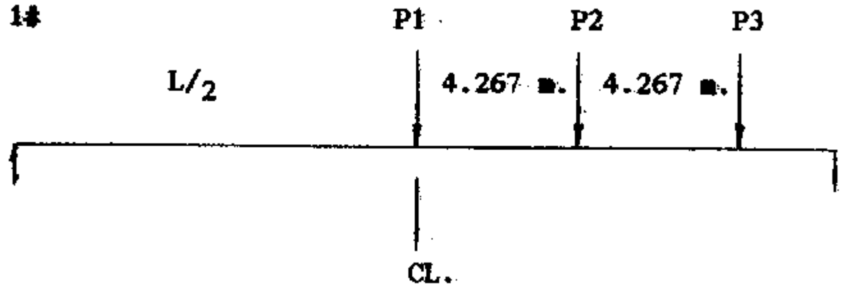
(f).Long term dead load

$$= 2.45(2.2)yps+2.7(2.4)yb+3.0ysd$$

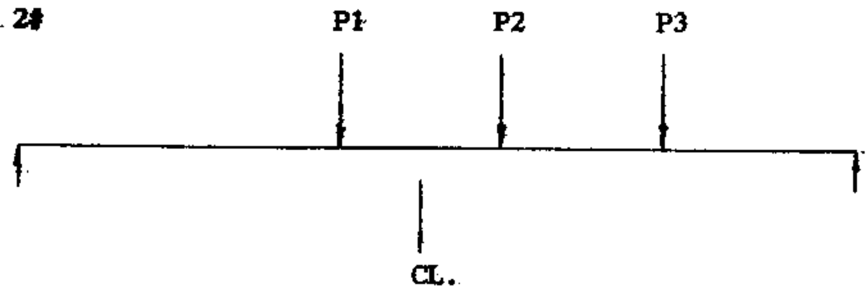
(g).Live Load deflection

สำหรับการหาค่า Live Load deflection ได้เลือกจุดที่น้ำหนักกระทำต่อโครงสร้างเพื่อที่จะประมาณค่า Maximum deflection 3 กรณี และจะเลือกจากกรณีที่ให้ค่า deflection สูงสุด

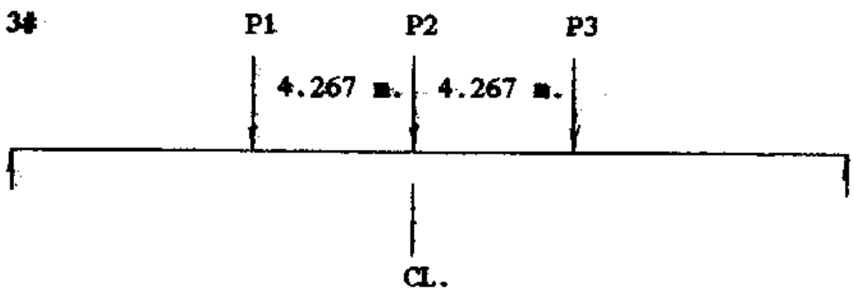
case 1#



case 2#

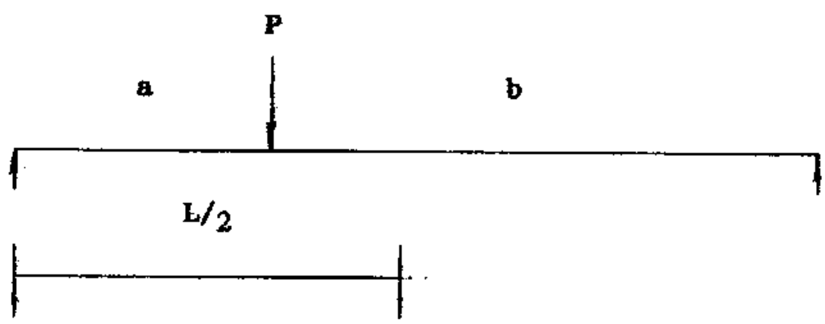


case 3#



For >> H15-44	P1	=	11,013	kg.	(108 kN.)
	P2	=	2,753	kg.	(27 kN.)
	P3	=	0		
For >> HS15-44	P1	=	11,013	kg.	(108 kN.)
	P2	=	11,013	kg.	(108 kN.)
	P3	=	2,753	kg.	(27 kN.)
For >> H20-44	P1	=	14,685	kg.	(144 kN.)
	P2	=	3,671	kg.	(36 kN.)
	P3	=	0		
For >> HS20-44	P1	=	14,685	kg.	(144 kN.)
	P2	=	14,685	kg.	(144 kN.)
	P3	=	3,671		(36 kN.)

ในการคำนวณหาค่า Maximum deflection ได้เลือกที่ตำแหน่ง
กึ่งกลางคาน โดยหาค่าจากสูตรดังนี้



$$y = \frac{Pb}{12EI}\left(\frac{3L^2}{4} - b^2\right) \qquad \text{for } a > L/2$$

$$y = \frac{Pb}{12EI}\left[\frac{L^3}{4b} + \frac{3L^3}{8} - \frac{aL^2}{b} - \frac{b^2L}{2} + \frac{a^2}{b}\right] \qquad \text{for } a < L/2$$

การคำนวณหาค่า deflection ที่ $L/2$ โดยจะคำนวณจาก
ผลรวมของ deflection ที่เกิดจาก P1,P2 และ P3

3.3 T-beam bridge

ออกแบบโดยวิธี Sevice Load Design Method โดยมีทฤษฎี และขั้นตอนของการออกแบบ ดังนี้

1> Design Conditions

1. Span Length (L) = ... m.
2. Width of Bridge (E) = ... m.
3. Number of Lanes (Nl) = ...
4. Type of Loads = ... (1-4)

2> Materials (AASHTO 8.7.1)

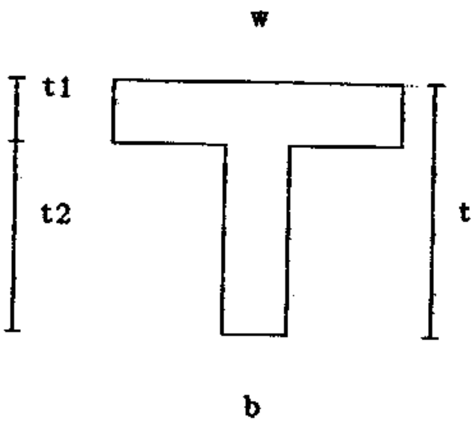
(a). Concrete

1. Compressive strength of concrete (fc') = ... ksc.
2. Extreme fiber stress in compression (fc) = 0.4fc' ksc.
3. Modulus of elasticity of concrete (Ec) = $15,114\sqrt{fcs'}$ ksc.

(b). Reinforcing Steel

1. Yield strength of reinforcing Steel (fy) = ... ksc.
2. allow.tensile stress of reinforcing Steel (fy) = ... ksc.
3. Modulus of elasticity of steel (Es) = 2.04×10^6 ksc.
4. Modula ratio of elasticity (n) = $Es/_{Ec}$
5. Compression block (k) = $\dfrac{1}{1 + fs/_{(nfc)}}$
6. Arm of moment factor (j) = $1 - k/_3$

3> Sectional Properties



w = ... m. $< L/4$

b = ... m.

t = ... m.

$t1$ = ... m. $=< \frac{(w-b)+3.047}{30}$

$t2$ = ... m.

1. Number of beams

$$Ng = E/w$$

2. Average stringer spacing

$$s_t = w \quad m.$$

3. Gross area of concrete

$$Ac = (wt1)+(bt2) \qquad m.^2$$

4. Distance from bottom fiber to the neutral axis

$$y_b = \left[\frac{bt_2^2}{2} + (wt1)\left(t2+\frac{t1}{2}\right)\right]/(Ac) \qquad m.$$

5. Distance from top fiber to the neutral axis

$$y_t = t - y_b \qquad m.$$

6. Moment of inertia of section

$$I = \left(\frac{1}{12}bt_2^3 + (bt_2)\left(\frac{t_2}{2} - y_b\right)^2\right) + \left(\frac{1}{12}wt_1^3 + (wt_1)\left(y_t - \frac{t1}{2}\right)^2\right]$$

4> Slab Design

(a). Dead Loads

1. Slab (Ws) = 2400 .t1 kg.
2. Span (l) = w - b m.
3. Moment due to dead load (md) = $\frac{1}{10}$ Ws.l^2 kg.-m./m.

(b). Live Load (for continuous span)

1. Live Load Moment for H20-44,HS20-44 Loading (AASHTO 3.24.3)

$$(ml) = 7{,}342\ \frac{(l + 0.61)}{9.74}\ (0.80)\ \text{kg-m./m.}$$

2. Live Load Moment for H15-44,HS15-44 Loading (AASHTO 3.24.3)

$$(ml) = 5{,}506\ \frac{(l + 0.61)}{9.74}(0.80)\ \text{kg-m./m.}$$

3. Impact loading (i) = $\frac{15.24}{L + 38}$ =< 0.30
4. LL.moment include impact (mL) = ml.(1+i) kg.-m.

(c). Design

>> concrete

> Maximum moment (m) = md + (mL) kg-m.

>> Main Reinforcement

> Diameter of reinforcing steel	$(ds) =$	.....	mm.
> Section area of reinforcing Steel	$(a_s) =$	$\frac{(\ .ds^2)}{(4*100)}$	$cm.^2$
> Area of steel requirement	$(As) =$	$\frac{M}{(fs.j.d)}$	$cm.^2$
> Spacing of steel	$(s) =$	$as/(As)$	

>>. Distribution Reinforcement

> Area of steel requirement	$(A^*s)=$	$121.5/\sqrt{1}$	$cm.^2$
> Diameter of reinforcing Steel	$(d^*s)=$	.....	mm.
> Section area of reinforcing steel	$(a^*s)=$	$\frac{(\pi.d^*s^2)}{(4*100)}$	$cm.^2$
> Spacing of steel	$(s) =$	A^*s/a^*s	

6> Beam-Design

(a). Dead Loads

1. Beam	(Wb)	= 2400 .Ac	kg.
2. Side walk & Rail	(Wr)	=	kg.
3. Total	(Wd)	= Wb + Wr	kg.
4. Moment due to dead load	(Md)	$= \frac{1}{8}\ Wd.L^2$	kg.-m.

(b). Live Load

1. Moment due to live load (Ml) = kg-m./lane

   Search from the table of Maximum Moment

2. Distribution of wheel load (dw)

   >> one traffic lane

   = (1) / (1.981)

   >> two or more traffic lanes

   = (1) / (1.828)

3. Impact loading (i) $= \dfrac{15.24}{L + 38} \le 0.30$

4. LL.moment include impact (ML) $= Ml.(1+i).\dfrac{dw}{2}$ kg.-m.

(c). Design

>> concrete

> Maximum moment (M) = Md + ML kg-m.

> Moment provided by concrete (Mc) $= 1/_2\ fc.k.j.b.d^2$ kg-m.

If Mc > M ok.

>> Main reinforcement

> Diameter of reinforcing steel (ds) = ... mm.

> Section area of reinforcing steel $(a_s) = \dfrac{(\pi . ds^2)}{(4*100)}$ cm.^{2}

> Area of steel requirement $(As) = \dfrac{M}{(fs.j.d)}$ cm.^{2}

> Number of steels $(s) = \dfrac{As}{as}$

6> Shear Strength

1.Shear force due to dead loads $(Vd) = W.\dfrac{L}{2}$ kg.

2.Shear force due to live load (Vl) = kg.

Search form the table of Maximum Shear

3.Shear force include impact (VL) = Vl.(1+i) kg.

4.Shear force (V) = Vd + Vl(dw)/$_2$ kg.

5.Compute moment capacity (M) = Md+ML kg.-m.

6.Permissible shear stress carried by concrete

(vc) = 0.252$\sqrt{fc'}$ (AASHTO 8.15.2) ksc.

7.Shear strength carried by concrete (Vc) = vc.b.d

8.Shear strength provide by Shear reinforcement

$$(Vs) = Vu - Vc \quad \text{kg.}$$

9.Design diameter of web

$$(ds) = \ldots\ldots \quad \text{mm.}$$

$$(av) = \frac{\pi . ds^2}{400} * 2 \quad \text{cm.}^2$$

10.Spacing of web

$$(s) = \frac{Av.fsv.d}{Vs} \quad \text{m.}$$

11.Reaction at support (R) = V kg.

7> Deflection

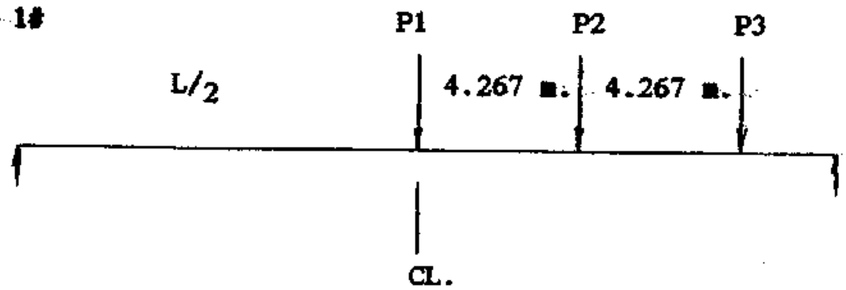
(a). Dead Loads

$$yd = \frac{5\ Wd.L^4}{384\ EI} \quad \text{m.}$$

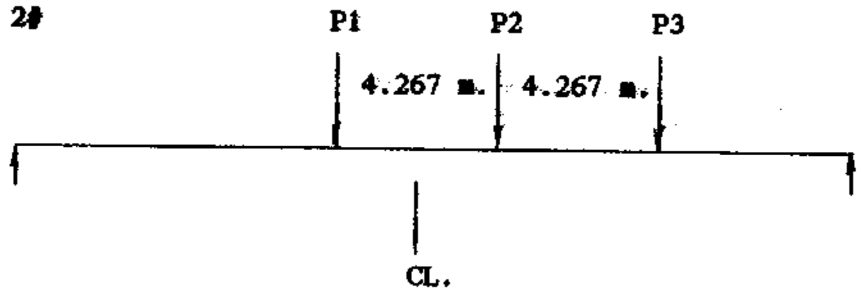
(b). Live Load

สำหรับการหาค่า live load deflection ได้เลือกจุดที่น้ำหนักกระทำต่อโครงสร้างเพื่อที่จะประมาณค่า Maximum deflection 3 กรณี และจะเลือกจากกรณีที่ ให้ค่า deflection สูงสุด

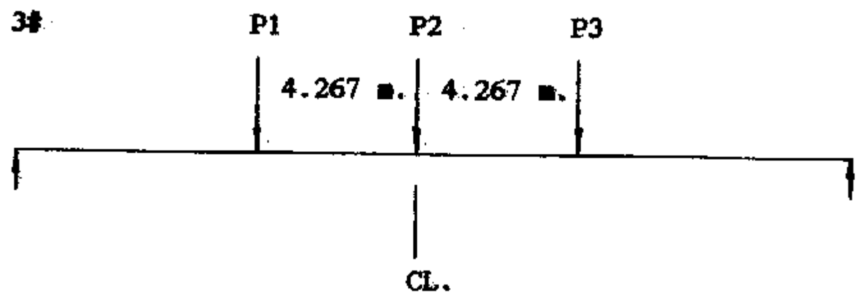
case 1#



case 2#



case 3#



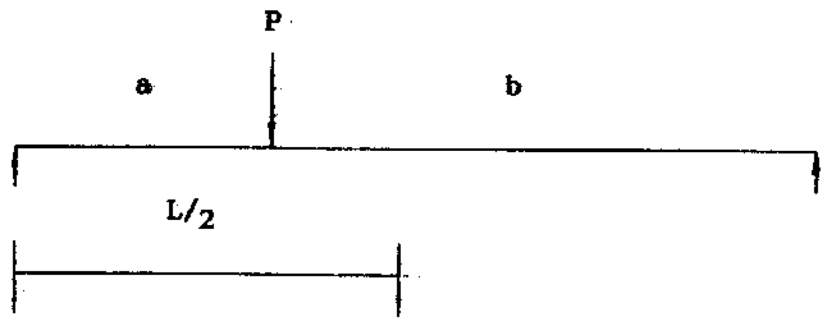
For >> H15-44	P1	=	11,013	kg.	(108 kN.)
	P2	=	2,753	kg.	(27 kN.)
	P3	=	0		
For >> HS15-44	P1	=	11,013	kg.	(108 kN.)
	P2	=	11,013	kg.	(108 kN.)
	P3	=	2,753	kg.	(27 kN.)
For >> H20-44	P1	=	14,685	kg.	(144 kN.)
	P2	=	3,671	kg.	(36 kN.)
	P3	=	0		

For >> HS20-44 P1 = 14,685 kg. (144 kN.)

P2 = 14,685 kg. (144 kN.)

P3 = 3,671 (36 kN.)

ในการคำนวณหาค่า maximum deflection ได้เลือกที่ตำแหน่งกึ่งกลางคาน โดยหาค่าจากสูตรดังนี้



$$y = \frac{Pb}{12EI}\left(\frac{3L^2}{4} - b^2\right) \quad \text{for} \quad a > L/_2$$

$$y = \frac{Pbx}{12EI}\left[\frac{L^3}{4b} + \frac{3L^3}{8} - \frac{aL^2}{b} - \frac{b^2L}{2} + \frac{a^2}{b}\right] \quad \text{for} \quad a < L/_2$$

การคำนวณหาค่า deflection ที่ $L/_2$ โดยจะคำนวณจากผลรวมของ deflection ที่เกิดจาก P1,P2 และ P3

3.2 precast prestres I-beam with cast-in-place deck slab

สำหรับการออกแบบ Precast prestress I-Beam with cast-in-place deck slab มีข้อมูล และขั้นตอนของการออกแบบ ดังนี้

1> Design Conditions

1. Span Length (L) = ... m.
2. Width of Bridge (E) = ... m.
3. Number of Lanes (Nl) = ...
4. Number of Beams (Nb) = ...
5. Spacing of Beams (s) = $\frac{E}{Nb}$

4. Type of Loads = ... (1-4)

1	=	H15-44
2	=	HS15-44
3	=	H20-44
4	=	HS20-44

2> Materials

(a). Precast Concrete

1.Compressive strength of concrete (fc') = ... ksc

2.Compressive strength of concrete at time of initial prestress

(fci') = 0.8 fc' ksc

(AASHTO 9.15)

3.Modulus of elasticity of concrete (Ec) = $15{,}114\sqrt{fc'}$ ksc

(AASHTO 8.7.1)

(b). Cast-in-place Concrete

1.Compressive strength of concrete (fcs') = ... ksc

2.Modulus of elasticity of concrete (Ecs) = $15{,}114\sqrt{fcs'}$ ksc

(AASHTO 8.7.1)

(c).Prestressing Steel

1.Diameter of prestressing steel (d^*_s) = ... mm.

2.Ultimate strength of prestressing steel (f^*s') = ... ksc.

3.Section area of prestressing steel (a^*_s) $= \frac{\pi}{4}(d^*_s)^2$ cm.^{2}

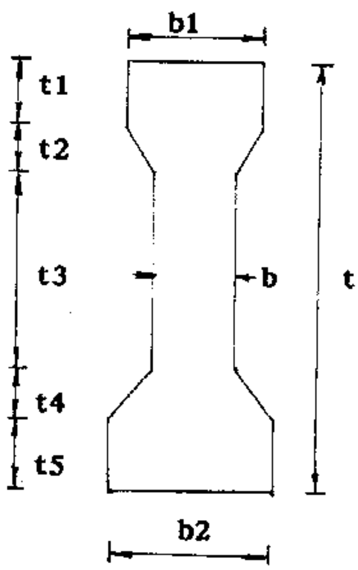
(d).Reinforcement Steel

1.Diameter of reinforcing steel (d_s) = ... mm.

2.Ultimate strength of reinforcing steel (fs') = ... ksc.

3.Section area of reinforcing steel (a_s) = $\frac{\pi}{4}(d_s)^2$ cm.^{2}

3> Sectional Properties



t1 = ... m.

t2 = ... m.

t3 = ... m.

t4 = ... m.

t5 = ... m.

t = t1+t2+t3+t4+t5

b = ... m.

b2 = ... m.

b3 = ... m.

1. Area of concrete section

$$A = (b1t1)+t2\left(\frac{b1-b}{2}\right)+b(t2+t3+t4)+t4\left(\frac{b2-b}{2}\right)+(t5b2) \quad m.^2$$

2. Distance from bottom fiber to the neutral axis

$$y_b = \Big[\frac{b2(t5)^2}{2}+t4\left(\frac{b2-b}{2}\right)\left(t5+\frac{t4}{3}\right)+b(t2+t3+t4)\left(t5+\left(\frac{t2+t3+t4}{2}\right)\right)$$

$$+t2\left(\frac{b1-b}{2}\right)\left(t5+t4+t3+\frac{2t2}{3}\right)+(b1t1)\left(t-\frac{t1}{2}\right)^2\Big] \;/\; (A)$$

3. Distance from top fiber to the neutral axis

$$y_t = t - y_b \qquad m.$$

4. Moment of inertia of section

$$I = \frac{1}{12} b2(t5)^3 + (b2t5)(y_b - \frac{t5}{2})^2 + 2(\frac{1}{12}(\frac{b2-b}{2})(t4)^3 +$$

$$+ t4((\frac{b2-b}{2})(y_b - t5)^2 + \frac{1}{12} b(t2+t3+t4)(y_b - (t5 + (\frac{t2+t3+t4}{2})))^2$$

$$+ 2(\frac{1}{12}(\frac{b1-b}{2})(t2)^3 + t2(\frac{b1-b}{2})(y_t - t1)^2 + \frac{1}{12} b1(t1)^3$$

$$+ (b1t1)(y_t - \frac{t1}{2})^2$$

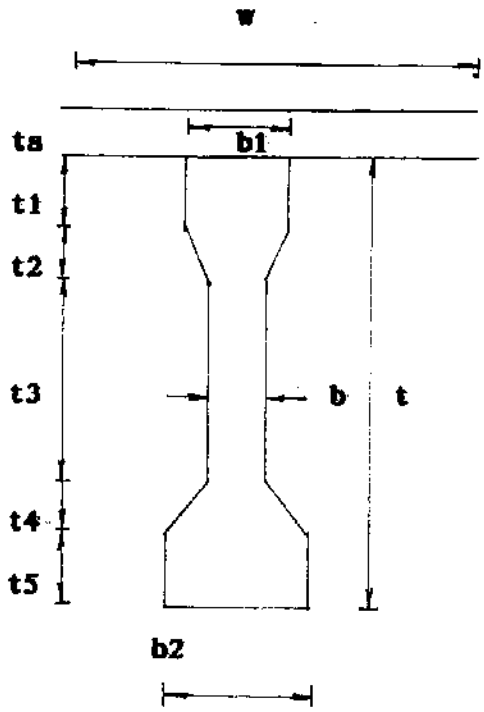
5. lower modulus of section

$$S_b = I/y_b \qquad m.^3$$

6. upper modulus of section

$$S_t = I/y_t \qquad m.^3$$

4> Sectional Properties (composite sections)



W = ... m.

ts = ... m.

t1 = t1 m.

t2 = t2 m.

t3 = t3 m.

t4 = t4 m.

t5 = t5 m.

t = t1+t2+t3+t4+t5

b = ... m.

b2 = ... m.

b3 = ... m.

1. Interpulate of concrete area

$$Nc = Ecs/_{Ec}$$

2. Area of concrete section

$$A = A + (w.ts)Nc \qquad m.^2$$

3. Distance from bottom fiber to the neutral axis

$$y_{cb} = [\ A.y_b + Nc.(w.ts)(t+\frac{ts}{2})\ ]/_{(Ac)}$$

4. Distance from top fiber to the neutral axis

$$y_{ct} = t - y_b \qquad m.$$

5. Moment of inertia of slab

$$Is = \frac{1}{12} w.(ts)^3$$

6. Moment of inertia of section

$$Ic = I + Is + A(y_b - y_{cb})^2 + As((t + \frac{ts}{2}) - y_{cb})^2$$

7. lower modulus of section

$$S_{cb} = I_c / Y_{cb} \qquad m.^3$$

8. upper modulus of section

$$S_{ct} = I_c / Y_{ct} \qquad m.^3$$

4> Slab Design

(a). Dead Loads

1. Slab (Ws) = 2400 .t1 kg.
2. Span (l) = w - b1 m.
3. Moment due to dead load (md) = $\frac{1}{10}$ Ws.l^2 kg.-m.

(b). Live Load

1. Live Load Moment for H20-44,HS20-44 Loading (AASHTO 3.24.3)

$$(ml) = 7{,}342 \left(\frac{l + 0.61}{9.74}\right)(0.80) \text{ kg-m./}_{\text{m.}}$$

2. Live Load Moment for H15-44,HS15-44 Loading (AASHTO 3.24.3)

$$(ml) = 5{,}506 \left(\frac{l + 0.61}{9.74}\right)(0.80) \text{ kg-m./}_{\text{m.}}$$

3. Impact loading (i) = $\frac{15.24}{L + 38}$ =< 0.30
4. LL.moment include impact (mL) = ml.(1+i) kg.-m.

(c). Design

>> concrete

> Maximum moment (m) = md + (mL) kg-m.

> Moment provided by concrete (mc) = $1/_2$ fc.k.j.b.d^2 kg-m.

If Mc > M ok.

>> Main Reinforcement

> Diameter of reinforcing steel (ds) = ... mm.

> Section area of reinforcing steel $(a_s) = \frac{(\pi.d^2)}{(4*100)}$ $cm.^2$

> Area of steel requirement $(As) = \frac{M}{(fs.j.d)}$ $cm.^2$

> Spacing of steel $(s) = \frac{as}{As}$

>>. Distribution Reinforcement

> Area of steel requirement $(A^*s) = 121.5/\sqrt{1}$ $cm.^2$

> Diameter of reinforcing steel (d^*s)= ..... mm.

> Section area of reinforcing steel $(a^*s) = \frac{(\pi.d^*s^2)}{(4*100)}$ $cm.^2$

> Spacing of steel $(s) = \frac{A^*s}{a^*s}$

6> Design Loads and Moments

(a). Dead Loads

1. Girder	(Wg)	= 2400 .A	kg.
2. Slab	(Ws)	= 2400.(w.ts)	kg.
3. Side walk & Rail	(Wr)	=	kg.
4. Moment due girder	(Mg)	= $(Wg.L^2)/8$	kg.-m.
5. Moment due to slab	(Ms)	= $(Ws.L^2)/8$	kg.-m.
6. Moment due to side walk & rail	(Mr)	= $((Wr.L^2)/8$	kg.-m.
7. Moment due to dead load	(Md)	= Mg+Ms+Mr	kg.-m.

(b). Live Load

1. Moment due to live load (Ml) = kg-m./lane

   Search from the table of Maximum Moment

2. Distribution of wheel load (dw)

   >> one traffic lane

   $= (l) / (2.134)$

   >> two or more traffic lanes

   $= (l) / (1.676)$

3. Impact loading (i) $= \dfrac{15.24}{L + 38} =< 0.30$

4. LL.moment include impact (ML) $= Ml.(1+i).\dfrac{dw}{2}$ kg.-m.

7> Prestressing Strands

Determine number of strands required base on stress conditions at service loads

(a).Bottom fiber

1. Gider	(fb1)	=	$(Mg)/S_b$	ksc.
2. Gider + Slab	(fb2)	=	$(Mg+Ms)/S_b$	ksc.
3. Side walk & Rail	(fb3)	=	$(Mr)/S_b$	ksc.
4. Live load	(fb4)	=	$(ML)/S_{cb}$	ksc.
5. Total	(fb)	=	fb2+fb3+fb4	

(b).Top fiber

1. Gider	(ft1)	=	$(Mg)/S_t$	ksc.
2. Gider + Slab	(ft2)	=	$(Mg+Ms)/S_t$	ksc.
3. Side walk & Rail	(ft3)	=	$(Mr)/S_t$	ksc.
4. Live load	(ft4)	=	$(ML)/S_{ct}$	ksc.
5. Total	(ft)	=	ft2+ft3+ft4	

(c).Allowable stress (AASHTO 9.15.2)

1.Final	(fb)	=	$1.591\sqrt{fc'}$	ksc.
	(ft)	=	$0.40fc'$	ksc.
2.Initial	(fb)	=	$0.60fci'$	ksc.
	(ft)	=	$1.989\sqrt{fci'}$	ksc.

(d).Limits of prestress

1.Final

>> Top fiber

> Total stress	(ft)	=	fb2+fb3+fb4	ksc.
> Allowable stress	(fta)	=	$1.59\sqrt{fc'}$	ksc.
> Required prestress	(ftr)	=	fb − fba	ksc.

>> Bottom fiber

> Total stress	(fb)	=	fb2+fb3+fb4	ksc.
> Allowable stress	(fba)	=	0.40fc'	ksc.
> Required prestress	(fbr)	=	fb − fba	ksc.

2.Initial

>> Top fiber

> Total stress	(ft)	=	fb2+fb3	ksc.
> Allowable stress	(fta)	=	$1.989\sqrt{fci'}$	ksc.
> Required prestress	(ftr)	=	fb − fba	ksc.

>> Bottom fiber

> Total stress	(fb)	=	fb2+fb3	ksc.
> Allowable stress	(fba)	=	0.60fci'	ksc.
> Required prestress	(fbr)	=	fb − fba	ksc.

(e).Finals bottom fiber stress controls

1. Bottom fiber stress due to prestress

$$(fbr) = \frac{Pse}{A} + \frac{Pse.e}{S_{cb}} \quad \text{ksc.}$$

2. Strand eccentricity (e) = ... m.

3. Effective prestress force after losses

$$(Pse) = \frac{fbr}{(^1/_A + ^e/_{Scb})} \quad \text{kg.}$$

4. Assume prestress per strand losses

(ls) = ... %

5. Final prestress strand (fs) = $[a^*_S.0.7.f^*_S'](1-ls)$ ksc.

6. Number of strands required (N^*_S) = $^{Pse}/_{fs}$

7. Area of prestressing strand(A^*_S) = $N^*_S.a^*_S$ cm.^{2}

6> Flexural Strength

1. Factored moment (Mu) = 1.3(Md+1.67ML) kg.-m.
2. f^*su = $f^*s'(1-0.5p^*f^*s'/_{fc'})$ ksc.
3. d = (t+ts)-e m.
4. p^* = $A^*s/_{bd}$
5. ϕMu = $A^*s.f^*su.d(1-0.6p^*f^*su/_{fc'})$ kg.-m.

   If $\frac{\phi Mu}{Mu} > 1.20$ ...... OK.

6. check as rectangular section (a) = $(A^*_S f^*_{su})/(0.85fc'w)$

   If a < ts ...... OK.

9> Maximum and Minimum Steel Percentage

(a).Maximum Steel (AASHTO 9.18.1)

> Reinforcement Index $= \frac{P^* . f^*su}{fc'} < 0.3$ .... OK

(b).Minimum Steel (AASHTO 9.18.2)

1. Average concrete stress at the c.g. of prestressing Steel

   $= 1.9887\sqrt{fc'}$ ksc.

2. Moment causing flexural cracking at section due to externally applied loads (Mcr) $= Sb\left(\frac{Pse}{A} + \frac{Pse.e}{Sb} + fcr\right)$ kg.-m.

If $\frac{Mn}{Mcr} >= 1.20$ ...... OK.

10> Prestress Losses

(a).Shrinkage

> Relative humidity (RH) = ... %

> Loss of prestress due to concrete shrinkage

(SH) = 1,195 − 10.5 RH ksc.

(b).Elastic Shortening

1. Effective prestress force after transfer (Assume .. %loss)

$$(Psi) = (1-loss)(0.7\ f^*s')\ n.a^*_s \quad kg.$$

2. Modulus of elasticity of concrete at time of initial prestress

$$(Eci) = 15,114\sqrt{fci'} \quad ksc.$$

3. Average concrete stress at the c.g. of prestressing steel at time of initial prestress $(fcir) = \frac{Psi}{Ac} + \frac{Pse.e^2}{I} - \frac{Md.e}{I}$ ksc.

4. Modulus of elasticity of prestressing steel

$$(Es) = 2.04 \times 10^6 \quad ksc.$$

5. Loss of prestress due to elastic shortening

$$(ES) = \frac{Es}{Eci} . fcir \quad ksc.$$

(c).Creep of Concrete

1. Concrete stress at level of prestressing steel due to supperimpose dead load $(fcds) = \frac{Ms.(ycb-e)}{I} + \frac{Mr(ycb-e)}{Ic}$ ksc.

2. Loss of prestress due to creep of concrete

$$(CRc) = 12\ fcir - 7\ fcds \quad ksc.$$

(d).Relaxation of Prestressing Steel

Loss of prestress due to relaxation of prestressing steel

$$(CRs) = 1,406-0.4ES-0.2(SH+CRc) \quad ksc.$$

(e).Total Loss of Prestress

$$fs = SH + ES + CRc + Crs \quad ksc.$$

$$= \frac{fs}{(0.7f*s')} \quad \%$$

11> Concrete Stress (AASHTO 9.15.2)

(a). Initial stress at prestress transfer

$$Psi = 0.9(N^*_s . a^*_s \; 0.7 \; f^*_s{}') \qquad kg.$$

(b). at span center

>> $$ft = \frac{Psi}{A} - \frac{Psi(Ycb-e)}{S_t} + \frac{Mg}{S_t} \qquad ksc.$$

If $ft < 0.60fci'$ ..... OK.

>> $$fb = \frac{Psi}{A} - \frac{Psi(Ycb-e)}{S_b} - \frac{Mg}{S_b} \qquad ksc.$$

If $f_b < 0.60fci'$ .... OK.

(c). at span end

>> $$ft = \frac{Psi}{A} - \frac{Psi(Ycb-e)}{S_t} \qquad ksc.$$

If $ft < 1.989\sqrt{fci'}$

** Remark for top fiber stress in tension at span ends exceeds 1.989 fci' must use reinforcement to provided cracking

10> Shear Strength

1. Shear force due to unfactored dead loads

$$(Vd) = (Wd.L/2) \qquad kg.$$

2. Shear force due to truck load (Vl) = kg./lane

>> Search from the table of Maximum Shear

3. Shear force due to truck load include Impact

$$(VL) = \frac{(1+I)VL.dw}{2} \quad kg./beam$$

4. Factored Shear force

$$(Vu) = 1.3\ (Vd + 1.67\ VL) \quad kg.$$

5. Reaction at the support

$$(R) = Vu.L/_2 \quad kg./beam$$

6. Maximum factored moment of section due to externally applied loads

$$(Mmax) = R.d/_2 \quad kg.$$

7. Moment causing flexural cracking at section due to externally applied loads

$$(Mcr) = \frac{I}{Yt}(1.591\sqrt{fc'}+fpe-fd) \quad kg.-m.$$

8. Compressive stress in concrete due to effective prestress force only (after allowance for all prestress losses.) at extreme fiber of section where tensile stress is caused by externally applied loads

$$(fpe) = \frac{Pse}{A} + \frac{Pse.e}{Sb} \quad ksc.$$

9. Stress due to unfactoredDead load at extreme fiber of section where tensile stress is caused by externally applied loads

$$(fd) = \frac{Md}{Sb} \quad ksc.$$

10.factored shear force due to externally applied loads

$$(Vi) = 1.3(1.67VL) \quad kg.$$

11.Norminal shear strength provided by concrete when diagonal cracking results from combined shear and moment

$$(Vci) = 0.1591\sqrt{fc'}.b .d + Vd + \frac{Vi.Mcr}{Mmax.} \quad kg.$$

12.Norminal shear strength provided by concrete when diagonal cracking results from excessive principal tensile stress in web

$$(Vcw) = (0.9281\sqrt{fc'} + 0.3fpc)b .d + Vp \quad kg.$$

13.Shear provided by concrete

$$(Vc) = \quad kg.$$

Use the lesser of the value Vci or Vcw

14.Shear provided by steel

$$(Vs) = Vu - Vc \quad kg.$$

** Remark Vs shall not be taken greater than $2.121\sqrt{fc'}.b .d$

15.Design diameter of web

$$(ds) = \ldots\ldots \quad mm.$$

$$(av) = \frac{\pi.ds^2}{400} * 2 \quad cm.^2$$

16.Spacing of web

$$(s) = \frac{Av.fsy.d}{Vs} \quad m.$$

10> Deflection to be Considered

Multipliers to be used as a guide in estimating long-time cambers and deflections for typical members

Deflection to be Considered	Without Composite Topping	With Composite Topping
>> At erection		
(1) Deflection (downward) component - apply to the elastic deflection to the member weight at release of prestress	1.85	1.85
(2) Camber (upward) component - apply to the elastic camber due to prestress at the time of release of prestress	1.80	1.80
>> Final		
(3) Deflection (downward) component - apply to the elastic deflection due to the member weight at release of prestress	2.70	2.40
(4) Camber (upward) component - apply to the elastic camber due to prestress at the time of release of prestress	2.45	2.20

(5) Deflection (downward) component - apply to the elastic deflection due to superimposed dead load only	3.00	3.00
(6) Deflection (downward) component - apply to the elastic deflection caused by the composite topping	-	2.30

(a).Prestress at transfer

$$yps = \frac{Psi.e.L^2}{8\ EI} \quad - \quad m.$$

(b).Beam dead load

$$yb = \frac{5Wb.L^4}{384EI} \quad + \quad m.$$

(c).Growth in storage

$$yg = 1.8\ (\ yps + yd\ ) \quad m.$$

(d).Superimpose dead loads

$$ysd = \frac{5Wd.L^4}{384EI} \quad m.$$

(e).Net long term after construction

$$yni = yg + ysd \quad m.$$

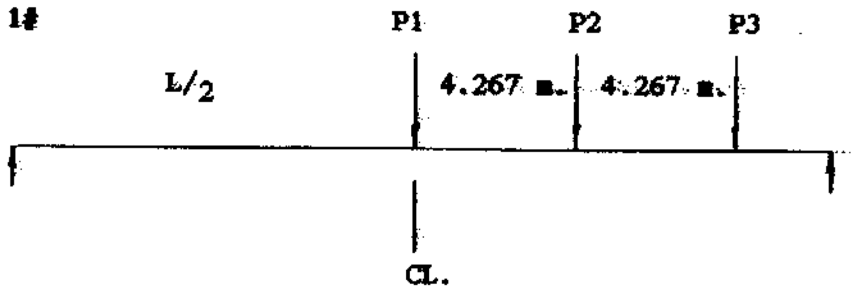
(f).Long term dead load

$$= 2.45(2.2)yps+2.7(2.4)yb+3.0ysd$$

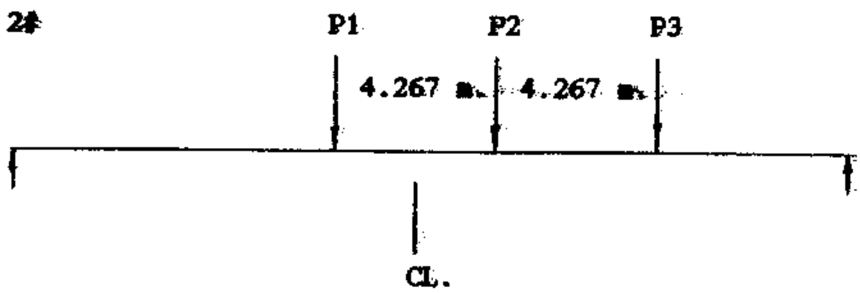
(g).Live load deflection

สำหรับการหาค่า live load deflection ได้เลือกจุดที่น้ำหนักกระทำต่อโครงสร้างเพื่อที่จะประมาณค่า Maximum deflection 3 กรณี และจะเลือกจากกรณีที่ให้ค่า deflection สูงสุด

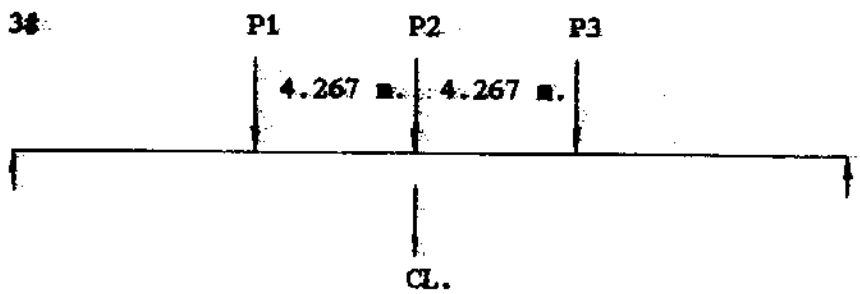
case 1#



case 2#

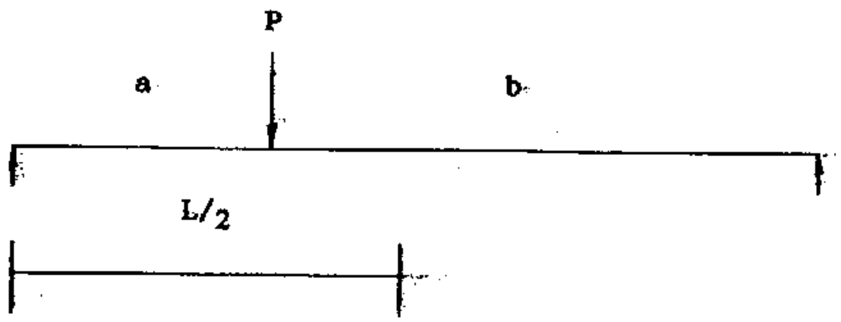


case 3#



For >> H15-44	P1	=	11,013	kg.	(108 kN.)
	P2	=	2,753	kg.	(27 kN.)
	P3	=	0		
For >> HS15-44	P1	=	11,013	kg.	(108 kN.)
	P2	=	11,013	kg.	(108 kN.)
	P3	=	2,753	kg.	(27 kN.)
For >> H20-44	P1	=	14,685	kg.	(144 kN.)
	P2	=	3,671	kg.	(36 kN.)
	P3	=	0		
For >> HS20-44	P1	=	14,685	kg.	(144 kN.)
	P2	=	14,685	kg.	(144 kN.)
	P3	=	3,671		(36 kN.)

ในการคำนวณหาค่า Maximum deflection ได้เลือกที่ตำแหน่ง ที่กลางคาน โดยหาค่าจากสูตรดังนี้



$$y = \frac{Pb}{12EI}\left(\frac{3L^2}{4} - b^2\right) \qquad \text{for } a > L/2$$

$$y = \frac{Pbx}{12EI}\left[\frac{L^3}{4b} + \frac{3L^3}{8} - \frac{aL^3}{b} - \frac{b^2L}{2} + \frac{a^2}{b}\right] \qquad \text{for } a < L/2$$

การคำนวณหาค่า deflection ที่ $x = L/2$ โดยจะคำนวณจาก ผลรวมของ deflection ที่เกิดจาก P1, P2 และ P3