I.

THE
STRESS CALCULATIONS
AFTER
THE REPAIR

(64M SPAN TRUSS)

Contents:

§1. Loading Condition:-

The stress calculations covered herein show the actual adoption of "Over Lay" method when reinforcing the concrete floor slab of Krun Dheb Bridge and Krun Dhon Bridge.

The loading conditions are classified into the following:-

Dead load; After the 4 cm pavement of the existing bridge has been removed, the 6 cm concrete floor slab shall be installed additionally.

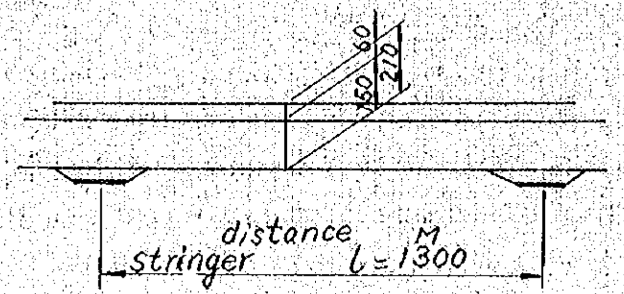
Live load; AASHO H20-S16-44 loading shall be used. However, the clause of Reduction against the 4 traffic lanes as stipulated in AASHO shall be disregarded and the live load calculated as 100%.

Allowable stress; It shall conform to the current allowable stress shown in the current specification for Steel Highway Bridge in Japan.

§2. Concrete floor slab

2.1 Direction perpendicular to bridge axis

1) Bending moment



① Dead load moment

$\omega = 2.4 \times 0.21 = 0.504$ t/m^2

As continuous slab

$$M_b = \frac{1}{10} \times 0.504 \times 1.3^2 = 0.085 \text{ t-m/m}$$

② Live load moment

From AASHO Article 1.3.2

$$M_L = \frac{S+2}{32} \times 16{,}000 = \frac{3{,}980+2}{32} \times 16{,}000 = 2{,}990 \text{ tt-lbs/tt}$$

$$= 2{,}990 \times 0.4536 = 1{,}302 \text{ t-m/m}$$

$$(S = \overset{M}{1.300} - \frac{1}{2} \times 175 = \overset{M}{1.213} = 3.980 \text{ }^{ft})$$

Impact factor

$$i = \frac{50}{L+125} = \frac{50}{3.98+125} = 0.4 > 0.3$$

As simple slab

$M_{L+i} = 1.3 \times 1.302 = 1.693$ $^{t-m}$

Hence, in continuous slab

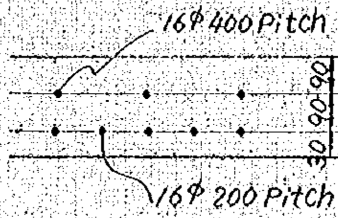
$M_{L+i} = 0.8 \times 1.693 = 1.354$ $^{t-m}$

③ Total bending moment

$M_{D+L+i} = 0.085 + 1.354 = 1.439$ $^{t-m}$/m

2) Section and stress

1 At center of span



Reinforcing bar at tension side AS = 10.05

Reinforcing bar at compression side AS' = 5.02

A = 15.07

$$x = -n\frac{AS + AS'}{b} + \sqrt{\left\{\frac{n(AS + AS')}{b}\right\}^2 + \frac{2n}{b}(dAS + d'AS')}$$

$$= -15 \times \frac{15.07}{100} + \sqrt{\left(\frac{15 \times 15.07}{100}\right)^2 + \frac{2 \times 15}{100}(18.0 \times 10.05 + 9.0 \times 5.02)}$$

$$= -2.261 + 8.540 = 6.279 \text{ cm}$$

$$Wc = \frac{bx}{2}\left(d - \frac{x}{3}\right) + nAS'\frac{x - d'}{x}(d - d')$$

$$= \frac{100 \times 6.279}{2}\left(18.0 - \frac{6.279}{3}\right) + 15 \times 5.02 \times \frac{6.279 - 9.0}{6.279}(18.0 - 9.0)$$

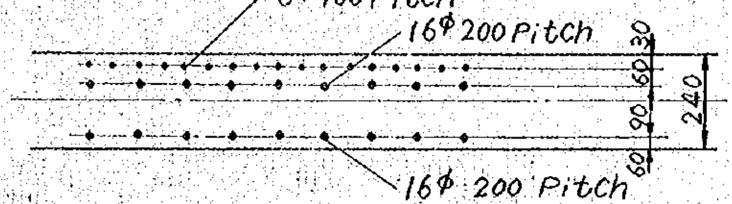
$$= 4,994 + 294 = 4,700 \text{ cm}^3$$

$$Ws = Wc \times \frac{x}{n(d - x)} = 4,700 \times \frac{6.279}{15 \times (18.0 - 6.279)} = 167.9 \text{ cm}^3$$

$$\delta c = \frac{1.439 \times 10^5}{4,700} = 31 \text{ kg/cm}^2 < 60 \text{ kg/cm}^2$$

$$\delta s = \frac{1.439 \times 10^5}{167.9} = 857 \text{ kg/cm}^2 < 1,400 \text{ kg/cm}^2$$

2 At support



Reinforcing bar $\quad AS = 10.05\ cm^2$

at tension side $\quad " = 2.827\ cm^2$

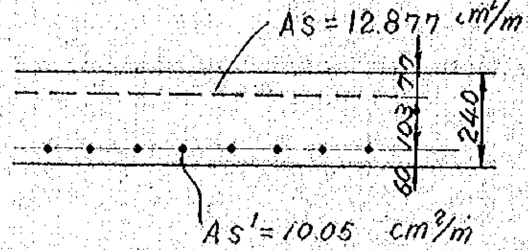
$\quad 12.877\ cm^2$

Reinforcing bar

at compression side $\quad AS' = 10.05\ cm^2$

$\quad \Sigma AS = 22.927\ cm^2$

Tension side reinforcing bars considered as one solid piece.



$$x = -n\frac{AS + AS'}{b} + \sqrt{\left\{\frac{n(AS + AS')}{b}\right\}^2 + \frac{2n}{b}(dAS + d'AS')}$$

$$= -15 \times \frac{22.927}{100} + \sqrt{\left(\frac{15 \times 22.927}{100}\right)^2 + \frac{2 \times 15}{100}(16.3 \times 12.877 + 6 \times 10.5)}$$

$$= -3.439 + 9.638 = 6.199\ \text{cm}$$

$$Wc = \frac{b.x}{2}\left(d - \frac{x}{3}\right) + nAS'\ \frac{x - d'}{x}(d - d')$$

$$= \frac{100 \times 6.199}{2}\left(16.3 - \frac{6.199}{3}\right) + 15 \times 15.05 \times \frac{6.199 - 6.0}{6.199}(16.3 - 6.0)$$

$$= 4{,}412 + 50 = 4{,}462\ \text{cm}^3/\text{m}$$

$$Ws = Wc \times \frac{x}{n\ (21.0 - x)} = 4{,}462 \times \frac{6.199}{15(21.0 - 6.199)} = 124.6\ \text{cm}^3/\text{m}$$

$$\delta c = \frac{1{,}439 \times 10^5}{4{,}462} = 32\ \text{kg/cm}^2 < 60\ \text{kg/cm}^2$$

$$\delta s = \frac{1{,}439 \times 10^5}{124.6} = 1155\ \text{kg/cm}^2 < 1{,}400\ \text{kg/cm}^2$$

2.2 The direction parallel to bridge axis:

a) Formula

$$M_Y = K\ \frac{2PL^2}{\pi 2} \sum_{m=1}^{\infty} \frac{1}{m^2}\ \text{Sin}\frac{m\pi\xi}{\ell}.\ \text{Sin}\frac{m\pi u}{\ell}\ ,\ \text{Sin}\frac{m\pi x}{\ell}\ \left[\ \frac{2V}{m\pi} - \left\{\frac{2\nu}{m\pi} - \right.\right.$$

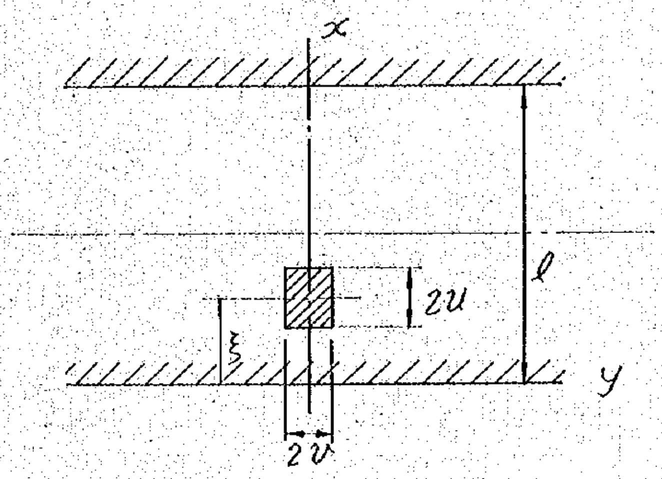
$$(1-\mathscr{L})\frac{S}{\ell}\}1-\frac{m\pi v}{\ell}\}$$

Where:

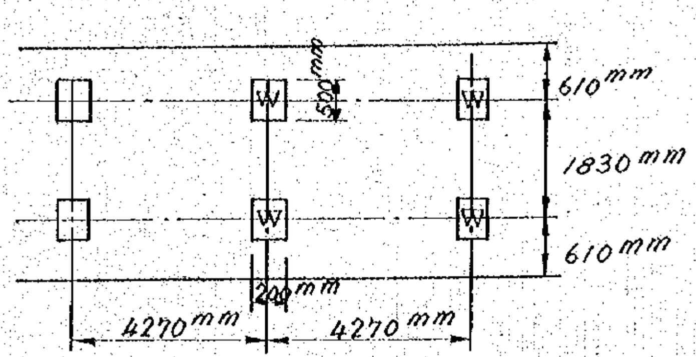
P: Partial load ℓ = span

$\mathscr{L}$ = poisson's ratio $\frac{1}{6}$

K: The compensating factor 0.8 required for exact understanding of continuous slab from theoretical understanding of simple slab.



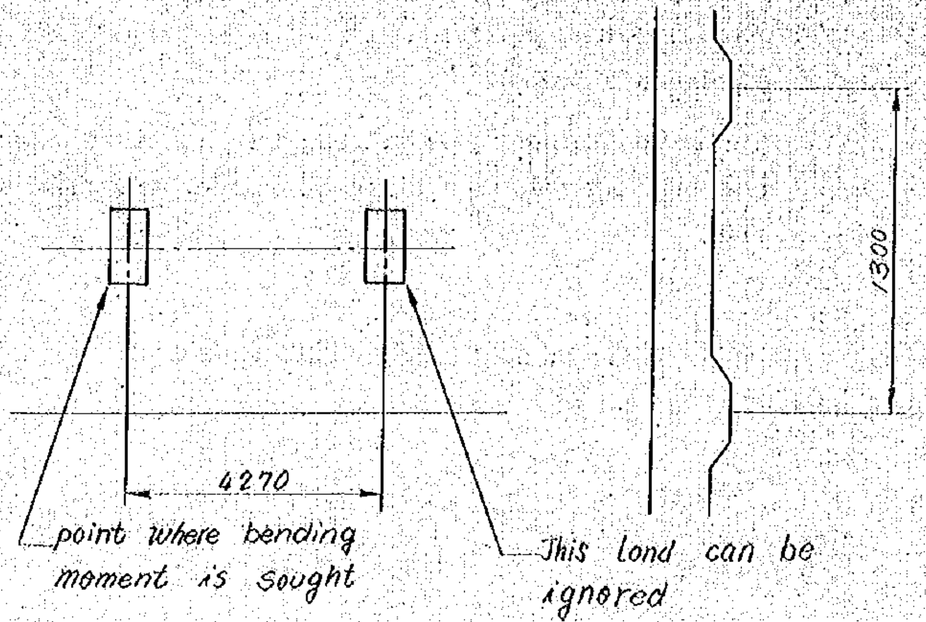
b) H20-S16-44 loading



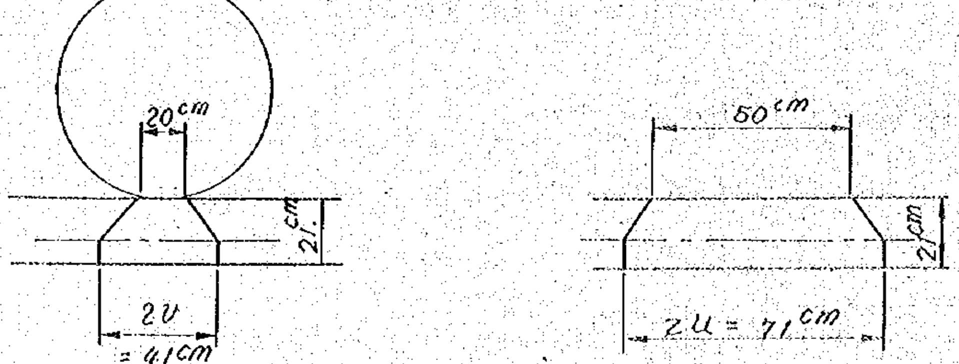
W = 16,000 lbs. = 7,260 kg

c) Loading position on the floor slab:

To be loaded only where bending moment is sought.



d) Determination of u v, ξ, ℓ and P



$$\xi = \frac{\ell}{2} \qquad \ell = 130cm$$

$$i = \frac{50}{\ell + 125} = 0.3$$

$$P = 1.3 \times W = 1.3 \times 7260 = 9438kg$$

$$P = \frac{9438}{0.41 \times 0.71} = 32.42\ t/m^2$$

e) Calculation of M_Y:

$$K.\frac{2P\ell^2}{\pi 2} = \frac{0.8 \times 2 \times 32.42 \times 1.3^2}{3.14159^2} = 8.882$$

$$\frac{m\pi\xi}{\ell} = \frac{\pi}{2} m, \quad \frac{m\pi u}{\ell} = \frac{0.355}{1.3} m\pi = 0.857896\ m$$

$$\frac{m\pi x}{\ell} = \frac{\pi}{2} m, \quad \frac{2\nu}{m\pi} = \frac{2 \times 0.167}{m\pi} = \frac{0.106316}{m}$$

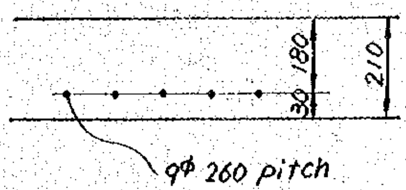
$$(1-\nu)\frac{v}{\ell} = (1-0.167)\frac{0.205}{1.3} = 0.13136$$

$$\frac{m\pi v}{\ell} = \frac{\pi \times 0.205\ m}{1.3} = 0.495405\ m$$

$$M_Y = 8.882 \sum_{m=1,3,5}^{\infty} \frac{1}{m^2} \sin 0.857896\ m \left[\frac{0.106316}{m} - \left(\frac{0.106316}{m} - 0.13136\right) e^{-0.495405\ m}\right]$$

$$= 8.882 \times 0.094165 = 0.836\ ^{t-m}/m$$

5) Direction parallel to bridge axis direction



$$AS = 2.45\ cm^2/m$$

$$n_1 = \frac{AS}{bh} = 2.45/100 \times 18 = 0.00136$$

$$K = -nn_1 + \sqrt{(nn_1)^2 + 2nn_1}$$

$$= -0.0204 + 0.2030 = 0.1826$$

$$j = 1 - \frac{K}{3} = 0.9391$$

$$W_c = \frac{1}{2} k \cdot j \cdot b \cdot h^2 = 0.5 \times 0.1826 \times 0.9391 \times 100 \times 18^2 = 2,778$$

$$W_s = n \cdot j \cdot b \cdot h^2 = A_s jh = 2.45 \times 0.9391 \times 18.0 = 41.41$$

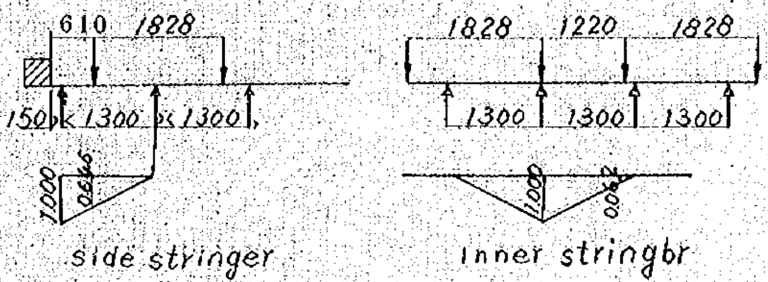
$$\delta_c = \frac{0.836 \times 10^5}{2778} = 30 \ kg/cm^2 < 60 \ kg/cm^2$$

$$\delta_s = \frac{0.836 \times 10^5}{41.41} = 2019 \ kg/cm^2 < 2400 \ kg/cm^2 \ \text{yield point}$$

§3. Stringer

Impact factor $I = \frac{50}{L + 125} = \frac{50}{6.4 \times 3.281 + 125} = 0.342$ —— 0.300

3.1 Stringer at roadway section



Side stringer

Front wheel	1.815 x 0.646 x 1.30 = 1.524 t
Rear wheel & trailing wheel	7.260 x 0.646 x 1.30 = 6.097 t

Inner stringer

Front wheel	1.815 x (1.000 + 0.062) x 1.30 = 2.506 t
Rear wheel & trailing wheel	7.260 x (1.000 + 0.062) x 1.30 + 10.023 t

Maximum bending moment

Bending moment due to dead load

Increase of dead load due to increase of pavement thickness

$$W = 2.4 \times 0.06 - 2.2 \times 0.04 = 0.056 \ t/m^2$$

Hence, bending moment due to dead load may be calculated based on the design calculations as:-

INNER $Md = 4.640 \times (1 + \frac{0.056}{0.663 + 0.0917})$

$= 4.640 \times 1.0742 = 4.984$ t-m

Side "

Bending moment due to live load

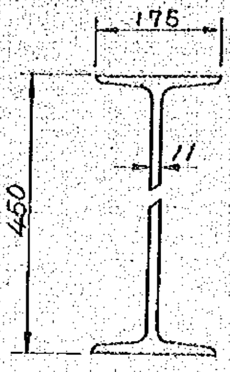
$$\text{INNER} \quad M_{\ell+i} = \frac{1}{4} \times 10.023 \times 6.4 = 16.037 \ ^{t-m}$$

$$\text{SIDE} \quad M_{\ell+i} = \frac{1}{4} \times 6.097 \times 6.4 = 9.755 \ ^{t-m}$$

Section:

1 - I 450 x 175 x 11

$Zx = 1740 \ cm^3$



Dead load

$$\text{Inner} \quad \delta = \frac{4,984}{1,740} = 286 \ kg/cm^2$$

$$\text{Side} \quad \delta = \frac{4,984}{1,740} = \text{" "}$$

Live load

$$\text{Innver} \ \delta = \frac{1603700}{1740} = 922 \ kg/cm^2$$

$$\text{Side} \quad \delta = \frac{975500}{1740} = 561 \ kg/cm^2$$

Dead load + live load

Inner 286 + 922 = 1208 kg/cm^2

Side 286 + 561 = 847 kg/cm^2

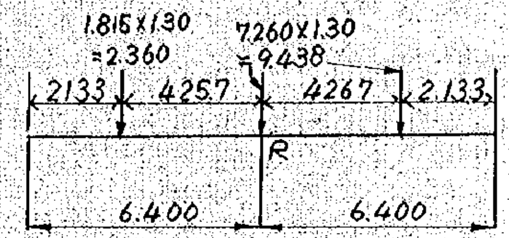
Shear

a) Due to dead load

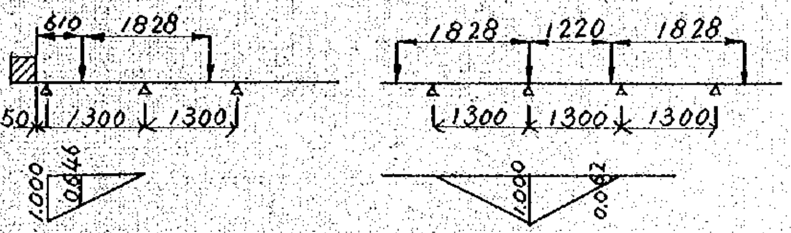
Inner Sd = 2.9 x 1.0742 = $3\overset{t}{,}115$

Side Sd = "

b) Live load



R_{l+i} = 9,438 + (2,360 + 9,438) x $\frac{2133}{6400}$ = 13,370



side stringer inner stringer

Side stringer

13.370 x 0.646 = $8\overset{t}{.}637$

Inner stringer

13.370 x (1.000 + 0.062) = $14\overset{t}{.}199$

Section 1 - I 450 x 175 x 11

Web Area 45 x 1.1 = 49.5 cm^2

Shearing stress

Inner

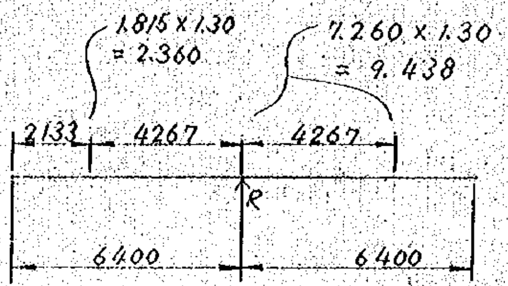
$\tau = \frac{3,115 + 14,199}{49.5}$ = 350 kg/cm^2

Side

$\tau = \frac{3,115 + 8,637}{49.5}$ = 237 kg/cm^2

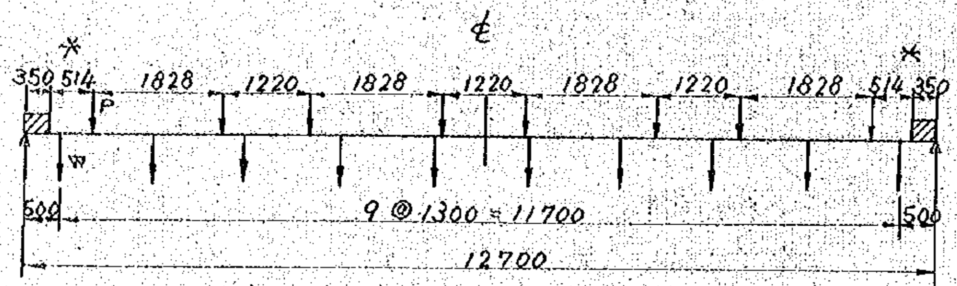
§4. Crossbeam

4.1 Intermediate crossbeam



$R_d = 5.8 \times 1.0742 = 6.230$

$R_{l+i} = 9.438 + (2.360 + 9.438) \times \frac{2133}{6400} = 13.370^{t}$



For * marked dimensions, they are 2' according to AASHO.

$P = 13^{t}.370$

$W = 3.115 \times 2 = 6^{t}.230$

Bending moment at central point

Dead load

$M_d = 6.230\,(5 \times 6.350 - 5{,}850 - 4.550 - 3.250 - 1.950 - 0.650)$

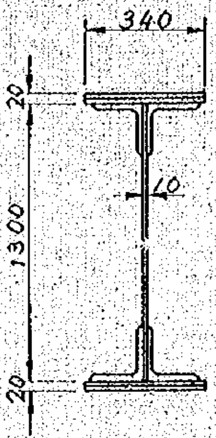
$= 96.6$ t-m

Live load

$M_{l+i} = 13.370\,(4 \times 6.350 - 5.486 - 3.658 - 2.438 - 0.610)$

$= 176.6$ t-m

$\Sigma\ M = 273.2$ t-m



4 – IP_s 340 x 10
4 – IP_s 150 x 150 x 15
1 – IP 1300 x 10

$I_x = 1491300 \text{ cm}^4$

Dead load

$$\delta_c = \frac{9660000 \times 67}{1491300} = 434 \text{ kg/cm}^2$$

$$\delta_t = 434 \times \frac{436.8}{379.8} = 499 \quad "$$

Live load

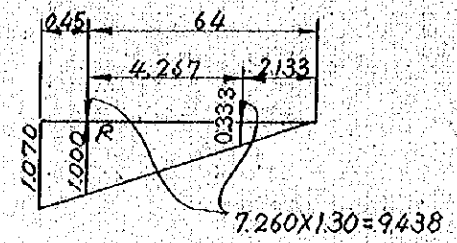
$$\delta_c = \frac{17659100 \times 67}{1491300} = 793 \text{ kg/cm}^2$$

$$\delta_t = 793 \times \frac{436.8}{379.8} = 912 \quad "$$

Dead load + live load

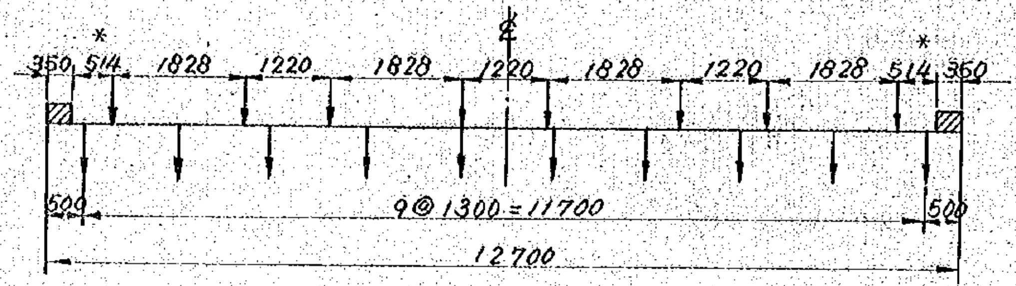
$$\delta_c = 434 + 793 = 1227$$
$$\delta_t = 499 + 912 = 1411$$

4.2 End cross beam



$R_d = 3.31^t \times 1.0742 = 3^t.555$

$R_{l+i} = 9.438 + 9.438 \times 0.333 = 12^t.581$



For * marked dimensions, they are 2' according to AASHO.

$P = 3^t.555$

$W = 12^t.581$

Bending moment at central point

Dead load

$M_d = 3.555 \times (5 \times 6.350 - 5.850 - 4.550 - 3.250 - 1.950 - 0.650)$

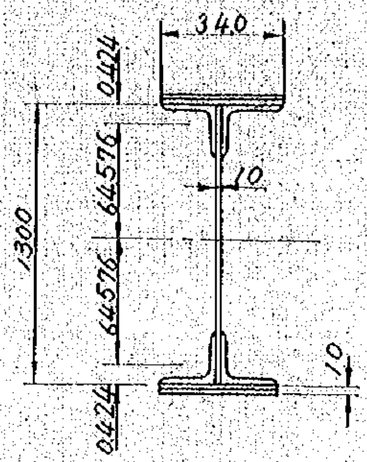
$= 55.107\ ^{t \cdot m}$

Live load

$M_{l+i} = 12.581 \times (4 \times 6.350 - 5.486 - 3.658 - 2.438 - 0.610)$

$= 166.170$

$\Sigma M = 221^t.277$



2 – P_l, 340 x 10

4 – L_S 150 x 150 x 15

1 – P_L 1300 x 10

I_x = 1,190,608 cm^4

Dead load

$$\delta c = \frac{55,107 \times 66}{1190608} = 306\ kg/cm^2$$

$$\delta t = 306 \times \frac{368.8}{321.8} = 351 \quad ''$$

Live load

$$\delta c = \frac{16617000 \times 66}{1190608} = 921\ kg/cm^2$$

$$\delta e = 921 \times \frac{368.8}{321.8} = 1055 \quad ''$$

Dead load + live load

$$\delta c = 306 + 921 = 1227\ kg/cm^2$$

$$\delta t = 351 + 1055 = 1406 \quad ''$$

§5. Main truss

5.1 Load

The following is the calculations made against H20-S16-44 load as stipulated in AASHO. The one exception, however, is that, to cope with the load increase in the future, the Clause of Reduction of load against the four traffic lanes stipulated in AASHO shall be disregarded and the load calculated as 100% in conformity with the intention of the Public and Municipal Works Department of Thailand.

Roadway: 4 traffic lanes

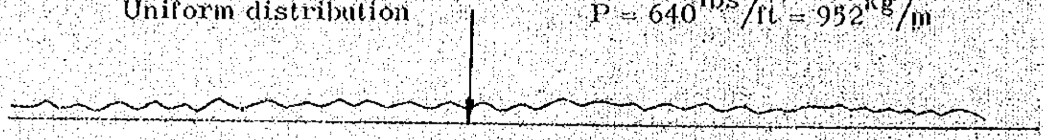
Reducing ratio: none

Load per traffic lane

Concentrated load: for M* $P = 18000^{lbs} = 8.165^{t}$

for S* $P = 26000^{lbs} = 11.794^{t}$

Uniform distribution $P = 640^{lbs}/ft = 952^{kg}/m$



Hence, in 4 traffic lanes

Concentrated load: for M, $P = 8.165 \times 4 = 32^{t}.660$

for S, $P = 11.794 \times 4 = 47^{t}.176$

Uniform load: $P = 952 \times 4 = 3.808$ t/m

Impact factor:

$$i = \frac{50}{64 \times 3.281 + 125} = \frac{50}{339.984} = 0.149$$

Hence, load per one main truss

Concentrated load: for M_1, $P_{L+i} = 1.149 \times 32.660 \times 1/2 = 18.763$

for S_1, $P_{L+i} = 1.149 \times 47.176 \times 1/2 = 27.103$

Uniform distribution $P = 1.149 \times 3.808 \times 1/2 = 2.188$ t/m

Footpath $$P_F = (30 + \frac{3000}{L})(\frac{55 - w}{50})$$

$$= (30 + \frac{30}{64 \times 3.281})(\frac{55 - 2.5 \times 3.281}{50})$$

$$= 30.143 \times 0.9360$$

$$= 28.214^{lbs}/ft^2 = 28.214 \times 4.8825 = 138\ kg/cm^2$$

*M: Bending Moment S: Shear

$P_P = 138 \times 2.5 = 345$ kg/m

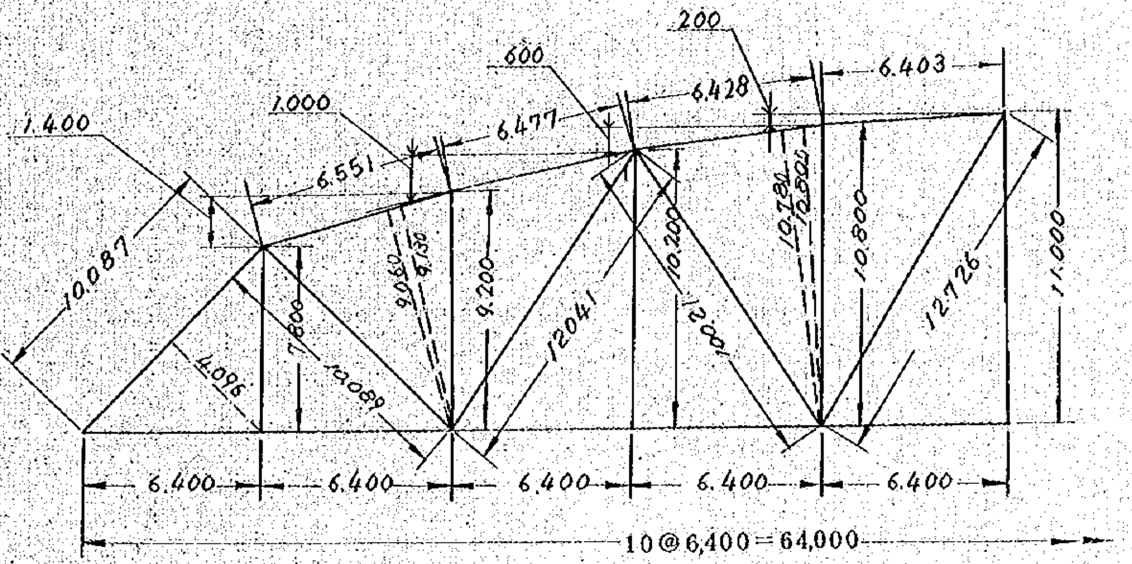
Concentrated load: for M $P_{L+I} = 18.763^{t}$

for S $P_{L+I} = 27.103^{t}$

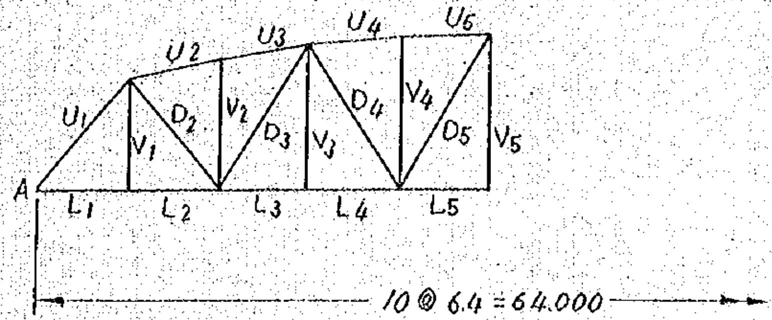
Uniform load : $P_{L+I+P} = 2.188 + 0.345 = 2.533$ t/m

Dimension and Notation for Main truss

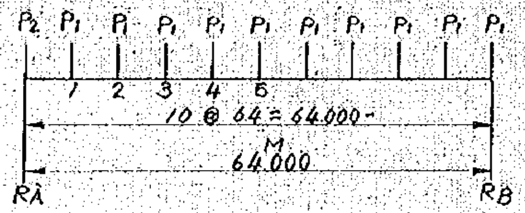
Dimension ;



Notation ;



5.2 Stresses of upper and lower chord members:-



1) Bending moment due to dead load

1-1) From the design calculations,

$P_t 1$: M = 1594.7 tm

$P_t 2$: M = 2674.9 "

$P_t 3$: M = 3510.7 "

$P_t 4$: M = 4012.1 "

$P_t 5$: M = 4179.2 "

Dead load bending moment due to an increase of floor slab thickness,

$w = 2.4 \times 0.06 - 2.2 \times 0.04 = 0.056\ t/m^2$

$w' = 0.056 \times \frac{17}{2} = 0.476\ t/m$

$Mc = \frac{1}{8} \times 0.476 \times 64^2 = 243.7\ t\text{-}m$

$P_t 1$ M = 87.7

$P_t 2$ M = 156.0

$P_t 3$ M = 204.7

$P_t 4$ M = 234.0

$P_t 5$ M = 243.7

Hence, total dead load moment will be,

$P_t 1$ Mb = 1682.4

$P_t 2$ " = 2830.9

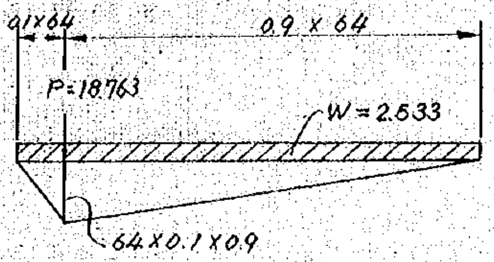
$P_t 3$ " = 3715.4

$P_t 4$ " = 4246.1

$P_t 5$ " = 4422.9

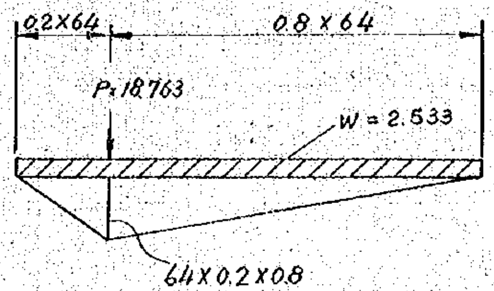
2). Bending moment at each point due to live load (laden with AASHO H20-S16-44 load);

① P_t 1



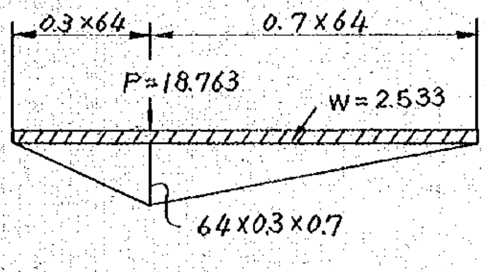
$$M_1 = 18.763 \times 64 \times 0.1 \times 0.9 + \frac{2.533 \times 64^2}{2} \times 0.1 \times 0.9 = 575 \ ^{t-m}$$

② P_t 2



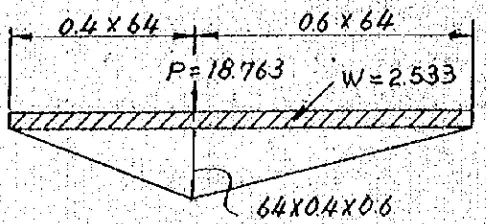
$$M_2 = 18.763 \times 64 \times 0.2 \times 0.8 + \frac{2.533 \times 64^2}{2} \times 0.2 \times 0.8 = 1022.3 \ ^{t-m}$$

③ P_t 3



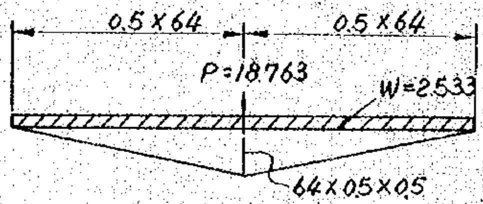
$$M_3 = 18.763 \times 64 \times 0.3 \times 0.7 + \frac{2.533 \times 64^2}{2} \times 0.3 \times 0.7 = 1341.7 \ ^{t-m}$$

④ P_t 4



$$M_4 = 18.763 \times 64 \times 0.4 \times 0.6 + \frac{2.533 \times 64^2}{2} \times 0.4 \times 0.6 = 1533.4 \ ^{t-m}$$

⑤ P_t 5

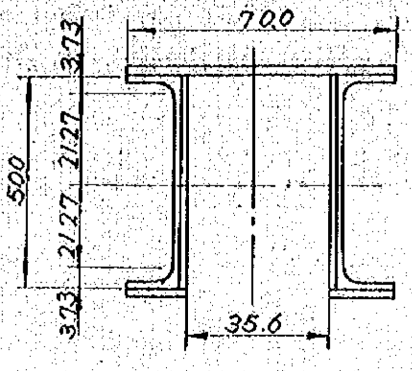


$$M_5 = 18.763 \times 64 \times 0.5 \times 0.5 + \frac{2.533 \times 64^2}{2} \times 0.5 \times 0.5 = 1597.3 \ ^{t-m}$$

Pf	Md	M_{L+i}	Total M	Name of Member	rm	Axial Force M	Length of Member
1	1682.4	575.0	2257.4	u_1	$4^m.96$	455.12	10.089
1	"	"	"	L_1, L_2	7.8	289.41	6.400
2	2830.9	1022.3	3853.2	u_2	9.06	425.30	6.551
2	"	"	"	u_3	9.13	422.04	6.477
3	3715.4	1341.7	5057.1	L_3, L_4	9.20	549.68	6.400
4	4246.1	1533.4	5779.5	u_4	10.78	536.13	6.428
4	"	"	"	u_5	10.80	535.14	6.403
5	4422.9	1597.3	6020.2	L_5	11.00	547.29	6.400

3) Stresses of chord members

① Stress of u_1



1-PL 700 x 16

4-LS 130 x 130 x 15

$2-PL_s$ 490 x 14

$2-PL_s$ 230 x 15

$2-PL_s$ 150 x 15

Aria = 513 cm^2

(i) Moment due to dead load $Md = 1682.4^{t-m}$

$r_m = 4.96$

Axial force $N = \frac{1682.4}{4.96} = 339^t.2$

$\delta_d = \frac{339.2 \times 10^3}{513} = 661$

(ii) Moment due to live load $M_{L+i} = 575.0$

$r_m = 7.8$

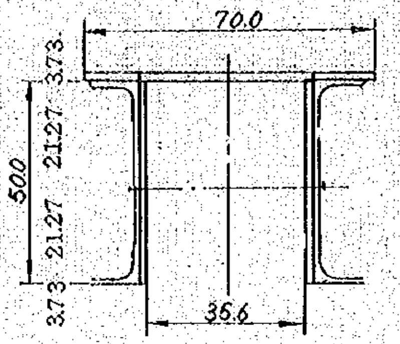
Axial force $N = \frac{575.0}{7.8} = 73^t.72$

$\delta_L = \frac{73720}{513} = 144$

Dead + Live

$= 661 + 144 = 805$ kg/cm^2

2 Stresses of u_2, u_3



1-PL 700 x 16

4-L_s 130 x 130 x 15

2-PL_s 490 x 12

2-PL_s 150 x 16

Aria = 4244 cm^2

(i) Moment due to dead load Md = 2830.9

$r_2 = 9.06$ (for u_2)

$r_3 = 9.13$ (for u_3)

Axial force $N_2 = \frac{2830.9}{9.06} = 312.5$ (for u_2)

$N_3 = \frac{2830.9}{9.13} = 310.0$ (for u_3)

$\delta_{2d} = \frac{312.5 \times 10^3}{424.4} = 736\ kg/cm^2$ (for u_2)

$\delta_{3d} = \frac{310.0 \times 10^3}{424.4} = 731$ " (for u_3)

(ii) Moment due to live load $M_{L+i} = 1022^{t-m}$

$N_2 = \frac{1022}{9.06} = 112^t.80$ (for u_2)

$N_3 = \frac{1022}{9.13} = 111^t.94$ (for u_3)

$\delta_{2L} = \frac{112.8 \times 10^3}{424.4} = 266$ (for u_2)

$\delta_{3L} = \frac{119.4 \times 10^3}{424.4} = 264$ (for u_3)

Dead + Live

$\delta_{2d} + \delta_{3d} = 736 + 266 = 1002$ (for u_2)

$\delta_{2L} + \delta_{3L} = 731 + 264 = 995$ (for u_3)

3 Stresses of u_4, u_5:-

Same as V_1 section, Aria = 513 cm^2

(i) Moment due to dead load   Md = 4246.1

$r_4 = 10.78$ (for u_4)

$r_5 = 10.80$ (for u_5)

Axial force $N_4 = \frac{4246.1}{10.78} = 393.9$ (for u_4)

$N_5 = \frac{4246.1}{10.80} = 393.2$ (for u_5)

$\delta_{4d} = \frac{393.9}{513} = 768$ (for u_4)

$\delta_{5d} = \frac{393.2}{513} = 766$ (for u_5)

(ii) Moment due to live load $M_L = 1533^{t-m}$

Axial force $N_4 = \frac{1533}{10.78} = 142^t.21$ (for u_4)

$N_5 = \frac{1533}{10.80} = 141^t.94$ (for u_5)

$\delta_{4L} = \frac{142.21}{513} = 277$ (for u_4)

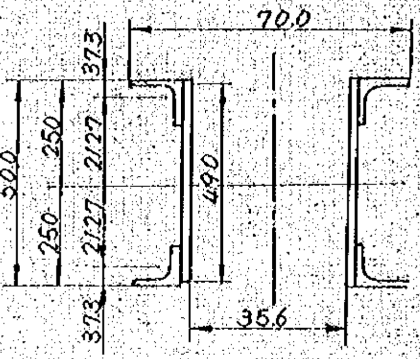
$\delta_{5L} = \frac{141.94}{513} = 277$ (for u_5)

Dead + Live

$\delta_{4d} + \delta_{4L} = 768 + 277 = 1045$ (for u_4)

$\delta_{5d} + \delta_{5L} = 766 + 277 = 1043$ (for u_5)

4 Stresses of L_1, L_2



4-L_s 130 x 130 x 15
2-PL_s 490 x 19

gr 333.2 cm^2, net 287.2 cm^2

(i) Moment due to dead load $M = 1682.4^{t\text{-}m}$

$r_m = 7.8$

Axial force $N = \frac{1682.4}{7.8} = 215^t.7$

$$\delta_d = \frac{215.7}{287.2} = 751 \text{ kg/cm}^2$$

(ii) Moment due to live load $M = 575.0^{t\text{-}m}$

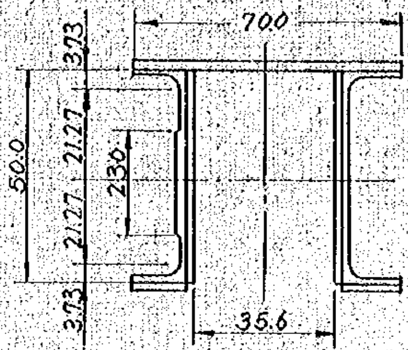
Axial force $N = \frac{575.0}{7.8} = 73.72$

$$\delta_L = \frac{73.72 \times 10^3}{287.2} = 257$$

Dead + Live

$$\Sigma\delta = 751 + 257 = 1008 \text{ kg/cm}^2$$

5 Stresses of L_3, L_4, L_5



2-PL_s 160 x 19
6-L_s 130 x 130 x 15
2-PL_s 490 x 19
2-PL_s 230 x 15

gr 536.2 cm^2, net 436.2 cm^2

(i) Moment due to dead load M = 3715.4 (For L_3, L_4) $r_m = 9.2$
M = 4422.9 (For L_5) $r_m = 11.0$

Axial force $N = \frac{3715.4}{9.2} = 403.8$ (For L_3, L_4)

$N = \frac{4422.9}{11.0} = 402.1$ (For L_5)

$\delta_{d_{3,4}} = \frac{403.8 \times 10^3}{436.2} = 926$ (For L_3, L_4)

$\delta_{d_5} = \frac{402.1 \times 10^3}{436.2} = 922$ (For L_5)

(ii) Moment due to live load M = 1342 (For L_3, L_4)
M = 1593 (For L_5)

Axial force $N = \frac{1342}{9.2} = 145^t.87$ (For L_3, L_4)

$N = \frac{1593}{11.0} = 144^t.82$ (For L_5)

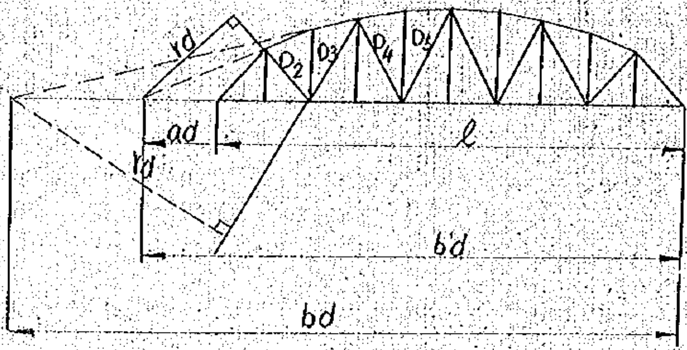
$\delta_L = \frac{145^t.87 \times 10^3}{436.2} = 334$ (For L_3, L_4)

$\delta_L = \frac{144.8 \times 10^3}{436.2} = 332$ (For L_5)

Dead + Live

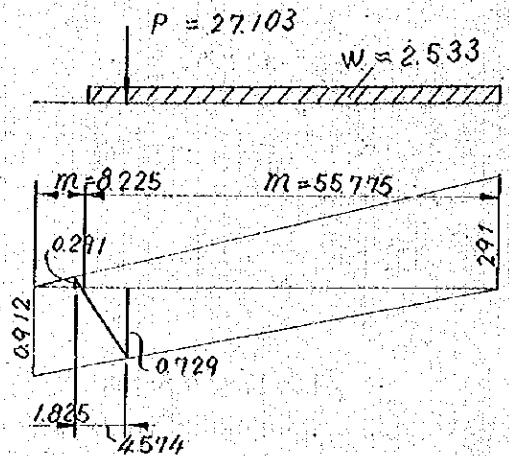
$\Sigma\delta = 926 + 334 = 1260$ kg/cm^2 (For L_3, L_4)
$\Sigma\delta = 922 + 332 = 1254$ " (For L_5)

5.3 Stresses of diagonal members



Name	Height of Truss	Difference of height	$\frac{Vn}{sv} - n$	Distance of Panels	a_d	$a_{d+n\lambda}$	Length of diagonal	r_d	b_d	$\frac{a_d}{r_d}$	$\frac{b_d}{r_d}$
D_2	7.800	1.4	4.57	64	29.3	42.1	10.090	32.15	93.3	0.912	2.91
D_3	9.200	1.0	7.7	64	46.1	58.9	12.045	59.80	110.1	0.779	1.842
D_4	10.200	0.6	14.0	64	89.6	102.4	12.045	97.60	153.6	0.918	1.572
D_5	10.800	0.2	50.0	64	32.0	332.8	12.726	29.80	384	1.070	1.29

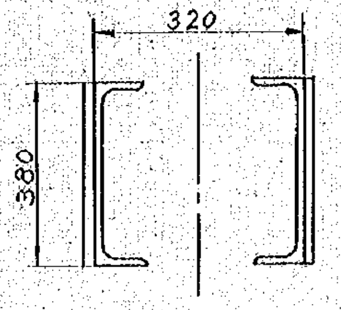
1 Stresses of diagonal member D_2



i) Dead load

$$Fd = 156^{t}.05 + 28.62 \times \frac{0.476}{1.5} = 165.13$$

$$\delta = \frac{165.13 \times 10^3}{194.4} = 849 \text{ kg/cm}^2$$



2-[$_s$ 380 x 100 x 13

2-PL$_s$ 380 x 10

Aria gr 228.6 net 194.4 cm^2

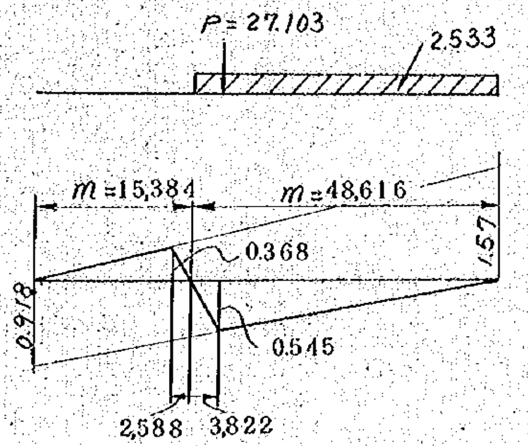
ii) Live load

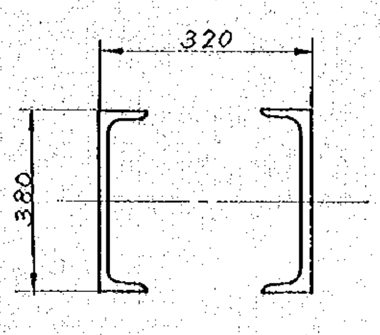
$$F_{L+i} = 27.103 \times 0.729 + 1/2 \times 55.775 \times 0.729 \times 2.533 = 71.253$$

$$\delta = \frac{71.253}{194.4} = 367$$

$$\Sigma\delta = 849 + 367 = 1216 < 1400$$

2 Stress of diagonal member D_3





i) Dead load

$$Fd = -(84.928 + 15.46 \times \frac{0.476}{1.5}) = -89.83$$

2L$_s$ 380 x 100 x 13

$$= \frac{89.83 \times 10^3}{171.4} = 524 \text{ kg/cm}^2$$

Aria gr 171.4 cm^2 net 152.6 cm^2

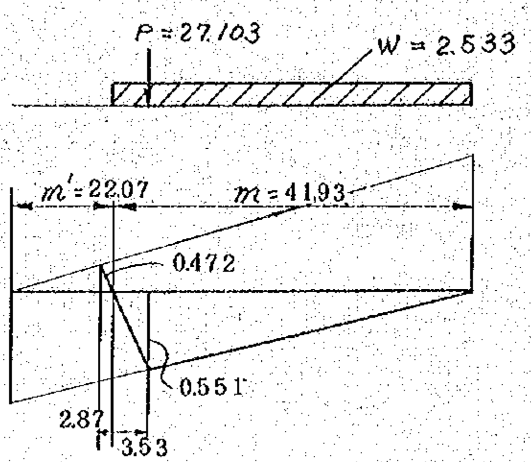
(ii) Live load

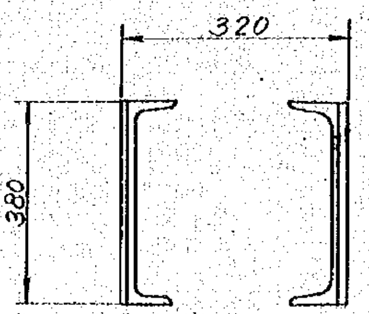
$$F_{L+i} = -27.103 \times 0.545 - 1/2 \times 48.616 \times 0.545 \times 2.533$$
$$= 48.328$$

$$\delta = \frac{48.328}{171.4} = 282 \text{ kg/cm}^2$$

$$\Sigma\delta = 524 + 282 = 806 \text{ kg/cm}^2$$

③ Stress of diagonal member D_4





(i) Dead load

$$Fd = 51^{t}.43 + 9.48 \times \frac{0.476}{1.5} = 54^{t}.44$$

$$\delta = \frac{54.44 \times 10^3}{123.8} = 440 \text{ kg/cm}^2$$

(ii) Live load

$2\text{-}L_s$ 380 x 100 x 10.5
Aria gr 138.8 cm^2 net 123.8 cm^2

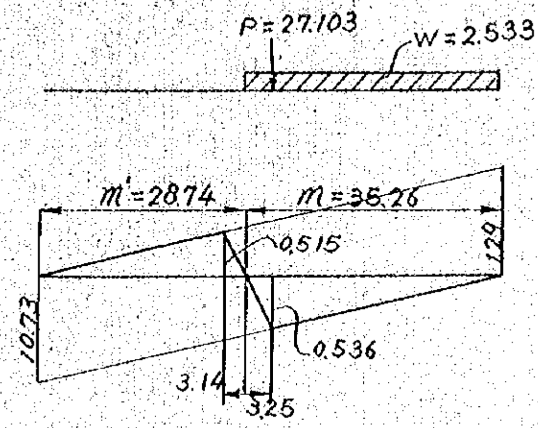
$$F_{L+i} = 27.103 \times 0.551 + 1/2 \times 41.93 \times 0.551 \times 2.533$$
$$= 44.193$$

$$\delta = \frac{44.193}{123.8} = 357 \text{ kg/cm}^2$$

$$\Sigma\delta = 440 + 357 = 797$$

4. Stress of diagonal member D_5

The section being the same as D_4,



(i) Dead load

$$Fd = -(16^{t}.7 + 3.07 \times \frac{0.476}{1.5}) = -17^{t}.67$$

$$\delta = \frac{17.67 \times 10^3}{138.8} = 127 \text{ kg/cm}^2$$

(ii) Live load

$$F_{i+L} = 27.103 \times 0.536 + 1/2 \times 35.26 \times 0.536 \times 2.533$$
$$= 38.463$$

$$\delta = \frac{38.463}{138.8} = 277 \text{ kg/cm}^2$$

$$\Sigma\delta = 127 + 277 = 404$$

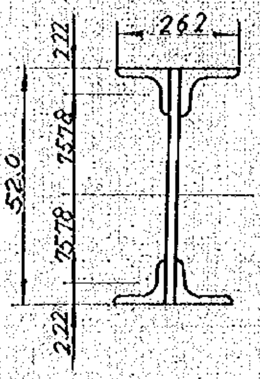
5.4 Stress of Vertical member

1 Stresses of V_1, V_3, V_5;

(i) Dead load

$$Fd = 52^t.25 + 9.6 \times \frac{0.476}{1.5} = 55^t.30$$

$$\delta = \frac{55.30 \times 10^3}{93.2} = 593 \text{ kg/cm}^2$$



4-L_s 125 x 90 x 10

1-PL_s 310 x 12

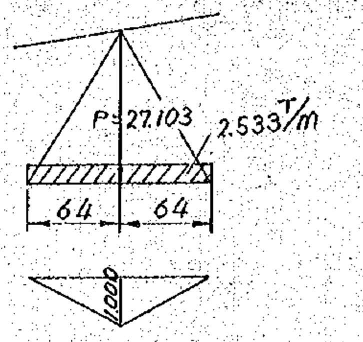
Arla gr 119.2㎠ net 93.2㎠

(ii) Live load

$$F_{L+i} = 27.103 + 1/2 \times 12.8 \times 2.533 = 44.951$$

$$\delta = \frac{44.951}{93.2} = 482$$

$$\Sigma\delta = 593 + 482 = 1075$$



2 Stress of V_2

(Same as Section V_1, V_3, V_5)

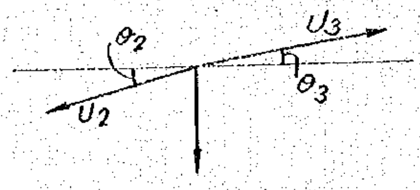
(i) Dead load

$$Fd = \frac{M_{d2}}{r_2} \times \frac{1.4}{5.966} - \frac{M_{d3}}{r_3} \times \frac{1.0}{5.885}$$

$$= \frac{2830.9}{9.06} \times \frac{1.4}{5.966} - \frac{2830.9}{9.13} \times \frac{1.0}{5.885}$$

$$= 73.3 - 52.7 = 20.6$$

$$\delta = \frac{20600}{93.2} = 221$$



(ii) Stress of live load

$$F_{L+i} = \frac{M_{L+i}}{r_2} \times \sin\theta_2 - \frac{M_{L+i}}{r_3} \times \sin\theta_3$$

$$= \frac{1022}{9.06} \times 0.214 - \frac{1022}{9.13} \times 0.154$$

$$= 6.90$$

$$\delta = \frac{6.90 \times 10^3}{93.2} = 74 \text{ kg/cm}^2$$

$$\Sigma\delta = 221 + 74 = 295$$

3 Stress of V_4 (Same as Section V_2)

(i) Dead load

$$Fd = \frac{M_{d4}}{r_4} \times \sin\theta_4 - \frac{M_{d5}}{r_5} \times \sin\theta_5$$

$$= \frac{4246.1}{10.78} \times 0.093 - \frac{4246.1}{10.80} \times 0.031 = 24.44$$

$$\delta = \frac{24.44 \times 10^3}{93.2} = 262 \text{ kg/cm}^2$$

(ii) Live load

$$F_{L+i} = \frac{M_{L+i}}{r_4} \times \sin\theta_4 - \frac{M_{L+i}}{r_5} \times \sin\theta_5$$

$$= \frac{1533}{10.78} \times 0.093 - \frac{1533}{10.80} \times 0.031$$

$$= 8.83$$

$$\delta = \frac{8.83 \times 10^3}{93.2} = 95 \text{ kg/cm}^2$$

$$\Sigma\delta = 262 + 95 = 357 \text{ kg/cm}^2$$

The above calculation results may be collected as below:-

Floor slab

Stress perpendicular to bridge axis

At center of span $\delta_c = 31$ kg/cm^2 $\delta_s = 857$ kg/cm^2

At support $\delta_c = 32$ " $\delta_s = 1155$ "

Stress to the direction of bridge axix

$\delta_c = 30$ kg/cm^2 $\delta_s = 2019$ kg/cm^2

Main truss

Unit : kg/cm^2

	Dead load stress	Live load stress	Max. stress	Allowable stress
INNER STRINGER	286	922	1208	1300
SIDE "	286	561	847	130
INNER CROSS BEAM				
δ_c	434	793	1227	1300
δ_t	499	912	1411	1400
END CROSS BEAM				
δ_c	306	924	1227	1300
δ_t	351	1055	1406	1400
MAIN TRUSS				
u_1	661	144	805	1132
u_2	736	266	1002	1241
u_3	731	264	995	1241
u_4	768	277	1045	1232
u_5	766	277	1043	1232
L_1, L_2	751	257	1008	1400
L_3, L_4	926	334	1260	1400
L_5	922	332	1254	1400
D_2	849	367	1216	1400
D_3	524	282	806	959
D_4	440	357	797	1400
D_5	127	277	404	923
V_1, V_3, V_5	593	482	1075	1400
V_2	221	74	295	1400
V_4	262	95	357	1400

From the above, after accomplishing the repairs by adopting the over lay method as described above, we find that the structural members of the bridge are all fully safe and sound.

II.

THE INSPECTION FOR THE PROPER MAINTENANCE OF MACHINERY

Maintenance of machinery comprises four requirements, namely, lubrication, cleaning, inspection and repair.

Lubrication to important parts reduces wear of machinery upto minimum and affords smooth operation.

Cleaning of machinery increases durability of machinery, facilitates inspection and examination of each component and part and assures efficient machinery operation.

For inspection of machinery, conduct necessary inspection and examination to assure proper driving, and if the defective portion is found, take remedial action accordingly.

Repair means to repair the defective portion/s or to replace it with another.

There are two kinds of inspections, namely, patrol inspection and periodical inspection:-

Patrol inspection means to check loosening, wear, and lubricating condition of each fastening and to check any hindrance to the service. The defective portions shall be remedied immediately.

Periodical inspection is that, at every established period, necessary parts shall be disassembled and are subjected to thorough examination and the driving performance inspection and tests conducted. The defective parts shall be duly repaired and nearly life-expired parts renewed.

The general time schedule and its requirement for inspection and repair are as follow:-

1) Patrol inspection:-

Every day: Check on lubrication, fitting and performance of parts.

Weekly: Same as above, but more in detail.

Monthly: Inspection on the condition of wear, deformation and/or damage of each component and part.

2) Periodical inspection:-

Every 6 months: To be inspected partly.

Every year: To be inspected on the main parts.

Every 5 years: To be inspected wholly and generally.

3) Extra inspection

Inspection shall be conducted by the followings:-

(1) The result of inspection shall be reported to supervisor and a man in charge, and a periodical inspection needs the presence of a supervisor and a man in charge.

(2) During inspection, all the switches shall be cut off and the sign "UNDER INSPECTION" to be shown.

(3) The result of inspection shall be recorded and maintained.

§1. Appearance Inspection

Mainly measuring with the eye, any wear, deformation or damage shall be checked externally. Where internal structure cannot be inspected due to cover, etc., the cover shall be removed for inspection.

1. Any damage or wear of gear

1) Check any poor gear meshing, or damage or wear of gear (if the addendum of gear worn more than 1/2 of its thickness, it shall be renewed).

2) Check if any gear cover has been damaged or deformed, or any damage on cover fitting bolts.

3) Check if the oil inside gear box has been deteriorated or not.

2. Lubrication of bearing, and wear or damage thereof:

1) Any overheating or seizure.

2) Any poor oil circulation.

3) Any poor lubricating device or any unsuitable quantity or grade in oil.

4) Is there any excessive limit due to gap enlargement with the shafting?

Gap: over 0.5 mm	Digmeter: less than 50 mm
over 1 mm	more than 50 mm

5) Any damage or flow in bearing or bearing metal.

6) Bearing lid; any loosened or too tight fastening.

7) Any unusualness in bearing cover, oil filler lid or packing.

8) Is there any loosening or the bearing fitting bolts?

9) Unusual signs in roller bearings:-

a) Any rust, damage or wear in the ball bearings.

b) Any dust deposited to the working surface or any abnormal phenomenon on the working surface.

c) Any damage on the race.

d) Any damage on the retainer.

3. Wear or loosening of key and coupling

1) Keyway of gear, shaft, etc. has been deformed and any fear of falling off.

2) Is there any deformed or head popped up key?

3) Any loosened key.

4) Any damaged flexible coupling bush.

4. Damage to chain

1) Any damaged chain.

2) Any overstretched chain.

3) Any damage or wear to chain wheel.

4) Any damage to cover or other component due to overstretching of chain.

5) Poor lubrication or extreme rusting.

5. Any trouble of power control panel

1) Unfit capacity of fuse, deformation or melting loss of fitting metal.

2) Damage to gages, glasses and lamps. Disconnection of lamp resistance.

3) Any poor contacts or traces of poor contacts.

4) Any unsatisfactory fitting of each component.

5) Damages to insulation or any poor insulation.

6. Any damages to wiring

1) Any damages to wire covering; or any poor insulation due to dust, deposit or oil, etc.

2) Any loosened joint; or melting or traces of overheating of soldering.

3) Any poor installation of conduit piping; any damages to wire covering of pipe end.

4) Any poor insulating resistance of wiring or its accessory fittings.

7. Damage or poor insulation of resistance

1) Unsatisfactory connection or locally overheating.

2) Resistance of any unfit capacity.

3) Any deformed grid or unsatisfactory clamping of insulating bolt for assembly.

4) Any adherence of dust or poor insulation.

8. Wear, scoring, loosening of electric rotating machine

1) Wear or any abnormality in the bearing. Is oil or grease properly filled?

2) Any poor condition, loosening or damage to the fitting position of brush holder or loosening of clamped position.

3) wear of brush, unsatisfactory lapping which may cause sparking.

4) Poor contact or gap between brush holder and brush; or unproper adjustment of spring.

5) Roughness, discolouring or irregular wear of commutator and A.C. slip ring face.

6) Sagging of commutator and segment due to burning loss or projection of

mica.

7) Any poor soldering on riser section.

8) Any unevenness in the air gaps.

9) Any unsatisfactory lead or terminal for connection; or any poor covered insulation.

10) Any poor insulating resistance of electric motor.

9. Adjustment of limit switch

1) Any defective connection or feed screw of each lever.

2) Adjustment of lever working position; also, adjustment of a striker for feeding screw.

3) Is the spring all right?

4) Poor contacts, roughened by sparks or poor insulation.

5) Any malfunction due to dust adhesion or poor fitting.

10. Trouble of electric brake

1) Poor joint between brake and lever.

2) Loosening, wear, damage or omission of rod, pin and screw.

3) Excessive wear or any flaws on the brake wheel face.

4) Wear of brake shoe or brake lining, etc.

5) Is the gap between brake lining and wheel proper?

6) Are the quality and quantity of the oil at pump section proper?

7) Is there any motor which is of poor insulating resistance?

11. Transformer

1) Is the rise of temperature proper?

2) Any oil leakage.

3) Are the oil level meter, temperature meter, radiator and cock, etc. all right?

4) Is the exterior case not damaged?

5) Any discolouration due to loosening, or overheating in the terminal portion.

6) Pressure resisting and acid value of insulating oil shall be measured once a year. If the destructive voltage is below 30 KV and the acid value below 0.3, the oil shall be filtered for regeneration or replaced with anew. The transformer shall be disassembled once in ten years for removal of slags inside and examination of clamped portion.

12. Oil circuit breaker and oil switch

1) Any discolouration due to heat generation at terminal and lead fitting portion.

2) Any bushing damage.

13. Insulator, bushing or steel framing, etc.

1) Any dust adhesion or discolouration.

2) Overheating or discolouration of joints.

3) Any damage of insulator.

14. Storage battery

1) Suitability of the volume and colouring of electrolyte; or any liquid leakage.

2) Any abnormality of plate.

3) Any corrosion of the metals for supporting wooden block and the terminal.

15. Diesel Engine

According to the "Handling and Maintenance Instructions of the Diesel Engine."

§2. Driving Instructions:-

1. Is the electric current value normal at the time of bridge driving?

2. Any jolting of bridge components at the time of bridge driving?

3. Any noise of driving components

1) Any unusually higher sounds of gear engagement.

2) Any abnormal sounds of bearing portion.

3) Vibration, abnormal sound of electric rotator; any rolling of rotator.

4. Any overheating of driving components while in driving:-

1) Unusual temperature rise or overheating of bearing of electric rotator.

2) Any sparking due to poor lapping of carbon brush.

3) Any local overheating of resistor.

5. Is meshing of gears all right?

6. Is the slipping revolution nos. at the time of brake stopping normal?

7. Does the automatic circuit breaker of power control panel function well?

1) Does the plunger of low voltage relay fall for certain with the knife switch off?

2) Can the plunger of low voltage relay drop from the mid height of whole stroke by hand and work correctly?

3) Operate an overload relay by hand and see if the cut-off motion works surely.

4) Check if the fuse is good or not.

8. Proper action of limit switch:-

Remove cover of limit switch and perform the actual motion, thereby confirming the secure cut-off motion of automatic circuit breaker.

9. Confirm the right motion of lubricator.

10. Confirm the right operation of the diesel power generating unit.

11. Confirm the right driving of the diesel engine.

§3. Wear limit and lasting life

Wear limit

	Part	Repair limit	Using limit	
Mechanical Parts	Gear tooth thickness	25% at pitch circle	40%	Rate of wear
	Brake wheel rim	40% at thickness	50%	"
	Unevenness of brake wheel surface	2 mm		
	Brake lining		50%	"
	Gap of pin & pin hole; Shaft and shaft bearing metal	2%; For below 75mm, 1.5mm	3%; For below 60mm, 2mm	
	Pin and shaft	4%	6%	"
	Chain	15%	20%	"
	Screw thread	20% by pitch	20%	"

	Part	Repair limit	Using limit	
Electrical Parts	Carbon brush		50%	Rate of wear
	Slip ring	4mm; below 20KW 5mm; above 20KW	3mm; below 20KW 4mm; above 20KW	Remaining size
	Air gap	1/2	1/3	Min/Max ratio
	Contactor	40%	50%	Rate of wear
	Contact piece	40%	50%	"
	Insulating resistance	1MΩ low voltage	0.1MΩ 0.2MΩ	Below 150V Below 300V
	"	5MΩ high voltage	0.4MΩ	Above 300V
	Storage battery		80% of rated capacity	
	Mercury rectifier		Color of arc turns reddish, glass wall near electrode blackened, mercury becomes sticky and glass face turns into like glass.	

Generally assumed lasting life

Storage battery	About 10 years
Mercury rectifier	10,000 ~ 50,000 hrs.
Limit switch	50,000 times
Solenoid contactor	500,000 times
Discharge lamp	3,000 ~ 6,000 hrs.
Mercury lamp	6,000 ~ 12,000 hrs.