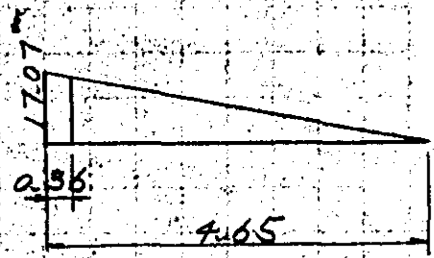
Front face of cross beam



$$M_{ty} = \frac{(4.65 - 0.36)}{4.65} \times 17.07 = 15.75^{tm}$$

$$\therefore M_{ty} = 15.75 \times 0.9429 = 14.85^{tm}$$

$$K_1 = 0.219$$

$$K_2 = 0.930$$

$$\tau_{ty1} = \frac{14.85 \times 10^5}{0.219 \times 120 \times 100} = 5.65^{kg/cm^2}$$

$$\tau_{ty2} = 5.65 \times 0.930 = 5.25$$

3. Combined shearing stress

At the 1/2 H point from support (point a)

$$\tau_a = \tau_{ba} + \tau_{ta} = 10.18 + 5.34 = 15.52 \ \mathrm{kg/cm^2}$$

(point b)

$$\tau_b = \tau_{bb} + \tau_{tb} = 6.63 + 3.06 = 9.69 \ "$$

At the center point (point c)

$$\tau_c = \tau_{bc} + \tau_{tc} = 3.02 + 0 = 3.02 \ "$$

Front face of cross beam

$$\tau_y = \tau_{ba} + \tau_{ty} = 10.18 + 5.65 = 15.83 \ "$$

Combined shearing stress will be,

$$3.9 \ \mathrm{kg/cm^2} < 15.83 \ \mathrm{kg/cm^2} < 17 \times 1.3 = 22.1 \ \mathrm{kg/cm^2}$$

(B) Single track loading

1. Bending shearing stress

At the 1/2H point from support (point a)

$S_a = 99.36^t$

$$\tau_{ba} = \frac{99.36 \times 10^3}{100 \times 110.6} = 8.98^{kg/cm^2} > 3.9^{kg/cm^2}$$

(point b)

$S_b = 64.02^t$

$$\tau_{bb} = \frac{64.02 \times 10^3}{100 \times 110.6} = 5.79 \text{ "} > 3.9 \text{ "}$$

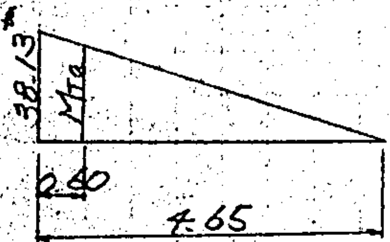
(point c)

$S_c = 26.70^t$

$$\tau_{bc} = \frac{26.70 \times 10^3}{100 \times 110.6} = 2.41 \text{ "} < 3.9 \text{ "}$$

4. Torsional shearing stress

At the 1/2 H point from support (point a)



$M_{ta} = -14.43 - 23.70$

$= -38.13^{tm}$

$$M_{Ta} = \frac{(4.65 - 0.60)}{4.65} \times 38.13 \times 0.9429 = 31.31^{tm}$$

$$\frac{h_0}{b_0} = 1.200$$

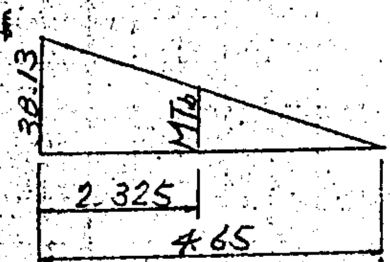
$K_2 = 0.219$

$K_3 = 0.930$

$$\tau_{ta1} = \frac{31.31 \times 10^5}{0.219 \times 120 \times 100^2} = 11.91^{kg/cm^2} > 3.9^{kg/cm^2}$$

$$\tau_{ta2} = 11.91 \times 0.930 = 11.03 \text{ " } > \text{ " }$$

(point b)



$$M_{tb} = \frac{(4.65 - 2.325)}{4.65} \times 38.13 \times 0.9429 = 17.98^{tm}$$

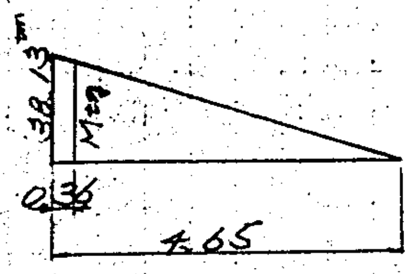
$$\tau_{tb1} = \frac{17.98 \times 10^5}{0.219 \times 120 \times 100^2} = 6.84 \ ^{kg/cm^2} > 3.9 \ ^{kg/cm^2}$$

$$\tau_{tb2} = 6.84 \times 0.930 = 6.36 \ '' > \ ''$$

(center point)

$$M_t = 0 \ ^{tm}$$

(Front face of cross beam)



$$M_{tg} = \frac{(4.65 - 0.36)}{4.65} \times 38.13 \times 0.9429 = 33.17 \ ^{tm}$$

$$\tau_{tg1} = \frac{33.17 \times 10^5}{0.219 \times 120 \times 100^2} = 12.62 \ ^{kg/cm^2} > 3.9 \ ^{kg/cm^2}$$

$$\tau_{tg2} = 12.62 \times 0.930 = 11.74 \ '' > \ ''$$

5. Combined shearing stress

At the 1/2 H point from support (point a)

$\tau_b = \tau_{ba} + \tau_{ta} = 8.98 + 11.91 = 20.89\ kg/cm^2$

(point b)

$\tau_b = \tau_{bb} + \tau_{tb} = 5.79 + 6.84 = 12.63$ "

center point (point c)

$\tau_c = \tau_{bc} + \tau_{tc} = 2.41 + 0 = 2.41$ "

Front face of cross beam

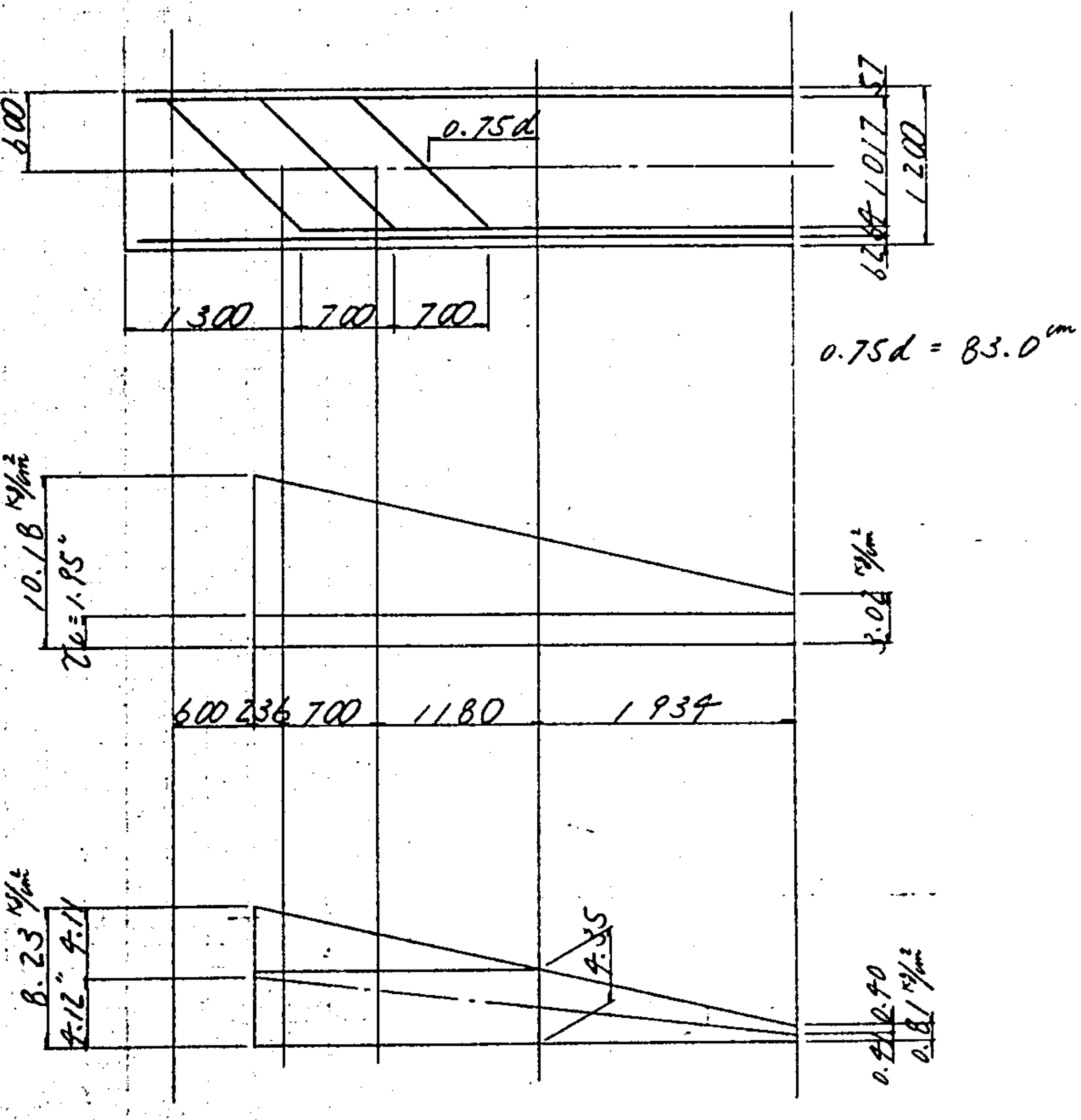
$\tau_\eta = \tau_{ba} + \tau_{t\eta} = 8.98 + 12.62 = 21.60$ "

Combined shearing stress

$3.9\ kg/cm^2 < 21.60\ kg/cm^2 < 17 \times 1.3 = 22.1\ kg/cm^2$

Calculation of diagonal bars (double track loading)

(A) Stress acting in stirrup caused by bending shear



- The range requiring arrangement of diagonal tension bars
- Said range shall be from the $\tau a = 3.9$ kg/cm² to the point at the distance equivalent to the effective depth d.

$$u' = \frac{3.9 - 3.02}{10.18 - 3.02} \times 4.05 = 0.498^{m}$$

$$u = 405.0 - 49.8 + 110.6 = 465.8^{cm} > 405.0^{cm}$$

Shearing stress beared by bars other than diagonal tension bars

$$\tau c = \frac{1}{2}\tau c$$

$$= \frac{1}{2} \times 3.9 = 1.95 \text{ kg/cm}^2$$

Area of shearing stress beared by diagonal tension bars

$$F = 1/2 \times (8.23 + 0.81) \times 405.0 = 1830.6 \text{ kg/cm}^2$$

Sharing proportion of shearing stress between turned up bars and stirrup bars can be determined at will, provided 1/2 or more area of shearing stress is shared by stirrup.

Stress of stirrup

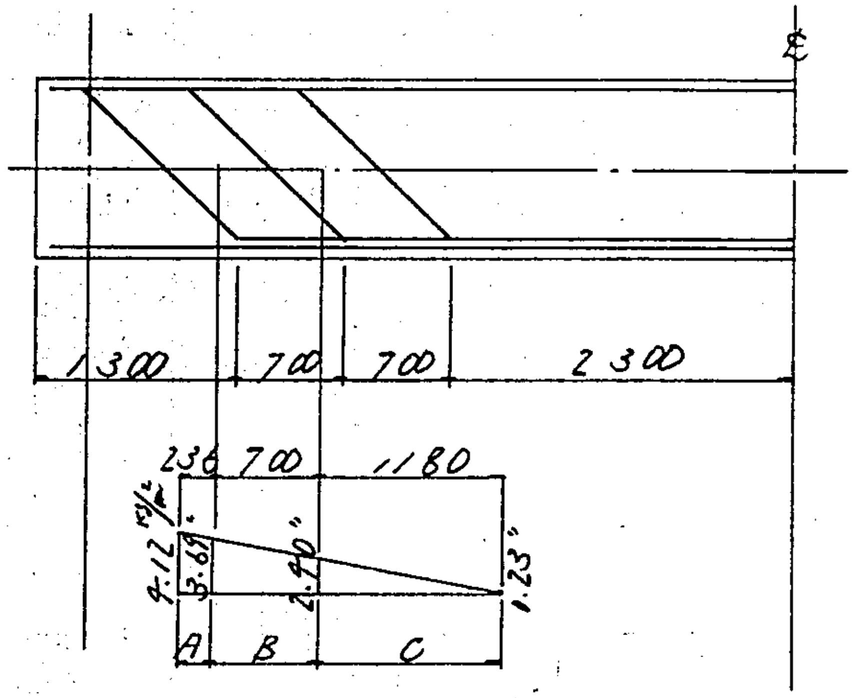
$F_v = 1830.6 - 1/2 \times (4.11 + 0.23) \times 211.6 = 1371.4$ kg/cm²

$\tau_0 = 4.12$ kg/cm²

D16 - 2 sets 15.0 cm ctc

$$\sigma_{sv} = \frac{1.15 \times 4.12 \times 100 \times 15.0}{1.986 \times 4} = 895 \text{ kg/cm}^2 < 1800 \text{ kg/cm}^2$$

(B) Stress acting in turned up bars



a) A. block

$S_{bA} = 1/2 \times (4.12 + 3.69) \times 23.6 = 92.2$ kg/cm²

$A_{bA} = D32 - 2 = 15.89$ cm²

$\sin\theta + \cos\theta = 1.414 \quad (\theta = 45°)$

$$\sigma_{sA} = \frac{1.15 \times 92.2 \times 100}{15.89 \times 1.414} = 472 \text{ kg/cm}^2 < 1800 \text{ kg/cm}^2$$

(b) B. block

$S_{bB} = 1/2 \times (3.69 + 2.40) \times 70.0 = 213.2$ kg/cm²

$A_{bB} = D32 - 2 = 15.89$ cm²

$\sin\theta + \cos\theta = 1.414 \quad (\theta = 45°)$

$$\sigma_{sB} = \frac{1.15 \times 213.2 \times 100}{15.89 \times 1.414} = 1091 \text{ kg/cm}^2 < 1800 \text{ kg/cm}^2$$

(c) C. block

$S_{bc} = 1/2 \times (2.40 + 0.23) \times 118.0 = 155.2$ kg/cm²

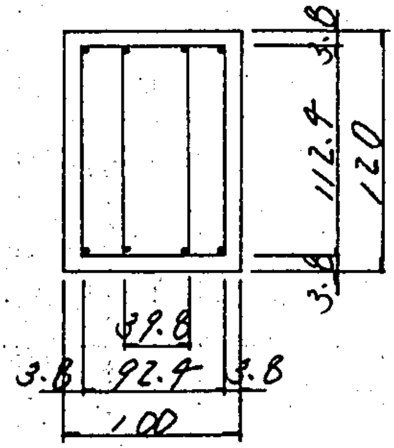
$A_{bc} = D32 - 2 = 15.89$ cm²

$\sin\theta + \cos\theta = 1.414 \quad (\theta = 45°)$

$$\sigma_{sC} = \frac{1.15 \times 155.2 \times 100.0}{15.89 \times 1.414} = 794 \text{ kg/cm}^2 < 1800 \text{ kg/cm}^2$$

Stress of stirrup due to torsional shearing stress

At the ½ H point from support



$M_T = 14.03$ tm

$$b_T = \frac{92.4^2 + 39.8^2}{92.4 + 39.8} = 76.56 \text{ cm}$$

$$F_{KS} = 76.56 \times 112.4 = 8605.3 \text{ cm}^2$$

$$\sigma_{st1} = \frac{14.03 \times 10^5 \times 15.0}{0.8 \times 7.944 \times 8605.3} \times \frac{92.4}{76.56} = 464 \text{ kg/cm}^2 < 1800 \text{ kg/cm}^2$$

Combined stress of stirrup

$\sigma_{sb1} = 895$ kg/cm²

$\sigma_{st1} = 453$ 〃

$\sigma_s = 895 + 464 = 1359$ kg/cm² $< 1800 \times 1.2 = 2160$ kg/cm² stress analysis on the front face of cross beam

$M_T = 14.85^{tm}$

$$\sigma_{sty} = \frac{14.85 \times 10^5 \times 15.0}{0.8 \times 7.944 \times 8605.3} \times \frac{92.4}{76.56} = 492 \ kg/cm^2 < 1800 \ kg/cm^2$$

Combined stress of stirrup

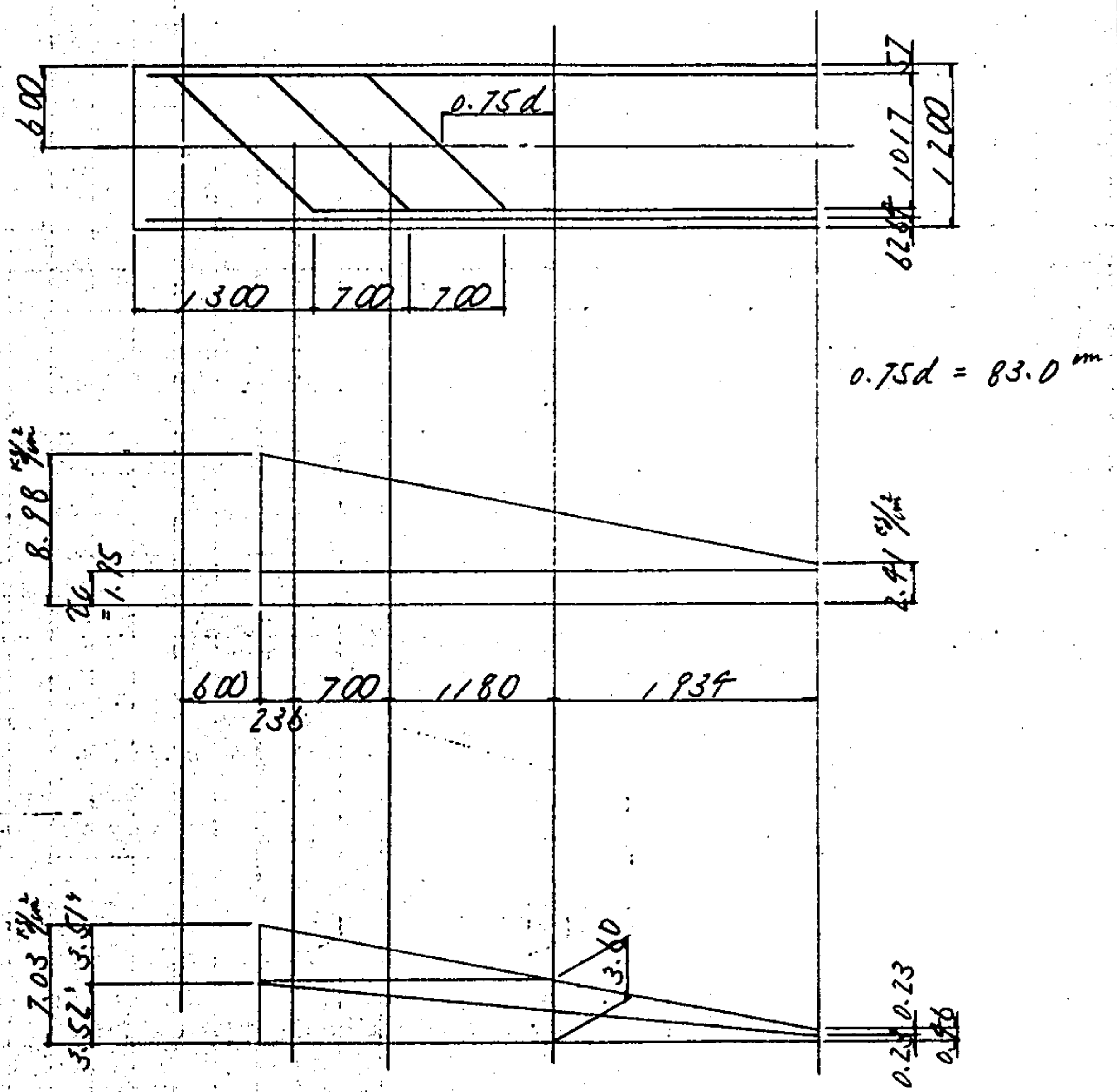
$\sigma_{sb1} = 895 \ kg/cm^2$

$\sigma_{sty} = 492$ 〃

$\sigma_s = 895 + 492 = 1387 \ kg/cm^2 < 2160 \ kg/cm^2$

Calculation of diagonal tension bars
(single track loading)

(A) Stress acting in stirrup caused by bending shear



- The range requiring arrangement of diagonal tension bars
- Said range shall be from the $\tau a = 3.9$ kg/cm² to the point at the distance equivalent to the effective depth d.

$$u' = \frac{3.9 - 2.41}{8.98 - 2.41} \times 4.05 = 0.918^{m}$$

$$u = 405.0 - 91.8 + 110.6 = 423.8^{cm} > 405.0^{cm}$$

Shearing stress beared by bars other than diagonal tension bars

$$\tau c = \frac{1}{2} \tau c$$

$$= \frac{1}{2} \times 3.9 = 1.95 \text{ kg/cm}^2$$

Area of shearing stress beared by diagonal tension bars

$$F = 1/2 \times (7.03 + 0.46) \times 405.0 = 1516.7 \text{ kg/cm}^2$$

Sharing proportion of shearing stress between turned up bars and stirrup bars can be determined at will, provided 1/2 or more area of shearing stress is shared by stirrups.

Stress of stirrup

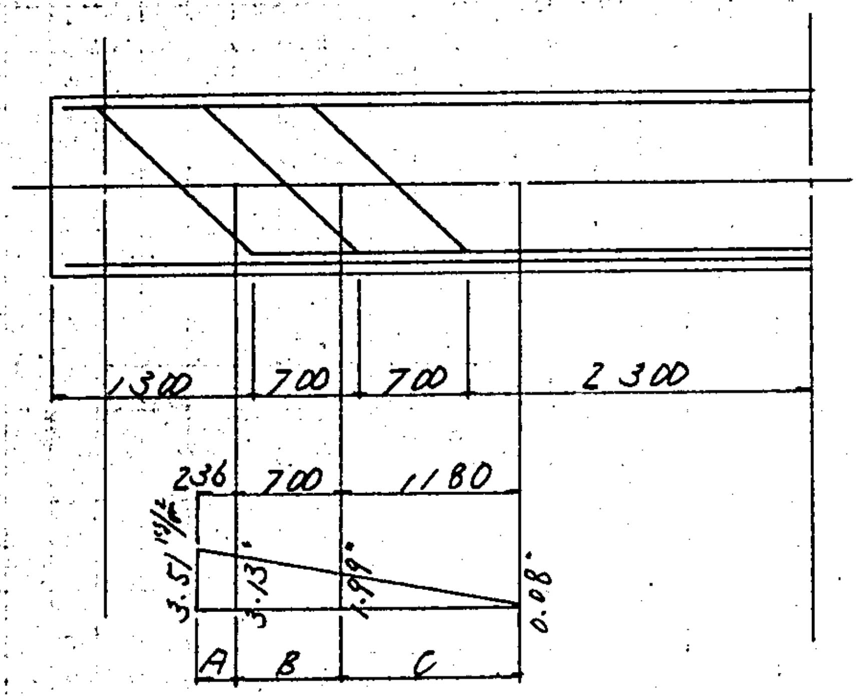
$F_v = 1516.7 - 1/2 \times (3.51 + 0.08) \times 211.6 = 1136.9$ kg/cm²

$\tau_o = 3.52$ kg/cm²

D16 - 2 sets 15.0 cm ctc

$$\sigma_{sv} = \frac{1.15 \times 3.52 \times 100 \times 15.0}{1.986 \times 4} = 764 \text{ kg/cm}^2 < 1800 \text{ kg/cm}^2$$

(B) Stress acting in turned up bars



a) A. block

$S_{bA} = 1/2 \times (3.51 + 3.13) \times 23.6 = 78.4$ kg/cm²

$A_{bA} = D32 - 2 = 15.89$ cm²

$\sin\theta + \cos\theta = 1.414 \quad (\theta = 45°)$

$$\sigma_{sA} = \frac{1.15 \times 78.4 \times 100}{15.89 \times 1.414} = 401 \text{ kg/cm}^2 < 1800 \text{ kg/cm}^2$$

(b) B. block

$SbB = 1/2 \times (3.13 + 1.99) \times 70.0 = 179.2\ kg/cm^2$

$AbB = D32 - 2 = 15.89\ cm^2$

$\sin\theta + \cos\theta = 1.414$

$$\sigma sB = \frac{1.15 \times 179.2 \times 100}{15.89 \times 1.414} = 917\ kg/cm^2 < 1800\ kg/cm^2$$

(c) C block

$Sbc = 1/2 \times (1.99 + 0.08) \times 118.0 = 122.1\ kg/cm^2$

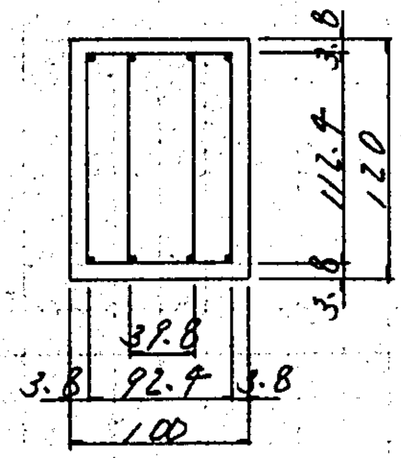
$Abc = D32 - 2 = 15.89\ cm^2$

$\sin\theta + \cos\theta = 1.414$

$$\sigma sc = \frac{1.15 \times 122.1 \times 100}{15.89 \times 1.414} = 625\ kg/cm^2 < 1800\ kg/cm^2$$

Stress of stirrup due to torsional shearing stress

At the 1/2 H point from support



$MT = 33.17^{tm}$

$$bT = \frac{92.4^2 + 39.8^2}{92.4 + 39.8} = 76.56 \text{ cm}$$

$$FKS = 76.56 \times 112.4 = 8605.3 \text{ cm}^2$$

$$\sigma sk1 = \frac{33.17 \times 10^5 \times 15.0}{0.8 \times 7.944 \times 8605.3} \times \frac{92.4}{76.56} = 1098 \text{ Kg/cm}^2 < 1800 \text{ Kg/cm}^2$$

Combined stress of stirrup

$\sigma sb1 = 764 \text{ Kg/cm}^2$

$\sigma sk1 = 1098$ "

$\sigma s = 764 + 1098 = 1862 \text{ Kg/cm}^2 < 1800 \times 1.2 = 2160 \text{ Kg/cm}^2$

Calculation of bar arrangement in axial direction

$$ASL = \frac{MT \cdot S}{1.6 \times \sigma sa \times FK}$$

Front face of cross beam (single track loading)

$MT = 33.17^{tm}$

$d_T = 112.4^{cm}$

$b_T = 92.4$ "

$S = 2 \times (112.4 + 92.4) = 409.6^{cm}$

$FSK = 112.4 \times 92.4 = 10385.8^{cm^2}$

$$ASL = \frac{33.17 \times 10^5 \times 409.6}{1.6 \times 1800 \times 10385.8} = 45.42^{cm^2}$$

The above ASL is divided into directions of longitudinal (ASL1) and transversal (ASL2)

$$ASL1 = 45.42 \times \frac{112.4}{409.6} = 12.46^{cm^2}$$

Besides, redundancy bars equivalent to 8% of main bars are arranged at the wed part.

$ASL1 = 7.942 \times 20 \times 0.08 \times 1/2 = 6.35^{cm^2}$ (per one side) $< 12.46^{cm^2}$

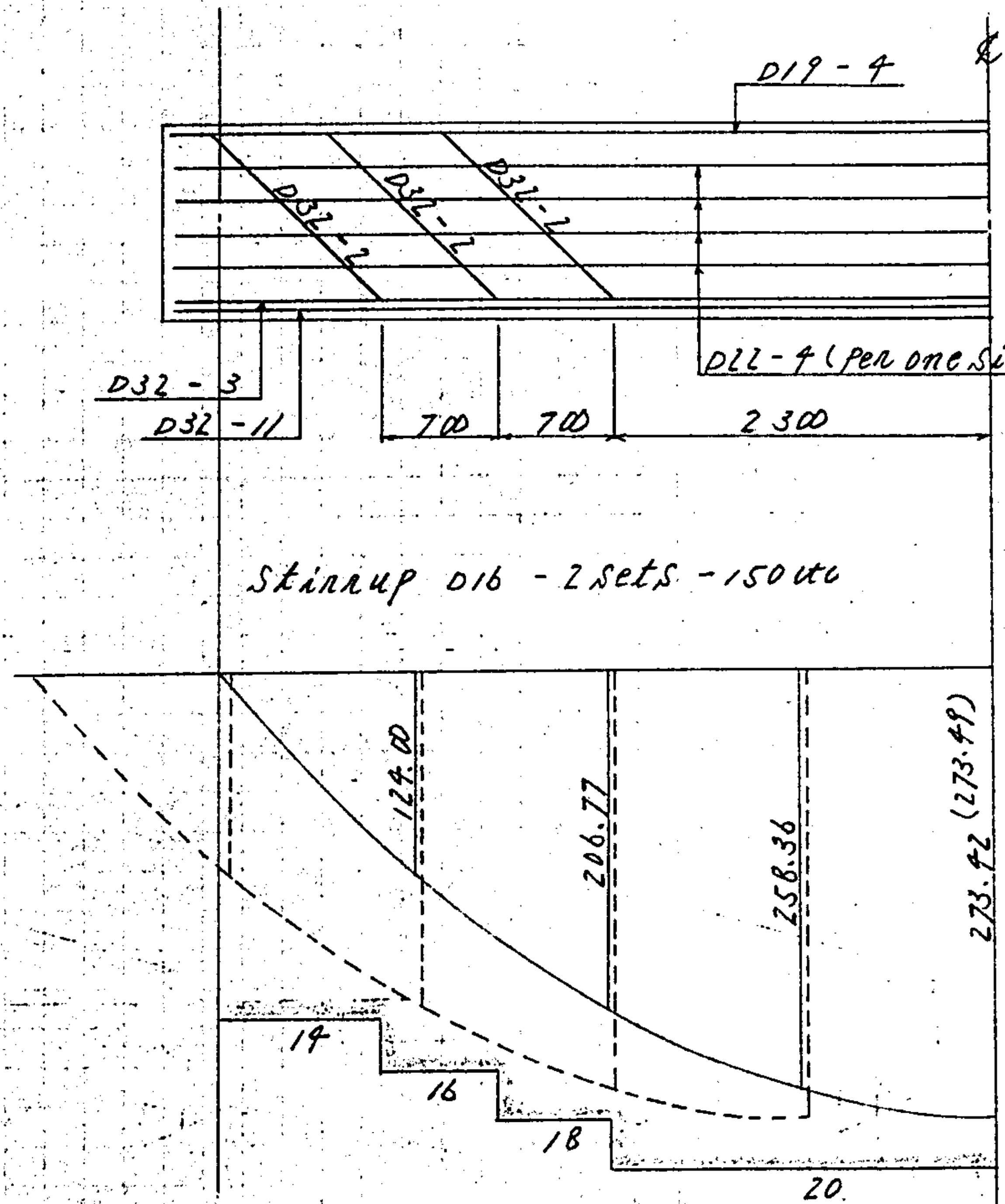
$D22 - 4 = 15.48^{cm^2} > 12.33^{cm^2}$

$$ASL2 = 45.42 \times \frac{92.4}{409.6} = 10.25^{cm^2}$$

$D19 - 4 = 11.46^{cm^2} > 10.25^{cm^2}$

Arranged at upper side.

Resisting moment diagram



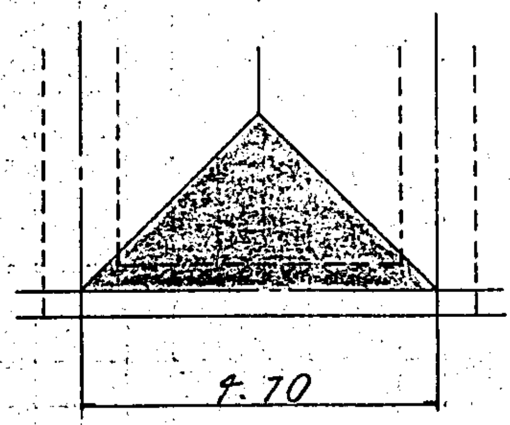
$MR = 1920 \times 0.906 \times 110.6 \times 7.942 = 15.28^{tm}$

Bending moment at various points is shifted with the distance equivalent to the effective height.

4. Calculation of cross beam

(A) Calculation of loads

4-1. Dead load



Both ends simple beam: Span is the distance between main beam centers.

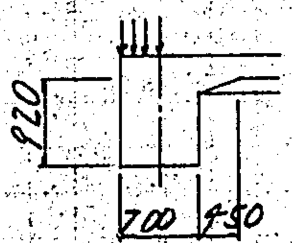
1) Distributed load

From the slab calculation

a. Dead load

$W_{d1} = 1.87\ t/m^2$ Refer (P -)

2) Own weight of cross beam and weight of slab haunch



$W_{d2} = (0.70 \times 0.92 + 1/2 \times 0.15 \times 0.45) \times 2.5 = 1.69\ t/m$

$W_{d3} = 1.88 \times 0.35 = 0.66$ "

$= 2.35\ t/m$

4-2. Train load + Impact (double track loading)

Equivalent uniformly distributed load

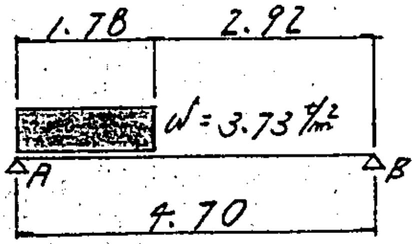
$W_e = 2.31\ t/m$

Impact coefficient $i = 0.487 \times \left(1 - \frac{4.70}{200}\right) = 0.476$

From the above

$W_{e+i} = 2.31 \times 1.476 = 3.41\ t/m$

4-3. Train load + Impact (single track loading)



$R_A = \frac{1}{4.70} \times (1.78 \times 3.73 \times 3.81) = 5.38\ t$

At $l/4$ point

$M_{l/4} = 5.38 \times 1.175 - \frac{1}{2} \times 3.78 \times 1.175^2 = 3.71\ tm$

$W_{l/4} = \frac{32 \times 3.71}{3 \times 4.70^2} = 1.79\ t/m > 1.07\ t/m$

At $l/2$ point

$M_{l/2} = 5.38 \times 2.35 - 3.73 \times 1.78 \times 1.46 = 2.95\ tm$

$W_{l/2} = \frac{8 \times 2.95}{4.70^2} = 1.07\ t/m$

$\therefore W_{e+i} = 1.79 \times 1.476 = 2.64\ t/m$

(B) Stress calculation

1) Bending moment Calculation

Bending moment is calculated at the span center point of cross beam.

Also, stress of upper part at the support point is referred the torsional moment of main beam at the support point.

[Span moment]

Case 1. Dead load

$$M = \frac{1}{12} \cdot w \cdot l^2 \qquad \frac{1}{8} wl^2$$

$$= \frac{1}{12} \times 1.87 \times 4.70^2 + \frac{1}{8} \times 2.35 \times 4.70^2$$

$$= 9.93^{tm}$$

Case 2. Train load + Impact (double track loading)

$$M = \frac{1}{12} \times 3.41 \times 4.70^2$$

$$= 6.28^{tm}$$

Case 3. Train load + Impact (single track loading)

$$M = \frac{1}{12} \times 2.64 \times 4.70^2$$

$$= 4.86^{tm}$$

Case 4. Dead load + Train load + Impact (double track loading)

$$M = 9.93 + 6.28 = 16.21^{tm}$$

(End moment) From (P

Case 1. Dead load

$M_T = -14.43^{tm}$

Case 2. Train load + Impact (single track loading)

$M_T = -23.70^{tm}$

Case 3. Dead load + Train load + Impact
(single track loading)

$M_T = -14.43 - 23.70 = -38.13^{tm}$

Analysis of bending stress, safe against dead load and allowable stress for cracking

Dead load + Train load + Impact	$= -38.13^{tm}$
Dead load	$= -14.43$ "
Train load + Impact	$= -23.70$ "

$-38.13 \times 0.25 = -9.53^{tm} < -23.70^{tm}$

From the above, σ_{sa} is assumed.

$\sigma_{sa} = 1000\ kg/cm^2$

2) Calculation of shearing force

Case 1. Dead load

$S = 1/2 \times 1.87 \times 2.35^2 + 1/2 \times 2.35 \times 4.70$

$= 10.69^t$

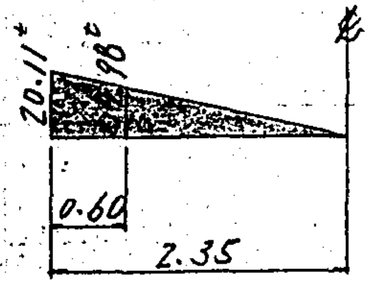
Case 2. Train load + Impact (double track loading)

$S = 1/2 \times 3.41 \times 2.35^2$

$= 9.42^t$

Case 3. Dead load + Train load + Impact (double track loading)

$S = 10.69 + 9.42 = 20.11^t$



Shearing stress

	support	support	span			
M (tm)	-14.43	-38.13	16.21			
N (t)						
S (t)						
b (cm)	70	70	120			
h (cm)	120	120	120			
d (cm)	111.6	111.6	111.2			
d' (cm)	8.4	8.4	8.8			
As (cm²)	D22 - 6 23.23	D22 - 6 23.23	D19 - 4 11.46			
p	0.00297	0.00297	0.00086			
As' (cm²)						
p'						
e = M/N (cm)						
e = M/N + u (cm)						
e = M/N − u (cm)						
~~e/h~~ (t)			(28)			
d/e						
d'/h						
d'/d						
Ne/bd² (kg/cm²)						
k						
c						
j						
1/Lc	8.51	8.51	14.2			
1/Ls	368	368	1225			
β = σs/σc						
σc (kg/cm²)	14.1	37.2	15.5			
σs (kg/cm²)	610	1610	1340			
τ (kg/cm²)						
σsa (kg/cm²)	1000	1800	1800			
σca (kg/cm²)		90	90			
τa (kg/cm²)						
Nomogram number	M-1	M-1	M-47.48			
combination	D	D+T+I	D+T+I			

3). Shearing stress

$S1 = 19.98^t$ (At the point of 1/2 H distance from support point)

$$\tau = \frac{19.98 \times 10^3}{70 \times 111.2} = 1.92 \ kg/cm^2 < 3.9 \ kg/cm^2$$

From the above, Calculation for the diagonal tension bars become unnecessary.

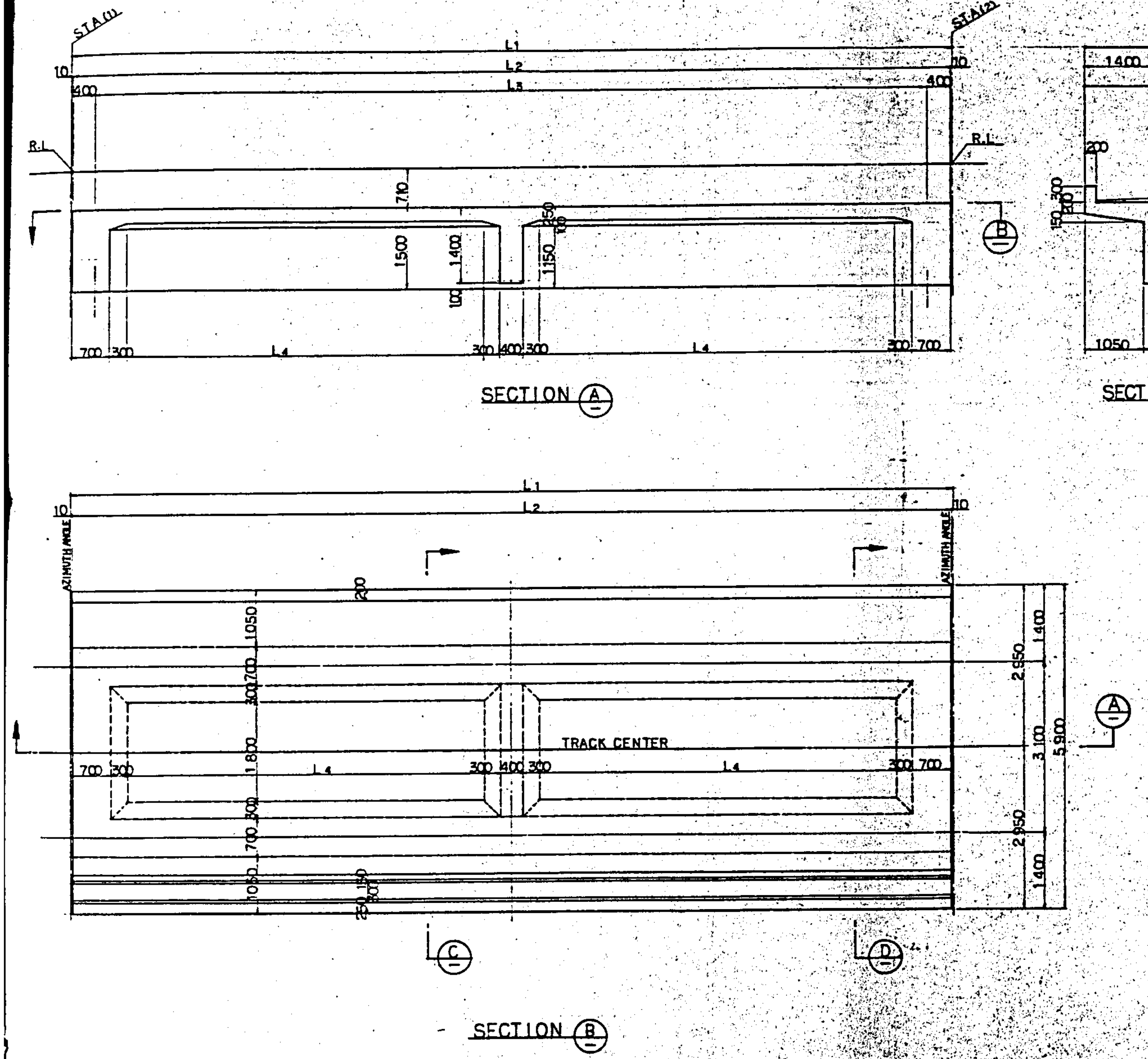
Redundancy bars for wed (8% of main bars)

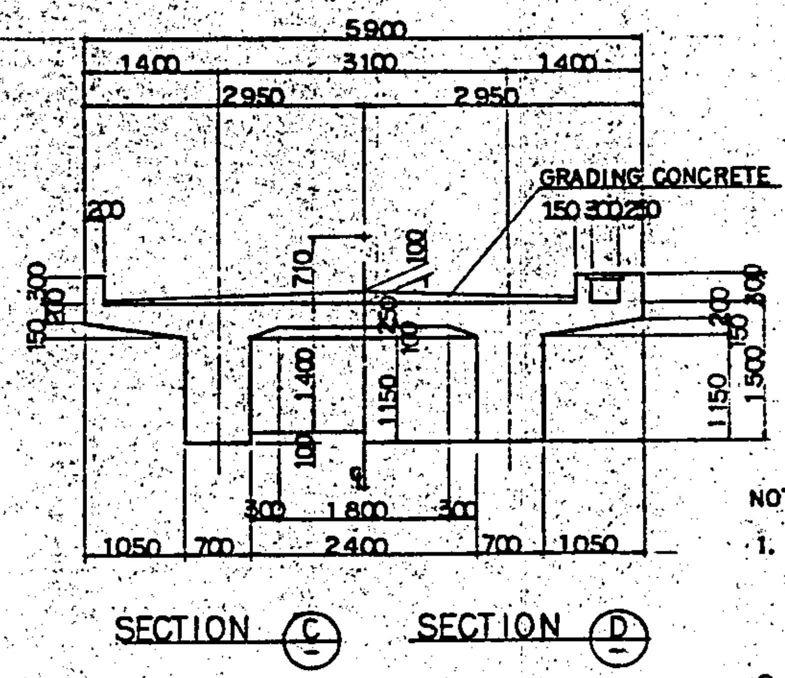
$$ASL = 3.871 \times 6 \times 0.08 \times 1/2 = 0.93 \ cm^2$$

D13 - 2 bars (One side)

§4. R.C. Girder RC103

1. GENERAL VIEW





NOTES;

1. ALL DIMENSIONS ARE SHOWN IN MILLIMETERS UNLESS OTHERWISE INDICATED
2. REFERENCE DRAWING FOR BAR ARRANGEMENT: CS-278~280
3. GRADING CONCRETE SHALL BE SIMULTANEOUSLY PLACED WITH SLAB CONCRETE

DIMENSTON SCHEDULE NO1

	RC103	RC104	RC105	RC106	RC107	RC108	RC109
STA (1)	19K149M254	19K165M254	19K181M254	19K197M254	19K212M254	19K227M254	19K242M254
STA (2)	19K165M254	19K181M254	19K197M254	19K212M254	19K227M254	19K242M254	19K257M254
AZIMUTH ANGLE (θ1)	75°05'10"71	75°05'10"71	75°05'10"71	75°05'10"71	75°05'10"71	75°05'10"71	75°05'10"71
DO (θ2)	〃	〃	〃	〃	〃	〃	〃
U 1	11K615M610	11K600M148	11K584M687	11K569M227	11K554M732	11K540M237	11K525M742
T 1	2K609M662	2K613M780	2K617M898	2K622M016	2K625M876	2K629M737	2K633M597
U 2	11K600M148	11K584M687	11K569M226	11K554M732	11K540M237	11K525M742	11K511M248
T 2	2K613M780	2K617M898	2K622M016	2K625M876	2K629M737	2K633M597	2K637M458
L 1	16000	16000	16000	15000	15000	15000	15000
L 2	15980	15980	15980	14980	14980	14980	14980
L 3	15180	15180	15180	14180	14180	14180	14180
L 4	6490	6490	6490	5990	5990	5990	5990
θ 1	90°00'00"00	90°00'00"00	90°00'00"00	90°00'00"00	90°00'00"00	90°00'00"00	90°00'00"00
θ 2	〃	〃	〃	〃	〃	〃	〃

	RC110	RC111	RC112	RC113	RC114	RC115	RC116
STA (1)	19K257M254	19K273M254	19K289M254	19K305M254	19K321M254	19K336M254	19K352M254
STA (2)	19K273M254	19K289M254	19K305M254	19K321M254	19K336M254	19K352M254	19K366M254
AZIMUTH ANGLE (θ1)	75°05'10"71	75°05'10"71	75°05'10"71	75°05'10"71	75°05'10"71	75°05'10"71	75°05'10"71
DO (θ2)	〃	〃	〃	〃	〃	〃	〃
U 1	11K511M248	11K495M787	11K480M325	11K464M864	11K449M403	11K434M909	11K419M448
T 1	2K637M458	2K641M576	2K645M693	2K649M811	2K653M929	2K657M789	2K661M907
U 2	11K495M787	11K480M325	11K464M864	11K449M403	11K434M909	11K419M448	11K405M919
T 2	2K641M576	2K645M693	2K649M811	2K653M929	2K657M789	2K661M907	2K665M510
L 1	16000	16000	16000	16000	15000	16000	14000
L 2	15980	15980	15980	15980	14980	15980	13980
L 3	15180	15180	15180	15180	14180	15180	13180
L 4	6490	6490	6490	6490	5990	6490	5490
θ 1	90°00'00"00	90°00'00"00	90°00'00"00	90°00'00"00	90°00'00"00	90°00'00"00	90°00'00"00
θ 2	〃	〃	〃	〃	〃	〃	〃

DIMENSION SCHEDULE NO2

	RC117	RC118	RC119	RC120
STA (1)	19K366M254	19K382M254	19K397M254	19K412M254
STA (2)	19K382M254	19K397M254	19K412M254	19K428M254
AZIMUTH ANGLE (θ1)	75°05'10"71	75°05'10"71	75°05'10"71	75°05'10"71
DO (θ2)	〃	〃	〃	〃
U 1	11K405M919	11K390M458	11K375M964	11K361M469
T 1	2K665M510	2K669M628	2K673M489	2K677M349
U 2	11K390M458	11K375M964	11K361M469	11K346M008
T 2	2K669M628	2K673M489	2K677M349	2K681M467
L 1	16000	15000	15000	16000
L 2	15980	14980	14980	15980
L 3	15180	14180	14180	15180
L 4	6490	5990	5990	6490
θ 1	90°00'00"00	90°00'00"00	90°00'00"00	90°00'00"00
θ 2	〃	〃	〃	〃

NOTES:

1. ALL DIMENSIONS ARE SHOWN IN MILLIMETERS UNLESS OTHERWISE INDICATED
2. REFERENCE DRAWING FOR GENERAL VIEW: CS-276

2. Calculation of slab

(Note)

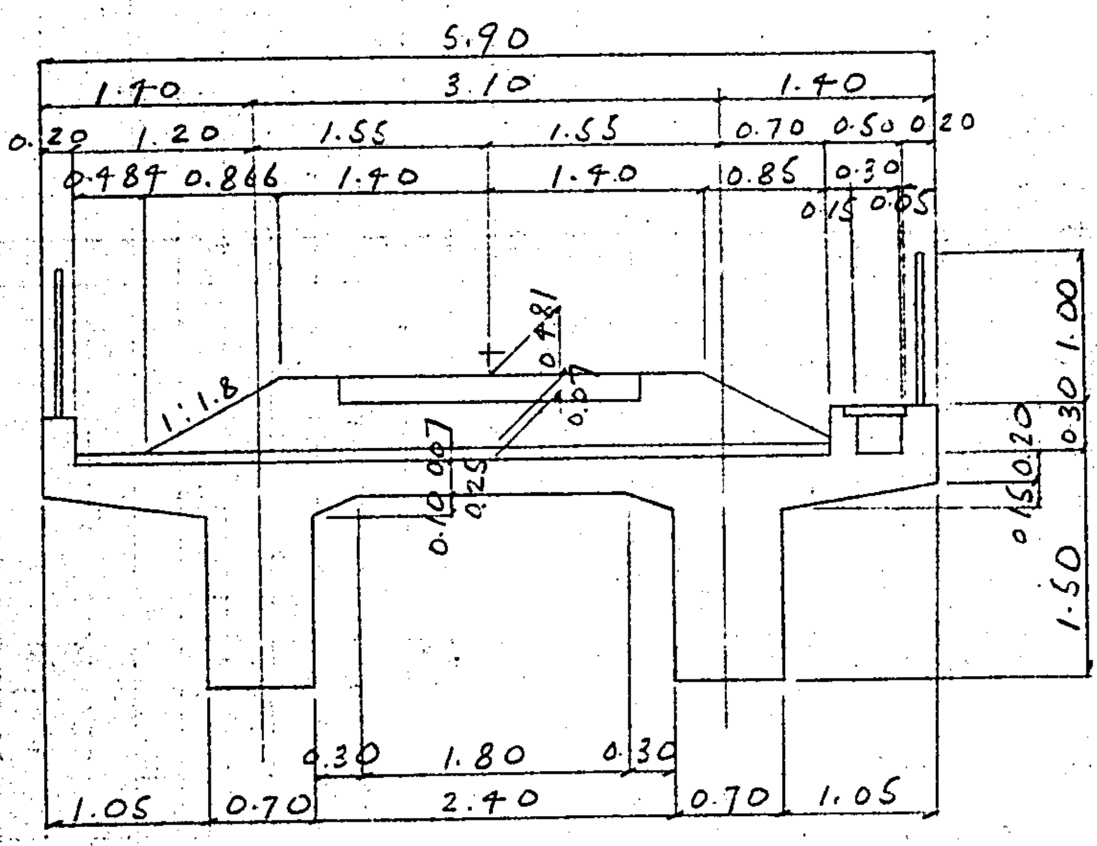
Referred to the Rahmen viaduct

3. Calculation of main beam

$L = 15.98^m$ $l = 15.18^m$

Cross beam at end part $U_0 = 0.70^m$ Cross beam at intermediate part $U_1 = 0.40^m$

1. Weight of elments on the slab

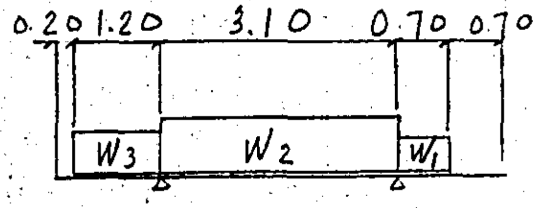


(1) Concentrated loads

Curb and Handrail (left)	$2.50^{t/m^3} \times 0.20 \times 0.30 + 0.20$	$= 0.35^{t/m}$
Curb (right)	$2.50 \times 0.25 \times 0.30$	$= 0.19$ "
Handrail (right)		$= 0.20$ "
Ballast stopper (right)	$2.50^{t/m^3} \times 0.15 \times 0.30$	$= 0.11$ "
Duct cover (right)	$2.50 \times 0.05 \times 0.30$	$= 0.04$ "

Cable (right) = 0.06 t/m

(2) Weight of elements on the slab except track weight



$W_1 = 1.90^{t/m^3} \times (0.481 + 0.009) \times 1/2 = 0.63^{t/m}$

$W_2 = 1.90'' \times 0.481 = 1.08''$

$W_3 = 1.90'' \times 0.481 \times 0.866 \times 1/2 \times 1/0.866 = 0.46''$

(3) Various dead loads on slab, with their acting eccentricity

	Calculation	N (t/m)	x (m)	N·x (t·m/m)
Track weight	——	0.450	——	——
Ballast	1.90 t/m³ × 0.481 × 2.80	2.559	——	——
do	1.90 × 0.481 × 0.866 × 1/2	0.396	-1.689	-0.669
do	1.90 × 0.85 × 0.472 × 1/2	0.381	1.683	0.641
do	1.90 × 0.85 × 0.009	0.015	1.825	0.027
Sloping concrete	2.35 × 5.00 × 0.07	0.823	-0.250	-0.206
Handrail (left)	——	0.200	-2.850	-0.570
do.	——	0.200	2.850	0.570
Curb (left)	2.50 t/m³ × 0.30 × 0.20	0.150	-2.850	-0.428
do (right)	2.50 × 0.30 × 0.25	0.188	2.825	0.531
Ballast stopper	2.50 × 0.30 × 0.15	0.113	2.325	0.263
Duct cover	2.50 × 0.050 × 0.30	0.038	2.550	0.097
Cable	——	0.060	2.550	0.153
Total		ΣN = 5.573		ΣN·x = 0.409 t

$$e = \frac{\Sigma N \cdot x}{\Sigma N} = \frac{0.409}{5.573} = 0.074^{m}$$

2 Train load

KS-16 $\quad l = 15.18^{m}$

Bending moment

$M_a = 60.69 \times 2 \times 16/18 = 107.89^{t}$

$M_b = 101.92 \times 2 \times$ 〃 $= 181.19$ 〃

$M_c = 124.54 \times 2 \times$ 〃 $= 221.40$ 〃

$M_d = 130.63 \times 2 \times$ 〃 $= 232.23$ 〃

$M_E = 131.43 \times 2 \times$ 〃 $= 233.65$ 〃

Shearing force

$S_A = 41.13 \times 2 \times 16/18 = 73.12^{t}$

$S_a = 31.98 \times 2 \times$ 〃 $= 56.85$ 〃

$S_b = 24.32 \times 2 \times$ 〃 $= 43.24$ 〃

$S_c = 17.40 \times 2 \times$ 〃 $= 30.93$ 〃

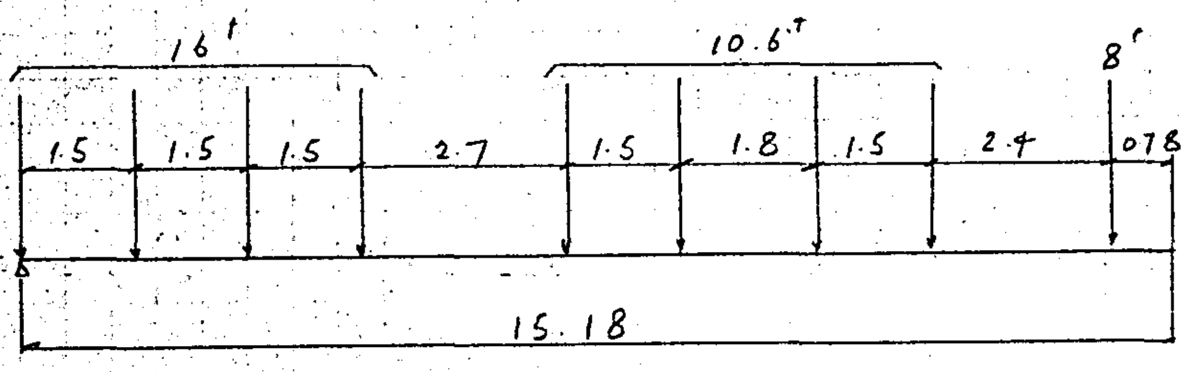
$S_d = 11.28 \times 2 \times$ 〃 $= 20.05$ 〃

3 Train lateral load

$$S = \frac{4 \times 16 \times 0.15}{15.18} = 0.63^{t/m}$$

$y = 0.748^{m}$

4 Brake load or Traction load



Brake load

$H_1 = (16 \times 4 + 10.6 \times 4 + 8) \times 0.15 = 17.16^t$

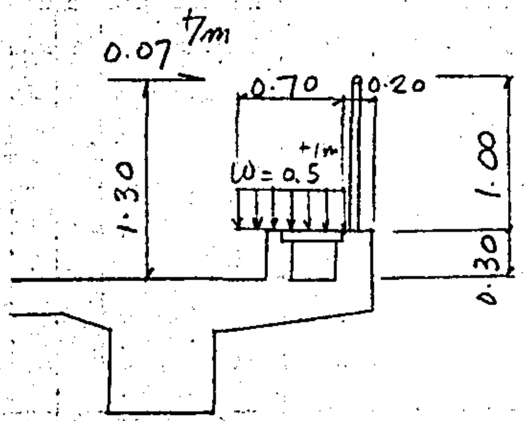
Traction load

$H_2 = 16 \times 4 \times 0.25 = 16.0^t < H_1$

Hence,

$H = 17.16^t$

5 Sidewalk live load and lateral thrust load



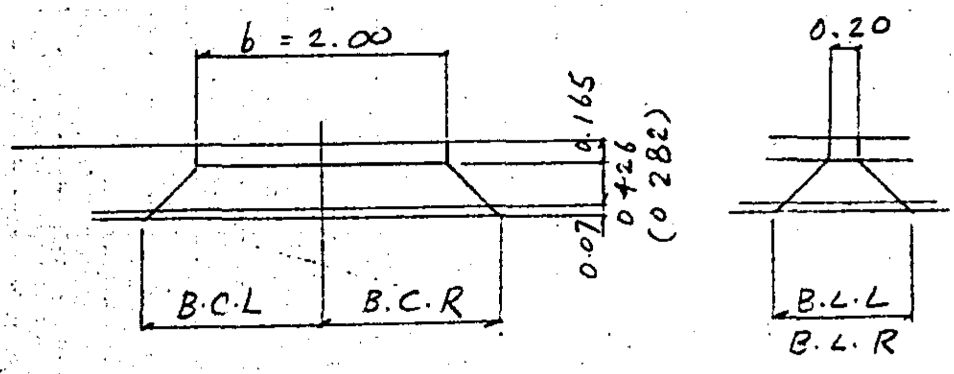
Sidewalk live load

0.5 t/m^2

Lateral thrust load : 0.07 t/m^2

$w = 0.5 \times 0.70 = 0.35$ t/m

6 Effective width



$B.C.L = 1.00 + 1.5 \times (0.316 + 0.07) \times 1/2 = 1.290^m$

$B.C.R = 1.290^m$

$B.L.L = 0.20 + 1.5 (0.316 + 0.07) = 0.779^m$

$B.L.R = 0.779^m$

SIMPLE BEAM INPUT DATA *Input data*

```
KENMEI                R.C GIRDER L=15.18 (KS-16)                                                   11/30/83
CASE      0           KETA NO SHURUI    TAN T GETA         KAJYU NO SHURUI    KS-16
KATAMOCHIBAN NO TYPE  LEFT   T3         RIGHT  T3          YOKOBARI HONSU     -0

     DANMEN SHOGEN                       BANJYO KAJYU                                  KATSU KAJYU NI      KYOYOORYOKUDO
                                                                                      YORU DANMENRYOKU    WARIMASHIKEISU
 KEIJYO SUNPO        OORYOKU KEISAN        KAJYU            SAYOICHI       SAIKAHABA

SMALL.B0     .700   KS.NP          16  SMALL.W0    .450   XW0   0.000                   MA   107.890   SHIGUMA.SAU1 20000.
SMALL.B1    1.050                      SMALL.W1    .630                  B1     .350    MB   181.190   SHIGUMA.SAU2 20000.
SMALL.B2     .000   THETA      90.000  SMALL.W2   1.080                  B2     .850    MC   221.400   SHIGUMA.SAU3 20000.
SMALL.B3    1.050                      SMALL.W3    .460                                 MD   232.230
SMALL.B4     .000   SMALL.A     1.500                               DELTA.C  0.000      ME   233.650   SHIGUMA.CAU1   900.
SMALL.B5     .300   SMALL.B     2.000
SMALL.B6    1.800    BLR         .779    NR1       .190   XR1    .925             SMALL.E     .454      TAU.AL1        39.
SMALL.B7   -0.000    BLL         .779    NR2       .200   XR2    .950                                   TAU.AL2        39.
SMALL.B8   -0.000    SCR        1.290    NR3       .110   XR3    .425                  SAA    73.120      TAU.AL3        39.
                     BCL        1.290    NR4       .100   XR4    .650                  SA     56.850      TAU.AU1       170.
SMALL.H0    1.500                        NR5      0.000   XR5   0.000                  SB     43.240      TAU.AU2       170.
SMALL.H1     .200   GAMMA.C     2.500    NL1       .350   XL1    .950                  SC     30.930      TAU.AU3       221.
SMALL.H2    0.000                        NL2      0.000   XL2   0.000                  SD     20.050
SMALL.H3     .150   SMALL.BE0A  1.050    NL3      0.000   XL3   0.000                                   ALPHA.1      1.000
SMALL.H4     .200   SMALL.BE0B  1.050    NL4      0.000   XL4   0.000                                   ALPHA.2      1.000
SMALL.H5    0.000                        NL5      0.000   XL5   0.000                                   ALPHA.3      1.150
SMALL.H6     .150   DD1.DASHU    .025                                                                   ALPHA.4      1.150
SMALL.H7     .250   DD2.DASHU    .030    NDD      5.573   XDD    .074                                   ALPHA.5      1.250
SMALL.H8     .100                                                                                       ALPHA.6      1.000
SMALL.H9     .050   P.DASHU/P  -0.000    NCR1      .350   XCR1   .475                                   ALPHA.7      1.000
SMALL.H10  -0.000                        NCR2     0.000   XCR2  0.000                                   ALPHA.8      1.150
SMALL.H11  -0.000   T-DANMEN        0    NCR3     0.000   XCR3  0.000
SMALL.H12  -0.000                        NCR4     0.000   XCR4  0.000                                   DELTA.A    800.000
                     N              5    NCR5     0.000   XCR5  0.000
DELTA.H      .050    BEHTA     45.000    NCL1     0.000   XCL1  0.000
DELTA.HD     .050                        NCL2     0.000   XCL2  0.000
HDMAX       1.500    EHTA           0    NCL3     0.000   XCL3  0.000
SMALL.L    15.160                        NCL4     0.000   XCL4  0.000
      L    15.980    E1      .270E+07    NCL5     0.000   XCL5  0.000
SMALL.L1    7.590    E2      .270E+07
SMALL.L2    7.590                         HCR      .070   YC    1.300
SMALL.L3   -0.000   GUZAI       1.000     HCL      .070
SMALL.L4   -0.000
SMALL.L5   -0.000   D22MIN       .059    NKR1     0.000   XKR1  0.000
                    D25MIN       .063    NKR2     0.000   XKR2  0.000
SMALL.U0     .700   D29MIN       .073    NKL1     0.000   XKL1  0.000
SMALL.U1     .400   D32MIN       .080    NKL2     0.000   XKL2  0.000
                                          HWR     0.000   YW    0.000
                                          HWL     0.000
                                                          XL    0.000
                                           S       .630   YS     .748
                                        ALPHA.F   0.000   YF    0.000
                                          BR.L   17.160   YBRL   .748
                                          TR.L    0.000   YTRL -0.000
                                          LONG    0.000   YLON  0.000
                                           K       .100
```

SHUBARI NO KEISAN   *Calculation of main girder*

KAJYUKEISAN OYOBI KAJYUSAYOICHI

SHIKAJYU	WD = 14.742 t/m	SMALL.	E(D) = .028		
YOKOBARI	WDF = 2.490				
KATSUKAJYU	WL = 5.387	SMALL.	E(L) = 0.000	SMALL.	E(D.L) = .018
SHOEEKIKEISU	I = .399				
SHOEEKIKAJYU	WI = 3.346	SMALL.	E(L.LI) = 0.000	SMALL.	E(D.L.LI) = .016
YOKOKAJYU	S = .630	SMALL.E(L.LI.F.S) = .040		SMALL.E(D.L.LI.F.S) = .033	

NEJIRIKEISU NO KEISAN

YO = .520
I = .34572
IS = .00533
IT = .14574
K = .40836
KD = .40836
K1 = .56315
K2 = -.13168
KT = .82559

BUNPUHABA SMALL.B 2OASHU = 2.960

BUNPUKAJYU	SAIKAHABA	SHOGEKIKEISU
SMALL. W6 = .151	B 7 = 0.000	
	B 8 = 0.000	
SMALL. WL3 = 2.815		
SMALL. WLI6 = 0.000	B13 = 0.000	LI6 = 0.000
SMALL. WLI7 = 0.000	B14 = 0.000	LI7 = 0.000
SMALL. WLI8 = 1.479	RAMDA = 3.100	LI8 = .526
SMALL. WLI9 = 0.000	B15 = 0.000	LI9 = 0.000
SMALL.WLI10 = 0.000	B16 = 0.000	LI10 = 0.000

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DANMENRYOKU NO KEISAN *Bending Moment*

MAGE MOMENT NO SOKATSU

	D	L.LI	L.LI.F.S	CASE 6 D.L.LI	CASE 8 D.L.LI.F.S	CASE 6 ALPHA 6	CASE 8 ALPHA 8
A BARI							
MA	54.75	75.46	76.26	170.22	171.02	170.22	148.71
MB	162.77	126.74	128.08	289.51	290.85	289.51	252.91
MC	204.05	154.86	156.50	358.91	360.55	358.91	313.52
MD	218.60	162.44	164.15	381.04	382.76	381.04	332.83
ME	217.55	163.43	165.16	380.98	382.71	380.98	332.79
B BARI							
MA	93.38	75.46	74.67	168.85	168.05	168.85	146.13
MB	160.42	126.74	125.39	287.16	285.82	287.16	248.54
MC	201.12	154.86	153.22	355.98	354.34	355.98	308.12
MD	215.47	162.44	160.72	377.91	376.19	377.91	327.12
ME	214.44	163.43	161.70	377.87	376.14	377.87	327.07

SENDANRYOKU NO SOKATSU *Shearing Force*

	D	L.LI	L.LI.F.S	CASE 6 D.L.LI	CASE 8 D.L.LI.F.S	CASE 6 ALPHA 6	CASE 5 ALPHA 8
A BARI							
SAA	56.98	51.14	51.69	108.12	108.67	108.12	94.49
SAD	54.75	49.68	50.20	104.43	104.96	104.43	91.27
SA	42.89	39.76	40.19	82.66	83.08	82.66	72.24
SB	28.80	30.24	30.56	59.05	59.37	59.05	51.62
SC	14.71	21.63	21.86	36.35	36.58	36.35	31.80
SD	.62	14.02	14.17	14.65	14.80	14.65	12.87
B BARI							
SAA	56.16	51.14	50.60	107.30	106.76	107.30	92.83
SAD	53.96	49.68	49.15	103.64	103.11	103.64	89.66
SA	42.27	39.76	39.34	82.04	81.62	82.04	70.97
SB	26.39	30.24	29.92	56.63	56.31	56.63	50.71
SC	14.51	21.63	21.41	36.14	35.91	36.14	31.23
SD	.62	14.02	13.86	14.65	14.50	14.65	12.81

NEJIRI MOMENT NO SOKATSU *Torsional Moment*

	D	L.LI	L.LI.F.S	CASE 6 D.L.LI	CASE 8 D.L.LI.F.S	CASE 6 ALPHA 6	CASE 8 ALPHA 8
A BARI SHITEN							
HENSHIN	.93	0.00	1.06	.93	1.98	.93	1.73
MOMENT SA	1.33	-18.13	-18.13	-16.81	-16.81	-16.81	-14.62
TOTAL	2.25	-18.13	-17.08	-15.88	-14.83	-15.88	-12.89
SHUBARI NO BUNTAN	1.86	-14.97	-14.10	-13.11	-12.24	-13.11	-10.64
A BARI CHUOTEN							
HENSHIN	0.00	0.00	.29	0.00	.29	0.00	.25
MOMENT SA	.01	-4.97	-4.97	-4.96	-4.96	-4.96	-4.31
TOTAL	.01	-4.97	-4.68	-4.96	-4.67	-4.96	-4.06
SHUBARI NO BUNTAN	.01	-4.11	-3.87	-4.09	-3.85	-4.09	-3.35
B BARI SHITEN							
HENSHIN	.93	0.00	1.06	.93	1.98	.93	1.73
MOMENT SA	-3.06	18.13	18.13	15.08	15.08	15.08	13.11
TOTAL	-2.13	18.13	19.19	16.00	17.06	16.00	14.84
SHUBARI NO BUNTAN	-1.76	14.97	15.85	13.21	14.09	13.21	12.25
B BARI CHUOTEN							
HENSHIN	0.00	0.00	.29	0.00	.29	0.00	.25
MOMENT SA	-.03	4.97	4.97	4.94	4.94	4.94	4.29
TOTAL	-.03	4.97	5.26	4.94	5.23	4.94	4.55
SHUBARI NO BUNTAN	-.03	4.11	4.34	4.08	4.32	4.08	3.75

TAWAMI NO KEISAN *Calculation of deflection*

WD =	14.74	E1 =	.270E+07	I1 =	.69143	SMALL.L =	15.18
ME =	233.65	E2 =	.270E+07	I2 =	.84490	GUZAI =	1.00

DELTA.D = 1/ 2760

DELTA.L = 1/ 6174

TOTAL = 1/ 1917

SHITEN HANRYOKU NO KEISAN

ENCHOKU SHITEN HANRYOKU (REACTION)

	D	L	L.F.S	L.LI	L.LI.F.S	D.E
RA	61.61	38.49	38.49	53.84	53.84	63.66
RB	60.74	38.49	38.49	53.84	53.84	58.70

KYOZIKU CHOKKAKU HOKO NO SUIHEI SHITEN HANRYOKU (1 SHOE ATARI)

HS	3.19
HE	8.17

KYOZIKU HOKO NO TATE KAJYU (1 SYUBARI ATARI) KAJYU SAYO TAKASA

TBR	8.58	YBR	2.248
TTR	0.00	YTR	1.500
TLN	0.00	YLN	1.500
TE	12.25	YE	1.980

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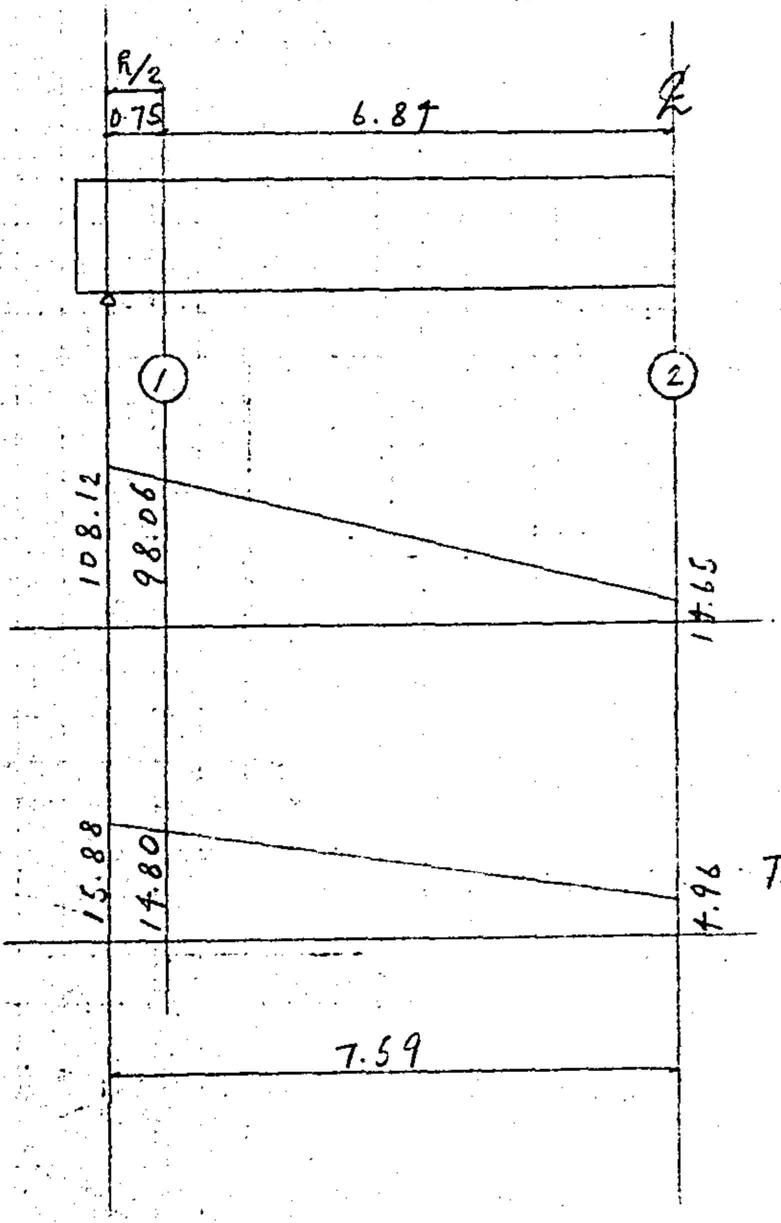
Bending stress		
	Center	
M (tm)	381.04	
N (t)		
S (t)	B = 295 cm	
b (cm)	70	
h (cm)	150	
d (cm)	137.7	
d' (cm)	12.3	
As (cm²)	D32-22 = 174.724	
p	0.00430	
As' (cm²)		
p'		
e=M/N (cm)	x = 45.3 cm	
e=M/N+u (cm)		
e=M/N−u (cm)		
e/h		
d/e		
d' /h		
d' /d		
Ne/bd² (kg/cm²)		
k	0.392	
c		
j	0.921	
1/Lc		
1/Ls		
β=σs/σc		
σc (kg/cm²)	56.3	
σs (kg/cm²)	1720	
τ (kg/cm²)		
σsa (kg/cm²)	1800	
σca (kg/cm²)	90	
τa (kg/cm²)		
	D+T+I	

Calculation of shearing stress



(1) Shearing stress

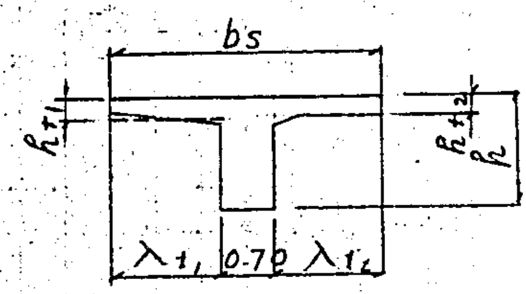
$$\tau = \frac{S}{b \cdot d}$$

$$\tau_1 = \frac{98.06 \times 10^3}{70 \times 137.7} = 10.17 \ ^{kg}/_{cm^2} > 3.9 \ ^{kg}/_{cm^2}$$

$$\tau_2 = \frac{19.65 \times 10^3}{70 \times 137.7} = 1.52 \ '' < \ ''$$

(2) Shearing stress caused by torsional moment

1) Effective width



One side effective width of projected flange subjected to the torsional moment is calculated followed the equation.

$\lambda_t = 3 h_t$

Cantilever part $\lambda_{t1} \leqq l_c$

Intermediate part $\lambda_{t2} \leqq l_b/2$

Where,

λ_t : One side effective width of projected flange (m)

h_t : Thickness of projected flange (m)

l_b : Net clearance between girders $l_b = 2.40^m$

l_c : Projecting length of cantilever slab $l_c = 1.05^m$

$h_{t1} = 0.275^m$ (Average thickness), $h_{t2} = 0.25^m$

$\lambda_{t1} = 3 \times 0.275 = 0.875^{m} < 1.05^{m}$

$\lambda_{t2} = 3 \times 0.25 = 0.75^{m} < \frac{l_b}{2} = 1.20$

Effective height $d = 137.7^{cm}$

2) Shearing stress caused by Torsion on T-section.

Torsional shearing stress is calculated followed the equation.

$$\tau_{ti} = \frac{M_T}{I_t} \times b_i \cdot \eta_i$$

Where,

τ_{ti} : Shearing stress of concrete calculated on each rectangular section (kg/cm^2)

M_t : Torsional moment (kg/cm^2)

b_i : Shorter side of each rectangular section (m)

η_i : Referred table - 40 (2)

I_t : Torsional moment of inertia (cm^4)

$I_t = \Sigma k_i \times a_i \cdot b_i^3$

a_i : Longer side of each rectangular section

k_i : Refferred table - 40 (2)

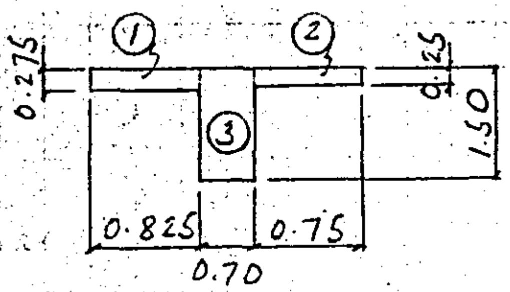
Table - 40 (2) Coefficient η_i

a/b	1.0	1.2	1.5	1.75	2.0	2.5	3.0	4.0	5.0
η_i	0.675	0.759	0.848	0.895	0.930	0.968	0.985	0.997	1.0

Table - 40 (3) Coefficient k_i

a/b	1.0	1.2	1.5	1.75	2.0	2.5	3.0	4.0	5.0
k_i	0.140	0.166	0.196	0.214	0.229	0.249	0.263	0.281	0.292

(a) Torsional moment of inertia



	a (m)	b (m)	a/b	k	$I_t = k \cdot a \cdot b^3$ (m^4)
①	0.825	0.275	3.00	0.263	$0.263 \times 0.825 \times 0.275^3 = 0.00451$
②	0.750	0.25	3.00	0.263	$0.263 \times 0.750 \times 0.25^3 = 0.00308$
③	1.500	0.70	2.143	0.235	$0.235 \times 1.50 \times 0.70^3 = 0.12091$
ΣI_t					0.12850

$$\Sigma I_t = 12.85 \times 10^6 \ cm^4$$

(b) Torsional moment beared by longitudinal beam

$$M_t = M_T \times \frac{I_{t3}}{\Sigma I_t}$$

Support point

$$M_{t0} = 15.88 \times \frac{12.091 \times 10^6}{12.850 \times 10^6} = 14.94^{t \cdot m}$$

h/2 point

$$M_{t1} = 14.80 \times \frac{12.091 \times 10^6}{12.850 \times 10^6} = 13.93$$

Center point

$$M_{t2} = 4.96 \times \frac{12.091 \times 10^6}{12.850 \times 10^6} = 4.67$$

(C) Torsional shearing stress of longitudinal beam

h/2 point

$M_t = 14.80^{t \cdot m}$

$h = 150^{cm}$ $b = 70^{cm}$

$$\frac{h}{b} = \frac{150}{70} = 2.143$$

Table -40 (2) $\eta = 0.941$

$$\tau_{t1} = \frac{14.80 \times 10^5}{12.85 \times 10^6} \times 70 \times 0.941 = 7.59^{kg/cm^2} > 3.9^{kg/cm^2}$$

(d) Combined shearing stress

Torsion is considered.

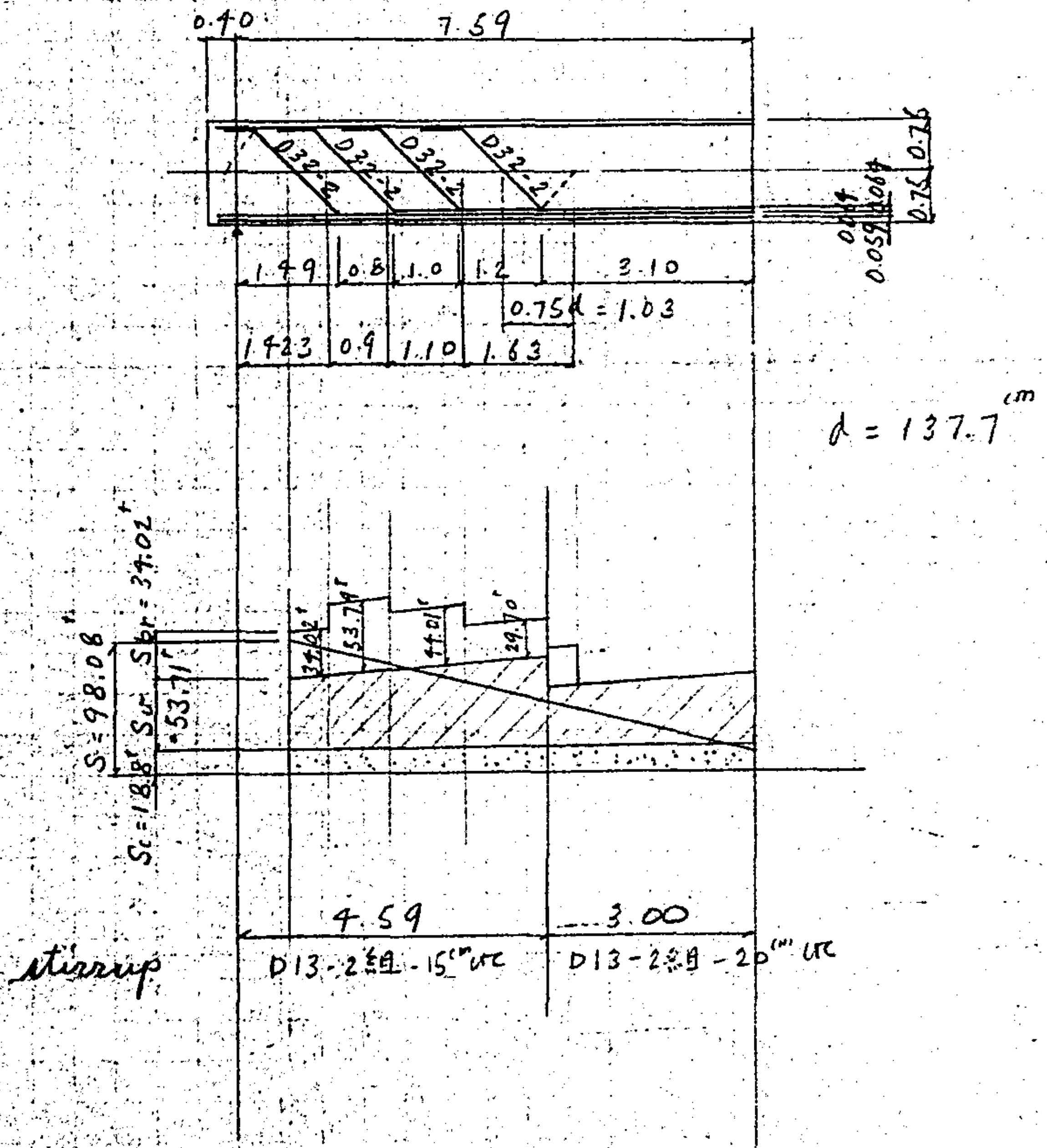
$\tau a = 17 \times 1.30 = 22$ kg/cm²

$\Sigma\tau = 10.17 + 7.59 = 17.76$ kg/cm² < 22 kg/cm²

Calculated as above, diagonal tension re-bars are axamined.

(3) Calculation of diagonal tension re-bars

shering stress caused by bending



$d = 137.7^{cm}$

1) Shearing force beared by concrete

$S_c = 1/2 \times \tau_a \times b \times d$

Where,

S_c : Shearing force beared by concrete (t)

τ_a : $\sigma_{ck} = 240 \, kg/cm^2$ $\tau_c = 3.9 \, kg/cm^2$

b : Width of section of member (cm)

d : Effective height of member

$S_c = 1/2 \times 3.90 \times 70 \times 137.7 \times 10^{-3} = 18.80^t$

2) Shearing force beared by stirrup

i) Torsional shearing stress

$$\sigma_{s1} = \frac{M_t \cdot s}{0.8 \cdot A_v \cdot b_1 \cdot h_1} \times \frac{a_1}{b_1}$$

Where,

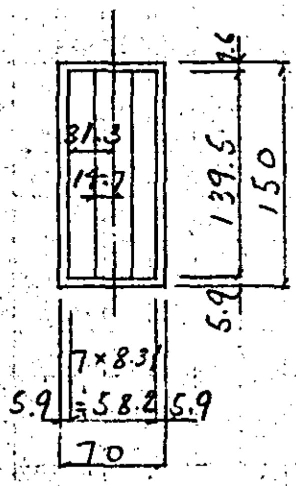
M_t . Torsional moment (t·m)

s : c/c distance of stirrups (cm)

A_v : Gross cross section of coupled stirrup

b_1, h_1 : Length of short/long side of stirrup

a) At the h/2 point



$M_t = 13.93^{t \cdot m}$

Arrange stirrup D13-2 sets in 15^{cm} ctc.

$s = 15^{cm}$

$A_v = 1.267 \times 4 = 5.07^{cm^2}$

$h_1 = 139.5 + 1.6 + 0.8 + 1.3 = 143.2^{cm}$

$$b_1 = \frac{14.7^2 + 31.3^2}{14.7 + 31.3} \times 2 = 52.0^{cm}$$

$$\sigma_{st} = \frac{13.93 \times 10^5 \times 15}{0.8 \times 5.07 \times 52.0 \times 143.2} \times \frac{31.3 \times 2}{52.0}$$

$= 833\ ^{kg}/_{cm^2} < 1800\ ^{kg}/_{cm^2}$

b) At the change point of stirrup

(3.0^m point from center)

$$M_t = \frac{13.93 - 4.67}{6.84} \times 3.00 + 4.67 = 8.73^{t \cdot m}$$

Arrange stirrup D13 - 2 sets in 20^{cm} (15) ctc.

$s = 20^{cm}$

$A_v = 5.07^{cm^2}$

$h_1 = 143.2^{cm}$, $b_1 = 52.0^{cm}$

$$\sigma_{st} = \frac{8.73 \times 10^5 \times \overset{(15)}{20}}{0.8 \times 5.07 \times 52.0 \times 143.2} \times \frac{31.3 \times 2}{52.0}$$

$= \overset{(522)}{696}\ ^{kg}/_{cm^2} < 1800\ ^{kg}/_{cm^2}$

c) At the center point

$M_t = 4.67^{t \cdot m}$

Arrange stirrup D13 - 2 sets in 20 cm ctc.

$s = 20^{cm}$

$A_v = 5.07^{cm^2}$

$h_1 = 143.2^{cm}$, $b_1 = 52^{cm}$

$$\sigma_{st} = \frac{4.67 \times 10^5 \times 20}{0.8 \times 5.07 \times 52.0 \times 143.2} \times \frac{31.3 \times 2}{52.0}$$

$= 372^{kg/cm^2} < 1800^{kg/cm^2}$

ii) Bending shear beared by stirrup

In the case when combined with torsional moment, allowable shearing stress is 20 percent increased.

$\sigma_{sa} = 1800 \times 1.2 = 2160^{kg/cm^2}$

$$S_v = \frac{(\sigma_{sa} - \sigma_{st}) \times A_v \cdot d}{1.15 \times s}$$

a) At the h/2 point

$2160 - 833 = 1327^{kg/cm^2}$

$d = 137.7^{cm}$

$$S_v = \frac{1327 \times 5.07 \times 137.7}{1.15 \times 15 \times 10^3} = 53.71^{t}$$

b) At the change point of stirrup

$$2160 - \overset{(522)}{696} = \overset{(1638)}{1464}\ \mathrm{kg/cm^2}$$

$d = 137.7^{cm}$

$$S_v = \frac{\overset{(1638)}{1464} \times 5.07 \times 137.7}{1.15 \times \underset{(15)}{20} \times 10^3} = \overset{(66.29)}{44.44}\ ^{t}$$

c) At the center point

$$2160 - 372 = 1788\ \mathrm{kg/cm^2}$$

$d = 137.7^{cm}$

$$S_v = \frac{1788 \times 5.07 \times 137.7}{1.15 \times 20 \times 10^3} = 54.28^{t}$$

3) Shearing force beared by turned up bar

$$S_{br} = \frac{\sigma_{sa} \cdot A_s \cdot d(\sin\theta - \cos\theta)}{1.15 \cdot S}$$

Where

σ_{sa} : Allowable Tensile stress of bar (kg/cm²)

A_s : Cross section of turned up bar

$A_s = D32 - 2$本 $= 15.884$ cm²

d : Effective height of member $d = 137.7$ cm

θ : Elevation angle of turned up bar with the axis of member $\theta = 45°$

c : Spacing of turned up bars in axial direction of member (cm)

$$S_{br_1} = \frac{1800 \times 15.884 \times 137.7 \times 1.414}{1.15 \times 1.423 \times 10^5} = 34.02^t$$

$$S_{br_2} = \frac{1800 \times 15.884 \times 137.7 \times 1.414}{1.15 \times 0.90 \times 10^5} = 53.79^t$$

$$S_{br_3} = \frac{1800 \times 15.884 \times 137.7 \times 1.414}{1.15 \times 1.10 \times 10^5} = 44.01''$$

$$S_{br_4} = \frac{1800 \times 15.884 \times 137.7 \times 1.414}{1.15 \times 1.63 \times 10^5} = 29.70''$$

4 Calculation of bars in axial direction

Required bars are calculated fallowed the equation,

$$As = \frac{M_t \cdot (b_1 + h_1)}{0.8 \times \sigma_{sa} \times b_1 \times h_1}$$

Where,

As : Bars in axial direction

M_t : Torsional moment

σ_{sa} : Allowable stress of bar

$b_1 \cdot h_1$: Langth of shoreter/longer side stirrup

$M_t = 14.94^{t \cdot m}$

$\sigma_{sa} = 1800^{kg/cm^2}$

$b_1 = 31.3 \times 2 = 62.6^{cm}$

$h_1 = 143.2^{cm}$

$$As = \frac{14.94 \times 10^5 (62.6 + 143.2)}{0.8 \times 1800 \times 62.6 \times 143.2} = 23.82^{cm^2}$$

Required bar arrangement for longer side

$$As_{h1} = 23.82 \times \frac{143.2}{(62.6 + 143.2) \times 2} = 8.29^{cm^2}$$

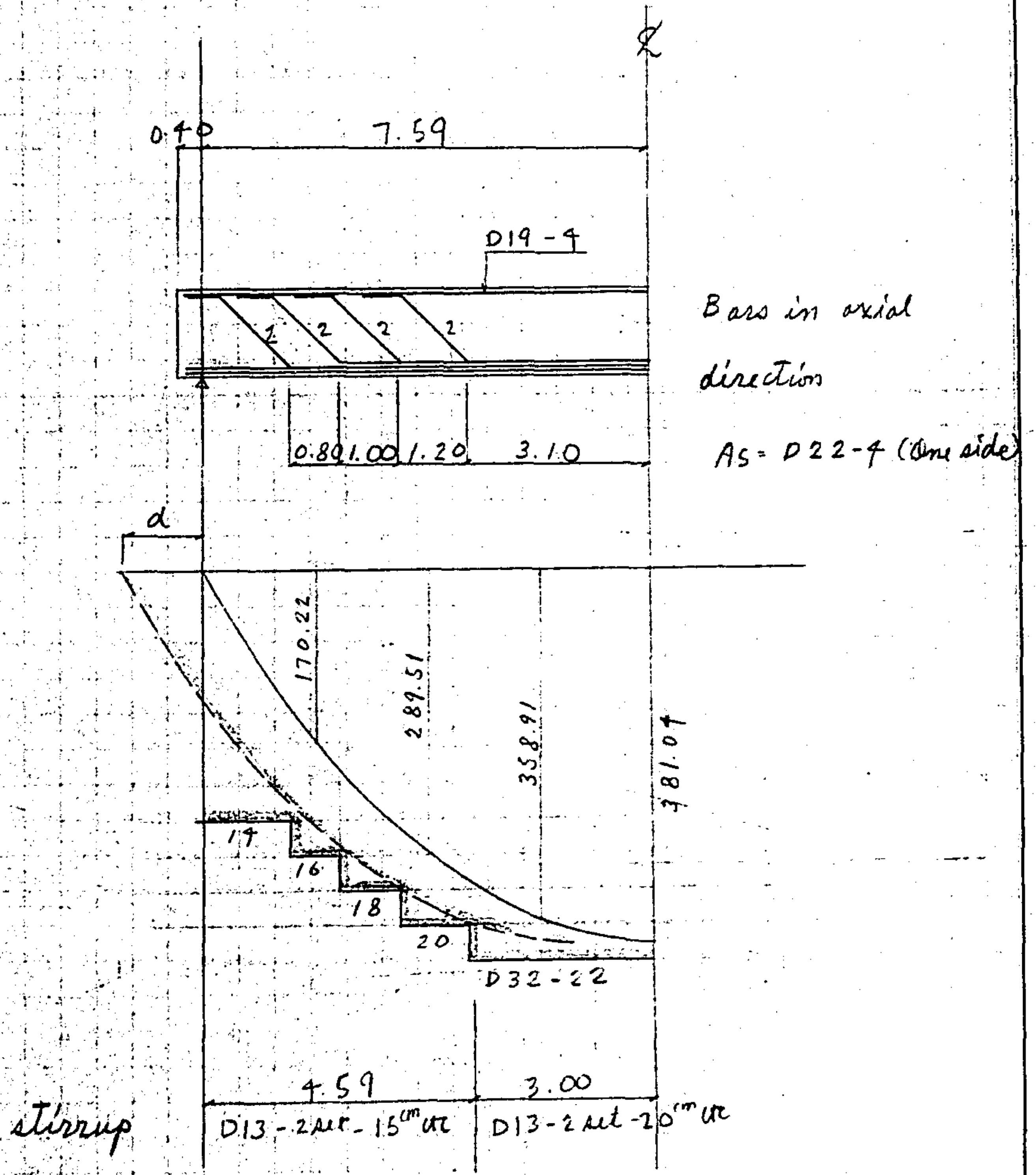
Section of bars calculated as 8% of main bars

$As = D32 - 22 \times 0.8 = 174.724 \times 0.08 = 13.98^{cm^2}$

Hence,

$As = D22 - 4 = 15.48^{cm^2} > 13.98^{cm^2}$

Resisting moment diagram

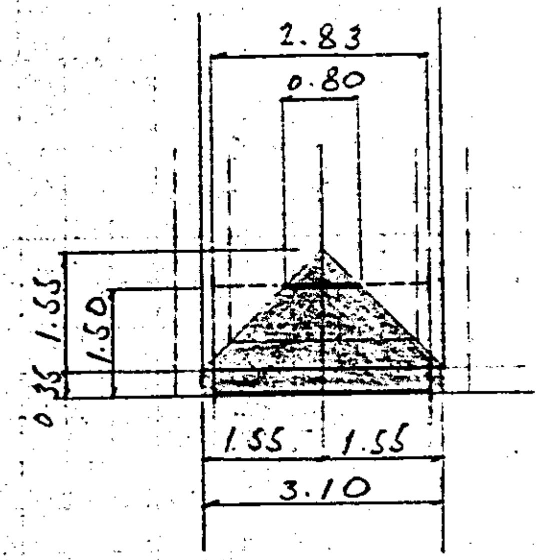


4. Calculation of cross beam

(1) Cross beam at end part

1 Calculation of load

(i) Dead load



Both ends simpl beam.
Span is the distance
between main beam centers

1) Distributed load

From the slab calculation.

a) Dead load

$w = 1.86\ ^{t/m^2}$

$w_{d1} = 1.86 \times 1.55 = 2.88\ ^{T/m}$

b) One weight of cross beam and weight of slab haunch

$w_d = 2.50 \times (0.70 \times 1.25 + 0.10 \times 0.3 \times 1/2) = 2.23\ ^{T/m}$

$w_d = 1.86 \times 0.35 \qquad = 0.65$

$\qquad 2.88\ ^{t/m}$

(2) Train load + Impact

KS - 16

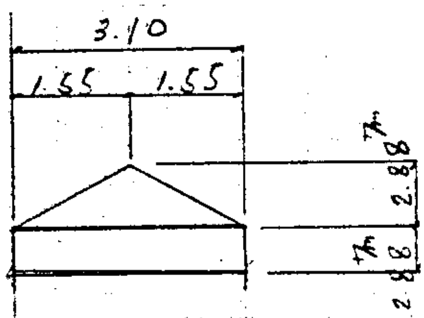
$$w_l = \frac{16}{2.83} = 5.65^{T/m}$$

$$l = 3.10^m \quad i = 0.526$$

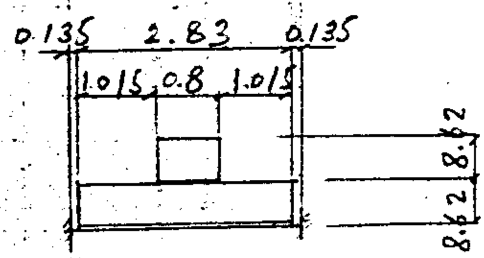
$$w_{l+i} = 5.65 \times 1.526 = 8.62^{T/m}$$

2 Loading diagram

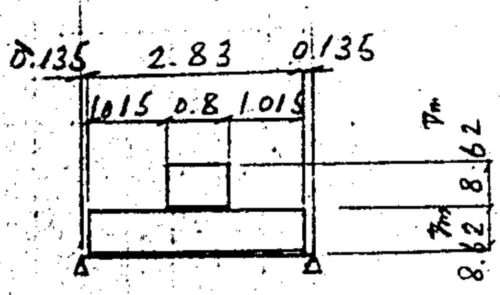
(1) Dead load case 1



(2) Train load - Impact (1) case 2



(3) Train load + Impact (2) case 3



SIDE BEAM [CRC547 RAHMEN]

** CONTROL DATA **

SETTEN SU	2
BUZAI SU	1
SHITEN SU	2
KIHON KAJYU CASE SU	3
KUMIAWASE CASE SU	0
PICK UP CASE SU	0
BUNPU BANE TYPE SU	0
SUPPORT TYPE SU	2

** JOINT DATA **

PT.	X(M)	Y(M)
1	0.000	0.000
2	3.100	0.000

** MEMBER DATA **

K	ITAN	JTAN	IP	JP	L (M)	A(M2)	I(M4)	E(T/M2)	EPS
1	1	2	0	0	3.1000	1.000000	1.000000	.2700E+07	.1000E-04

** SUPPORT TYPE **

<TYPE NO. 1>

SUPPORT	KX (T/M)	KY (T/M)	KZ (T-M/RAD)
1	0.	0.	0.
2	0.	0.	0.

<TYPE NO. 2>

SUPPORT	KX (T/M)	KY (T/M)	KZ (T-M/RAD)
1	1.	0.	1.
2	0.	0.	1.

** CHAKUMOKU TEN DATA & LENGTH **

MEMBER	I-DISTANCE						
1	0.000	.350	.800	1.550	2.300	2.750	3.100

KIHON KAJYU CASE 1
BUNPU BANE TYPE NO. 1
SUPPORT TYPE NO. 1
LOAD TITLE D

[SW]	[NN]	[LL]	[A]	[B]	[C]	[D]
4	1	2	-2.880	-5.760	0.000	1.550
4	1	2	-5.760	-2.880	1.550	1.550

KIHON KAJYU CASE 2
BUNPU BANE TYPE NO. 1
SUPPORT TYPE NO. 1
LOAD TITLE T+I (1)

[SW]	[NN]	[LL]	[A]	[B]	[C]	[D]
4	1	2	-8.620	-8.620	.135	2.830
4	1	2	-8.620	-8.620	1.150	.800

KIHON KAJYU CASE 3
BUNPU BANE TYPE NO. 1
SUPPORT TYPE NO. 2
LOAD TITLE D+L (2)

[SW]	[NN]	[LL]	[A]	[B]	[C]	[D]
4	1	2	-8.620	-8.620	.135	2.830
4	1	2	-8.620	-8.620	1.150	.800

R E A C T I O N

CASE 1 D

SUPPORT	X (TON)	Y (TON)	Z (TON.M)
1	0.000	6.696	-3.748
2	0.000	6.696	3.748

CASE 2 T+I (1)

SUPPORT	X (TON)	Y (TON)	Z (TON.M)
1	0.000	15.645	-9.440
2	0.000	15.645	9.440

CASE 3 D+L (2)

SUPPORT	X (TON)	Y (TON)	Z (TON.M)
1	0.000	15.645	0.000
2	0.000	15.645	0.000

D E F L E C T I O N

CASE 1 D

JOINT	X (MM)	Y (MM)	Z (M.RAD)
1	0.000	0.000	0.000
2	0.000	0.000	0.000

CASE 2 T+I (1)

JOINT	X (MM)	Y (MM)	Z (M.RAD)
1	0.000	0.000	0.000
2	0.000	0.000	0.000

CASE 3 D+L (2)

JOINT	X (MM)	Y (MM)	Z (M.RAD)
1	0.000	0.000	-.005
2	0.000	0.000	.005

SIDE BEAM CCRC547 RAHMEN]

M E M B E R F O R C E

CASE 1 D

I	---L(M)---	---B.M(T.M)---	---S.F(T)---	---A.F(T)---
* * MEMBER 1 (1 - 2) * *				
1	0.000	-3.748	6.696	0.000
	.350	-1.594	5.574	0.000
	.800	.529	3.797	0.000
	1.550	2.018	-.000	0.000
	2.300	.529	-3.797	0.000
	2.750	-1.594	-5.574	0.000
2	3.100	-3.748	-6.696	0.000

CASE 2 T+I (1)

I	---L(M)---	---B.M(T.M)---	---S.F(T)---	---A.F(T)---
* * MEMBER 1 (1 - 2) * *				
1	0.000	-9.440	15.645	0.000
	.350	-4.163	13.792	0.000
	.800	1.170	9.913	0.000
	1.550	5.491	0.000	0.000
	2.300	1.170	-9.913	0.000
	2.750	-4.163	-13.792	0.000
2	3.100	-9.440	-15.645	0.000

CASE 3 D+L (2)

I	---L(M)---	---B.M(T.M)---	---S.F(T)---	---A.F(T)---
* * MEMBER 1 (1 - 2) * *				
1	0.000	0.000	15.645	0.000
	.350	5.277	13.792	0.000
	.800	10.610	9.913	0.000
	1.550	14.931	0.000	0.000
	2.300	10.610	-9.913	0.000
	2.750	5.277	-13.792	0.000
2	3.100	0.000	-15.645	0.000

	Top side	Bottom side	
M (t·m)	8.46	16.95	
N (t)			
S (t)			
b (cm)	70	70	
h (cm)	150	150	
d (cm)	142.2	141.7	
d' (cm)	7.8	8.3	Top side (Semi-fixed span)
As (cm^2)	D16-4 = 7.96	D16-4 = 7.96	$M = -3.74 - 9.44 \times 1/2 = -8.46$ t·m
p	0.000799	0.000802	
As' (cm^2)			Bottom side (Simple span)
p'			$M = 2.02 + 14.93 = 16.95$ t·m
e=M/N (cm)			
e=M/N+u (cm)			
e=M/N−u (cm)			
e/h			
d/e			
d'/h			
d'/d			
M/bd^2 (kg/cm^2)	0.60	1.21	
k			
c	—		
j			
l/Lc	14.65	14.63	
l/Ls	1313	1310	
β=σs/σc			
σc (kg/cm^2)	8.8	17.7	
σs (kg/cm^2)	790	1590	
τ (kg/cm^2)			
σsa (kg/cm^2)	1800	1800	
σca (kg/cm^2)	90	90	
τa (kg/cm^2)			
	D+T+I	D+T+I	

Shearing stress

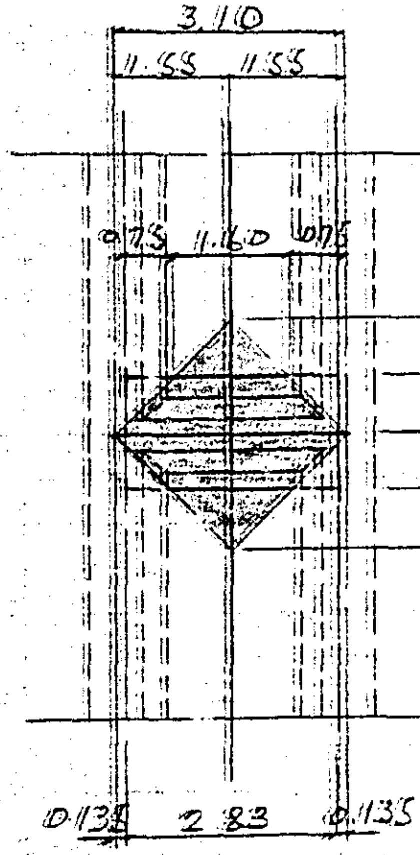
At the $h/2$ point

$S = 13.71$

$$\tau = \frac{13.71 \times 10^3}{70 \times 141.7} = 1.38\ \mathrm{kg/cm^2} < 3.9\ \mathrm{kg/cm^2}$$

Arrange stirrups D13 - 1 set in 20 cm ctc

[2] Cross beam at intermediate part.



Effective width

$b = 2.00 + 1.5 \times (0.316 + 0.07) + 0.25 = 2.83^{m}$

1. Calculation of load

(1) Dead load

Distributed load

Ballast	$1.90^{t/m^3} \times 0.481$	$= 0.91^{t/m^2}$
Weight of slab	2.50×0.25	$= 0.63$ "
Sloping concrete	2.35×0.07	$= 0.16$ "

Track weight 0.45 × 1/2.83 $= 0.16^{t/m}$

$w = 1.86^{t/m}$

$w_{d_1} = 1.86 \times 1.55 \times 2 = 5.77^{t/m}$

Distributed load

Beam of weight $2.50^{t/m^3} \times 0.40 \times 1.15 = 1.15^{t/m}$

Haunch of slab $2.50 \times 0.30 \times 0.1 \times 1/2 \times 2 = 0.08$ "

$w_{d_2} = 1.23^{t/m}$

(2) Train load + Impact

KS - 16

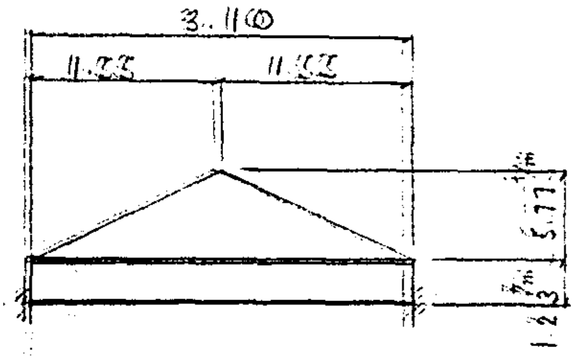
$w_L = \dfrac{16}{2.83} = 5.65^{t/m}$

$l = 3.10^{m}$ $i = 0.526$

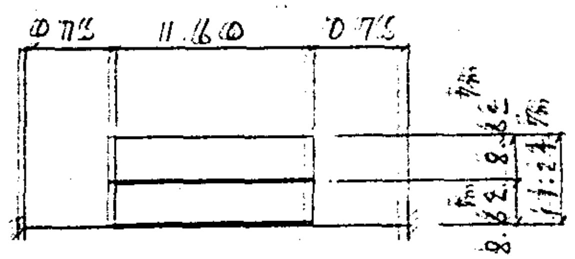
$w_L + i = 5.65 \times 1.526 = 8.62^{t/m}$

2. Loading diagram

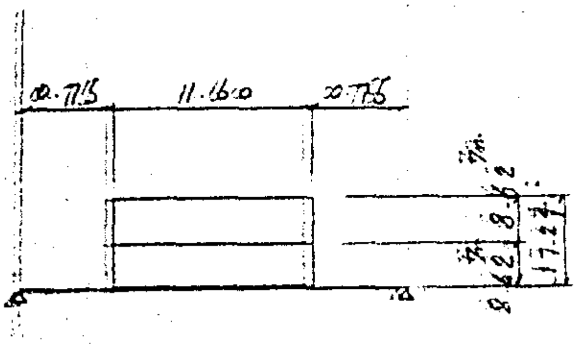
(1) Dead load Case 1



(2) Train load + Impact Case 2



(3) Train load + Impact Case 3



```
** CONTROL DATA **
   SETTEN SU                2
   BUZAI  SU                1
   SHITEN SU                2
   KIHON KAJYU CASE SU      3
   KUMIAWASE   CASE SU      0
   PICK UP     CASE SU      0
   BUNPU BANE TYPE  SU      0
   SUPPORT    TYPE  SU      2

** JOINT DATA **
   PT.            X(M)     Y(M)
   1             0.000    0.000
   2             3.100    0.000

** MEMBER DATA **
   K ITAN JTAN   IP   JP    L (M)       A(M2)        I(M4)       E(T/M2)      EPS
   1    1    2    0    0   3.1000    1.000000     1.000000    .2700E+07   .1000E-04

** SUPPORT TYPE  **

  <TYPE  NO.  1>
   SUPPORT        KX (T/M)         KY (T/M)      KZ (T-M/RAD)
         1              0.               0.                0.
         2              0.               0.                0.

  <TYPE  NO.  2>
   SUPPORT        KX (T/M)         KY (T/M)      KZ (T-M/RAD)
         1              1.               0.                1.
         2              0.               0.                1.


** CHAKUMOKU TEN DATA  &  LENGTH **

   MEMBER            I-DISTANCE
        1   0.000   .350  1.050  1.550  2.050  2.750  3.100
```

KIHON KAJYU CASE 1
BUNPU BANE TYPE NO. 1
SUPPORT TYPE NO. 1
LOAD TITLE D

[SW]	[NN]	[LL]	[A]	[B]	[C]	[D]
4	1	2	0.000	-5.770	0.000	1.550
4	1	2	-5.770	0.000	1.550	1.550
3	1	2	-1.230	0.000	0.000	0.000

KIHON KAJYU CASE 2
BUNPU BANE TYPE NO. 1
SUPPORT TYPE NO. 1
LOAD TITLE L+I (1)

[SW]	[NN]	[LL]	[A]	[B]	[C]	[D]
4	1	2	-17.240	-17.240	.750	1.600

KIHON KAJYU CASE 3
BUNPU BANE TYPE NO. 1
SUPPORT TYPE NO. 2
LOAD TITLE L+I (2)

[SW]	[NN]	[LL]	[A]	[B]	[C]	[D]
4	1	2	-17.240	-17.240	.750	1.600

R E A C T I O N

CASE 1 D

SUPPORT	X (TON)	Y (TON)	Z (TON.M)
1	0.000	6.378	-3.673
2	0.000	6.378	3.673

CASE 2 L+I (1)

SUPPORT	X (TON)	Y (TON)	Z (TON.M)
1	0.000	13.792	-9.740
2	0.000	13.792	9.740

CASE 3 L+I (2)

SUPPORT	X (TON)	Y (TON)	Z (TON.M)
1	0.000	13.792	0.000
2	0.000	13.792	0.000

D E F L E C T I O N

CASE 1 D

JOINT	X (MM)	Y (MM)	Z (M.RAD)
1	0.000	0.000	0.000
2	0.000	0.000	0.000

CASE 2 L+I (1)

JOINT	X (MM)	Y (MM)	Z (M.RAD)
1	0.000	0.000	0.000
2	0.000	0.000	0.000

CASE 3 L+I (2)

JOINT	X (MM)	Y (MM)	Z (M.RAD)
1	0.000	0.000	-.006
2	0.000	0.000	.006

M E M B E R F O R C E

CASE 1 D

I	---L(M)---	---B.M(T.M)---	---S.F(T)---	---A.F(T)---
* * MEMBER 1 (1 - 2) * *				
1	0.000	-3.873	6.378	0.000
	.350	-1.743	5.720	0.000
	1.050	1.428	3.035	0.000
	1.550	2.225	-.000	0.000
	2.050	1.428	-3.035	0.000
	2.750	-1.743	-5.720	0.000
2	3.100	-3.873	-6.378	0.000

CASE 2 L+I (1)

I	---L(M)---	---B.M(T.M)---	---S.F(T)---	---A.F(T)---
* * MEMBER 1 (1 - 2) * *				
1	0.000	-9.740	13.792	0.000
	.350	-4.912	13.792	0.000
	1.050	3.966	8.620	0.000
	1.550	6.121	0.000	0.000
	2.050	3.966	-8.620	0.000
	2.750	-4.912	-13.792	0.000
2	3.100	-9.740	-13.792	0.000

CASE 3 L+I (2)

I	---L(M)---	---B.M(T.M)---	---S.F(T)---	---A.F(T)---
* * MEMBER 1 (1 - 2) * *				
1	0.000	0.000	13.792	0.000
	.350	4.827	13.792	0.000
	1.050	13.706	8.620	0.000
	1.550	15.861	0.000	0.000
	2.050	13.706	-8.620	0.000
	2.750	4.827	-13.792	0.000
2	3.100	0.000	-13.792	0.000

	Top side Bottom side	
M (tm)	13.61	
N (t)		
S (t)		
b (cm)	40	
h (cm)	140	
d (cm)	133.3	
d' (cm)	6.7	
As (cm²)	D16-4 = 7.94	
p	0.00149	
As' (cm²)		
p'		
e=M/N (cm)		
e=M/N+u (cm)		
e=M/N−u (cm)		
e/h		
d/e		
d' /h		
d' /d		
Ne/bd² (kg/cm²)	1.915	
k		
c		
j		
1/Lc	11.23	
1/Ls	717	
β=σs/σc		
σc (kg/cm²)	21.5	
σs (kg/cm²)	1370	
τ (kg/cm²)		
σsa (kg/cm²)	1800	
σca (kg/cm²)	90	
τa (kg/cm²)		

(1) Shearing stress

h/2 point

$S = 11.66^{t}$

$$\tau = \frac{11.66 \times 10^3}{40 \times 133.3} = 2.19^{kg/cm^2} < 3.9^{kg/cm^2}$$

Arrange stirrups D13 - 1 set in 20^{cm} ctc

5. Calculation of shoes and beam supporting parts

(1) Calculation of shoes

1 Calculation of load

(1) Dead load

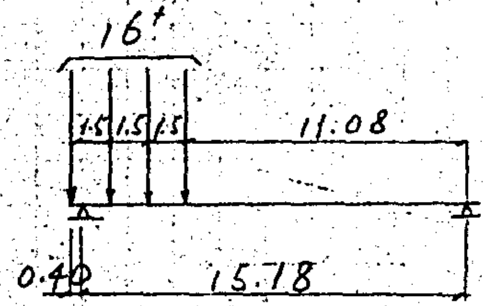
Reaction of T-section simple beam

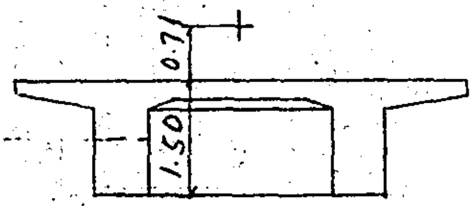
$R = 61.61^t$

(2) Train load + Impact

$R_{l+i} = 53.84^t$

(3) Train lateral load





$$R_A = \frac{1}{15.18} \times 16 \times 4 \times 13.33 = 56.20^t$$

$$H = 56.20 \times 0.15 = 8.43^t$$

$$N = \pm \frac{H \cdot h}{l} = \pm \frac{8.43 \times 2.21}{3.10} = \pm 6.01^t$$

(4) Summary of reactions of beam

		REACTION
Vertical load	Dead	61.61
	Train + Impact	53.84
	Train Lateral	6.01
	D + L + I (α=1.0)	115.95
	D+L+I+TL	121.46
	(α = 1.15)	(105.62)
Horizontal force	Seismic load	11.63

Values in ( ) are the converted figures of ordinary condition.

2. Calculation of rubber shoes

(1) Required area for supporting

$$15 \leqq \frac{R}{A} \leqq 80$$

$R_{max} = 115.95^{t}$ $R_{min} = 61.61^{t}$

$$\frac{R_{max}}{80} \leqq A \leqq \frac{R_{min}}{15}$$

$$\frac{R_{max}}{80} = \frac{115.95 \times 10^3}{80} = 1440^{cm^2}$$

$$\frac{R_{min}}{15} = \frac{61.61 \times 10^3}{15} = 4110$$

Assumed the size of rubber shoe as,

$60^{cm} \times 30^{cm}$

$A = 60 \times 30 = 1800^{cm^2}$

(2) Relative displacement between beam and substructure

(A) Displacement of beam caused by the deflection of beam : Δl_d

i) Calculation of beam deflection

From calculation of T-section simple beam

$E = 2.70 \times 10^6 \ t/m^2$, $I = 0.34572 \ m^4$

(a) Deflection caused by dead load

Uniformly distributed load (From reaction calculation of T-section simple beam)

$$R_d = 123.22 - \overset{\text{(cross beam)}}{5.25} = 117.97^t$$

$$w_d = \frac{117.97}{15.18} = 7.77 \ t/m$$

$$\delta_d = \frac{5 \cdot w_d \cdot l}{384 E \cdot I} = \frac{5 \times 7.77 \times 15.18^4}{384 \times 2.7 \times 10^6 \times 0.34572}$$

$$= 0.00576^m$$

(b) Deflection caused by train load

Maximum bending moment at the center point of span

KS - 16

$$M_l = 233.65 \times 1/2 = 116.83^{t \cdot m}$$

$$\delta_l = \frac{5 \cdot M_l \cdot l^2}{48 E \cdot I} = \frac{5 \times 116.83 \times 15.18^2}{48 \times 2.7 \times 10^6 \times 0.34572}$$

$$= 0.00301^m$$

$\delta_{\ell+i} = 0.00301 \times 1.398 = 0.0042^m$

ii) Displacement of beam caused by bending deflection: Δl_2

a) Dead load

$\Delta l_d = 2 \cdot h \cdot \alpha$

h: Distance from beam bottom to neutral axis

$h = 1.50 - 0.52 = 0.98^m$

α ; Deflection angle of beam at the support point (Radian)

$\delta = 0.00576^m$ (From calculation of T section simple beam)

$l = 15.18^m$ (span)

$$\alpha = \frac{3.2 \times 0.00576}{15.18} = 0.00121$$

$\Delta l_\alpha = 2 \times 98.0 \times 0.00121 = 0.24^{cm}$

(b) Train load

$\delta = 0.00301$

$$\alpha = \frac{3.2 \times \underset{}{\overset{(0.0042)}{0.00301}}}{15.18} = \overset{(0.000885)}{0.000635}$$

Value in ( ) is the case considered impact

$\Delta l_{\alpha \ell} = 2 \times 98.0 \times 0.000635 = 0.124$

$\Delta l_{\alpha \ell + i} = 2 \times 98.0 \times 0.000885 = 0.174$

(B) Displacement of beam caused by temperature change : Δl_t

$\Delta l_t = \Delta t \cdot \alpha \cdot l$

Δt : Temperature change $\pm 20°C$

α : Coefficient of linear expansion of beam $1 \times 10^{-5}/°C$

l : Span $l = 15.18^{m}$

$\therefore \Delta l_t = \pm 20 \times 10^{-5} \times 15.18 = \pm 0.0030^{m} = \pm 0.30^{cm}$

(C) Displacement of beam caused by drying shrinkage : Δl_s

$\Delta l_s = \varepsilon_{cs} \cdot l$

ε_{cs} : Ratio of drying shrinkage of concrete 20×10^{-5}

$\therefore \Delta l_s = 20 \times 10^{-5} \times 15.18 = 0.0030^{m} = 0.30^{cm}$

(D) Displacement in horizontal direction in case of earthquake

Displacement caused by horizontal force in case of earthquake : Δe_1

$$\Delta e_1 = \frac{H \cdot t}{G \cdot A_c}$$

$H = 11.63^{t}$

G : shear modulus $G = 8.0^{kg/cm^2}$

Ac : Area of rubber shoes $A_c = 1800^{cm^2}$

t : Thickness of rubber shoes $t = 32^{mm}$ (Assumed)

$$\Delta e_1 = \frac{11.63 \times 10^3 \times 3.2}{8.0 \times 1800} = 2.58^{cm}$$

Relative displacement between beam and substructure

$\Delta e_2 = 2.0^{cm}$

(E) Required thickness Σt_e

i) Ordinary case

$\Delta m = \Delta l_d + \Delta l_t + \Delta l_s + \Delta l_e$

$= -0.24 - 0.30 - 0.30 = -0.84^{cm}$

$\Sigma t_{e_1} = \frac{\Delta m}{0.7} = \frac{0.84}{0.7} = 1.20^{cm}$

ii) Temporary case

$\Delta m' = \Delta m + \Delta l_{de} = -0.84 - 0.174 = -1.014$

$\Sigma t_{e_2} = \frac{\Delta m'}{0.7} = \frac{1.014}{0.7} = 1.45^{cm}$

iii) Earthquake case

$\Delta E = \Delta l_d + \Delta l_t - \Delta l_s - (\Delta e_1 + \Delta e_2)$

$= -0.84 - 0.30 - 0.30 - (2.58 + 2.0) = -6.02^{cm}$

$\Sigma t_{e_3} = \frac{\Delta E}{2.0} = \frac{6.02}{2} = 3.01^{cm}$

Therefore,

Use $t_e = 16^{mm}$ of two layers

(3) Restricted tortoional strain corresponding to deflection ange at the support point

(a) $\Sigma \Delta te > \frac{a}{2} \tan \alpha$

$\Sigma \Delta te$: Avarage deformation of rubber shoe in vertical direction (cm)

a : Side lenght of rubber shoe in direction of bridge akis (cm)

α : Angle between beam bottom face and support face at the support point.

$\Delta te = C_t \cdot \frac{f}{G} \cdot \frac{te^3}{a_0^2}$

C_t : Factor determined by the ratio of both side lengthes (From nomiogram)

$\frac{b_0}{a_0} = \frac{60}{30} = 2.00$ then, $C_t = 1.455$

f : Bearing stress of rubber shoe in vertical direction (kg/cm²)

(Dead load) $f_d = \frac{R_d}{A} = \frac{61.61 \times 10^3}{30 \times 60} = 34.23$ kg/cm²

(Trainload + Impact) $f_{T+I} = \frac{R_{T+I}}{A} = \frac{53.84 \times 10^3}{30 \times 60} = 29.91$ "

G : Elastic modulus of rubber shoe in terms of shear (kg/cm²)

Subjected dead load $G = 6.2$ kg/cm²

Subjected live load $G = 8.0$ "

te : Thickness of rubber shoe, $te = 16^{mm}$

$$\Delta ted = 1.455 \times \frac{34.23}{6.2} \times \frac{1.6^3}{30^2} = 0.037^{cm}$$

$$\Delta te_{T+i} = 1.455 \times \frac{29.91}{8.0} \times \frac{1.6^3}{30^2} = 0.025^{cm}$$

Hence,

$$\Delta te = 0.037 + 0.025 = 0.062^{cm}$$

$$\Sigma te = 0.062 \times 2 = 0.124^{cm}$$

$$\alpha = 0.00121 + 0.00089 = 0.0021$$

$$\frac{a \cdot \tan\alpha}{2} = \frac{30 \times 0.0021}{2} = 0.0315 < \Sigma \Delta te = 0.062$$

(b) Maximum deformation in vertical direction : $\Sigma \Delta te\ max$

$$\Sigma \Delta te\ max = \Sigma \Delta te + a \tan\alpha/2$$

$$= 0.062 + 0.0315 = 0.0935$$

$$0.15\ \Sigma te = 0.15 \times 3.2 = 0.48^{cm} > \Sigma \Delta te\ max$$

(4) Sefety analysis in terms of buckling when subjected vertical load

$a \cdot b \geqq 5 \cdot \Sigma te$

$a = 30^{cm},\ b = 60^{cm} > 5 \times 3.2 = 16.0^{cm}$

Analyzed as above, dimensions of rubber shoe are determined as follows.

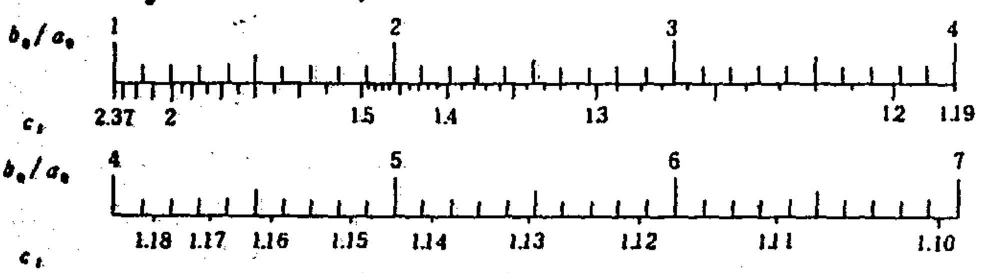
Bridge axis direction $a = 30^{cm}$

Cross sectional direction $b = 60^{cm}$

Thickness of the layer $t = 1.6^{cm}$ Use two layer

Gross thickness 3.5^{cm} (Including stainless steel cover plates)

Nomogram for finding the relation between size ratio of b_0/a_0 and C_t



[2] Calculation of stopper, made of steel rod

1 Horizontal seismic load applied for the stopper design

$Ksh = \Delta 4 \cdot Kh$

$\Delta 4$: Extra factor

In direction of bridge axis $\Delta 4 = 1.2$

In direction of cross section $\Delta 4 = 1.4$

Kh : Horizontal seismic load for design $kH = 0.1$

Horizontal seismic load applied for the stopper design will be,

Bridge axis $Ksh = 1.2 \times 0.1 = 0.12$

Cross section $Ksh = 1.4 \times 0.1 = 0.14$

2 Horizontal force acting the stopper

(1) Bridge axis

(a) Seismic force due to dead weight

$Hsd = Ksh \cdot \Sigma W - 1/2 \cdot Rd \cdot \mu$

$= 0.12 \times 244.70 - 1/2 \times 122.35 \times 0.1$

$= 23.25^{t}$

One unit of steel rod is attatched to one main girder.

$H = 23.25 \times 1/2 = 11.63^{t}$

(2) Cross sectional direction

(a) Train lateral load

$H_T = 8.43 \times 1/2 = 4.22^t$

(b) Seismic load

$H_{sd} = K_{sh} \cdot R_d$

$= 0.14 \times 122.35 = 17.13^t$

$H_E = 17.13 \times 1/2 = 8.57^t$

$\frac{H_T}{\alpha} = \frac{4.22}{1.15} = 3.67^t < \frac{H_E}{\alpha} = \frac{8.57}{} = \underline{5.71}^t$

Hence, analysis is carried out in terms of seismic load.

3. Stress calculation of the stopper made of steel rod

(1) Fixed support side

Analysis is carried out in the direction of railway

1) Shearing stress

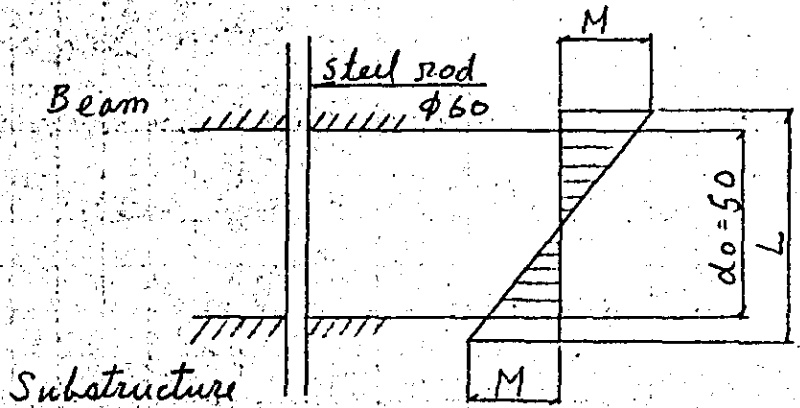
Steel rod $\phi = 60^{mm}$ (SS41) $A_s = 28.27^{cm^2}$

$H = 11.63^t$

$\tau = \frac{H}{A_s} = \frac{11.63 \times 10^3}{28.27} = 410^{kg/cm^2} < 850 \times 1.5$

$= 1275^{kg/cm^2}$

2) Bending stress



$L = d_0 + \frac{1}{2}\phi = 50 + 60 \cdot \frac{1}{2} = 80^{cm}$

$H = 11.63^{t}$

$M = \frac{1}{2} \times H \cdot L$

$= \frac{1}{2} \times 11.63 \times 0.08 = 0.47^{t \cdot m}$

Section modulus $Z = \frac{\pi \cdot \phi^3}{32} = 0.098 \cdot \phi^3$

$\sigma_s = \frac{M}{Z}$

$= \frac{0.47 \times 10^5}{0.098 \times 6.0^3} = 2220^{kg/cm^2} < 1500 \times 1.5$

$= 2250^{kg/cm^2}$

(3) Combined stress

$\sqrt{\left(\frac{\sigma_s}{\sigma_{sa}}\right)^2 + \left(\frac{\tau}{\tau_a}\right)^2} = \sqrt{\left(\frac{2220}{2400}\right)^2 + \left(\frac{410}{1360}\right)^2}$

$= 0.97 < 1.1$

(2) Movable support side

Analysis is carried out in the direction of railway cross section.

1) Shearing stress

Steel rod $\phi = 55^{mm}$ (SS41) $A_s = 23.76^{cm^2}$

$H = 8.57^{t}$

$$\tau = \frac{8.57 \times 10^3}{23.76} = 360^{kg/cm^2} < 850 \times 1.5$$
$$= 1275^{kg/cm^2}$$

2) Bending stress

$L = d_0 + 1/2\ \phi = 50 + 55 \times 1/2 \doteq 78^{cm}$

$H = 8.57^{t}$

$M = 1/2 \times 8.57 \times 0.078 = 0.33^{t \cdot m}$

$$\sigma_s = \frac{0.33 \times 10^5}{0.098 \times 5.50^3} = 2024^{kg/cm^2} < 1500 \times 1.60$$
$$= 2400^{kg/cm^2}$$

3) Combined stress

$$\sqrt{\left(\frac{2024}{2400}\right)^2 + \left(\frac{360}{1360}\right)^2} = 0.88 < 1.1$$