2) Moment of cantilever slab

Pavement $1.1^{t/m^3} \times 0.05 = 0.055^{t/m^2}$

Slab $2.5〃 \times 0.15 = 0.375〃$

〃 $2.5〃 \times 0.10 \times 1/2 = 0.125〃$

$$M = 0.055 \times 1.68^2 \times 1/2 + 0.375 \times 1.43 \times 0.965$$
$$+ 0.125 \times 1.43 \times 0.727 = 0.725^{tm}$$

3) Hence,

Torsional moment acting at the longitudinal beam

$$M_T = (-0.194 + 0.725) \times 9.48 \times 1/2$$
$$= 2.52^{tm}$$

At the l/2 point

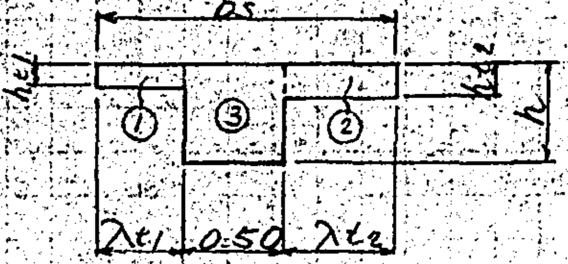
$$M_{T'} = 2.52 \times \frac{4.44}{4.74} = 2.36^{tm}$$

4) Torsional moment, beared by main beam

Effective width

$$bs = b_0 + \lambda t$$

$$\lambda t = 3 \cdot ht$$



Intermediate part

$$\lambda t_1 = 3 \times 0.15 = 0.45^m$$

Cantilever part

$$\lambda t_2 = 3 \times (\overset{0.20}{0.25} + 0.15) \times 1/2$$

$$= 0.60^m$$

$$bs = 0.50 + 0.45 + 0.60 = 1.55^m$$

Calculation of distribution ratio

	a	b	a/b	k	$I_t = k \cdot a \cdot b^3$ (m^4)
①	0.45	0.15	3.000	0.263	$0.263 \times 0.45 \times 0.15^3 = 0.00040$
②	0.60	0.20	3.000	0.263	$0.263 \times 0.60 \times 0.15^3 = 0.00053$
③	0.60	0.50	1.200	0.166	$0.166 \times 0.60 \times 0.50^3 = 0.01245$
Total					$\Sigma I_t = 0.01338$

Torsional moment beared by the beam

(h/2 point) $M_t = 2.36 \times \dfrac{0.01245}{0.01338} = 2.20^{tm}$

5) Shearing stress caused by torsion

Shearing stress caused by torsion is calculated followed the equation

$$\tau_t = \frac{M_t}{I_t} \, b \cdot \eta$$

b : Shorter side length

a : longer side length

k : Table – 40.2

At the $l/2$ point

$M_t = 2.20^{tm}$

$b = 50^{cm}$ $a = 60^{cm}$

$$\frac{a}{b} = \frac{60}{50} = 1.200 \quad \eta = 0.759$$

$$\tau_t = \frac{2.20 \times 10^5}{13.38 \times 10^6} \times 50 \times 0.759 = 0.62 \ ^{kg/cm^2}$$

6) Combined shearing stress

combined allowable shearing stress

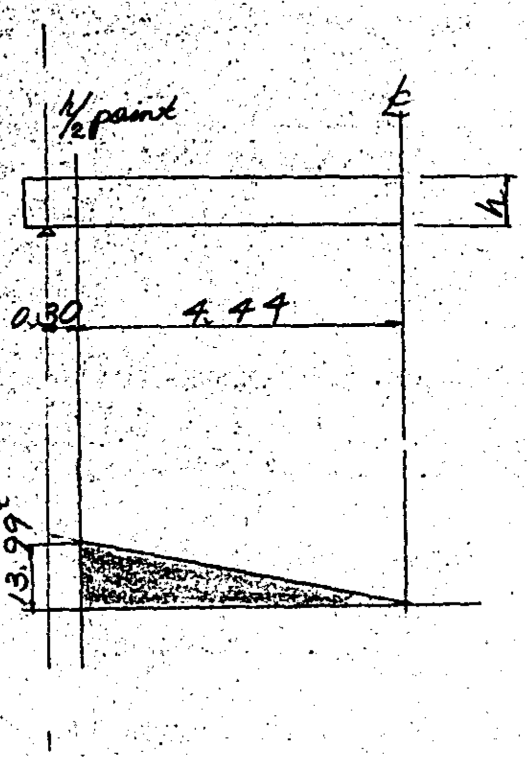
$$\tau_a = 17 \times 1.3 = 22.1 \ ^{kg/cm^2}$$

Combined shearing stress

$$\tau_i = 5.12 + 0.62 = 5.74 \ ^{kg/cm^2} < 22.1 \ ^{kg/cm^2}$$

(1) Calculation of diagonal tension re-bars

Shearing stress caused by bending



Shearing force diagram

a) Shearing stress beared by concrete

$$S_c = 1/2 \cdot \tau_c \cdot b \cdot d$$

where τ_c : 3.9 $^{kg/cm^2}$

b : Width of member (cm)

d : Effective height of member at the examining section.

$$S_{c1} = 1/2 \times 3.9 \times 50 \times 54.7 \times 10^{-3} = 5.33^{t}$$

b) Shearing force beared dy stirrup

Arrange stirrups D13 - 1 Sets in 25.0^{cm} ctc

Torsional shearing stress

$$\sigma_{st} = \frac{Mt \cdot S}{0.8 \cdot Av \cdot b_1 \cdot h_1} \times \frac{a_1}{b_1}$$

Whore

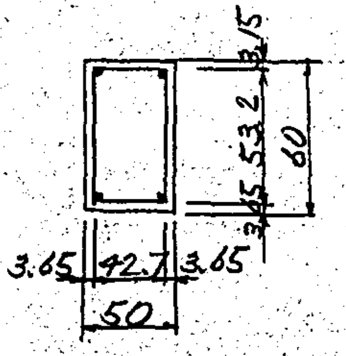
Mt : Torsional moment (tm)

S : ctc distance of stirrup (cm)

Av : Gross cross Sectiom of coupled stirrups (cm²)

b_1, h_1 : length of shont long side of stirrup

- At ℓ/2 point



$Mt = 2.20^{tm}$

$S = 25.0^{cm}$

$Av = 1.267 \times 2 = 2.53^{cm^2}$

$h = 53.2^{cm}$

$b = 42.7^{cm}$

$$\sigma_{st} = \frac{2.20 \times 10^5 \times 25.0}{0.8 \times 2.53 \times 42.7 \times 53.2} = 12.00^{kg/cm^2} < 1800^{kg/cm^2}$$

c) Bending Shear beared by stirrup

In the case When Combined with corsional moment, allowable shearing stress is as 20 percent increased.

$\sigma_{sa} = 1\,800 \times 1.2 = 2\,160$ kg/cm²

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

- At h/2 point

$(2\,160 - 1200) = 960$ kg/cm² $< 1\,800$ kg/cm²

$d = 54.7$ cm

$$S_v = \frac{960 \times 2.53 \times 54.7}{1.15 \times 25 \times 10^3} = 4.62^{t}$$

d) Shear beared by eurned bar

$$F_{ba} = \frac{\sigma_{sa} \cdot A_s \cdot d \cdot (\sin\theta + \cos\theta)}{s}$$

$\sigma_{sa} = 1\,800$ kg/cm²

$A_s = D25 - 2 = 10.13$ cm²

$\theta = \sin\theta + \cos\theta = 45°$ $\quad d = 54.7$ cm

$$F_{ba} = \frac{1800 \times 10.13 \times 54.7 \times 1.414}{1.15 \times 124 \times 10^3} = 9.89^{t}$$

e) Total Shear

$$\Sigma SR = S_a + S_v + S_b$$

$$\Sigma SR = 5.33 + 4.62 + 9.89$$

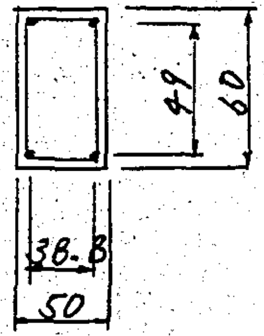
$$= 19.84^t > S = 13.99^t$$

(2) Calculation of axial re-bar arrangement, resisting torsional moment

a) Required re-bar arrangemet is calculated followed the equation.

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

Front face of column



$Mt = 2.20$ tm

$\sigma_{sa} = 1800$ kg/cm²

$b_1 = 38.8$ cm

$h_1 = 49.0$ cm

$$As = \frac{2.20 \times 10^5 \times (38.8 + 49.0)}{0.8 \times 1800 \times 38.8 \times 49.0} = 7.06 \text{ cm}^2$$

Required cross section of re-bars arranged at shorter side

$$Asb_1 = 7.06 \times \frac{38.8}{2(38.8 + 49.0)} = 1.56 \text{ cm}^2$$

b) Required cross section of re-bars arranged at longer side

$$A_{sh1} = 7.06 \times \frac{49.0}{2 \times (38.8 + 49.0)} = 1.97 \text{ cm}^2$$

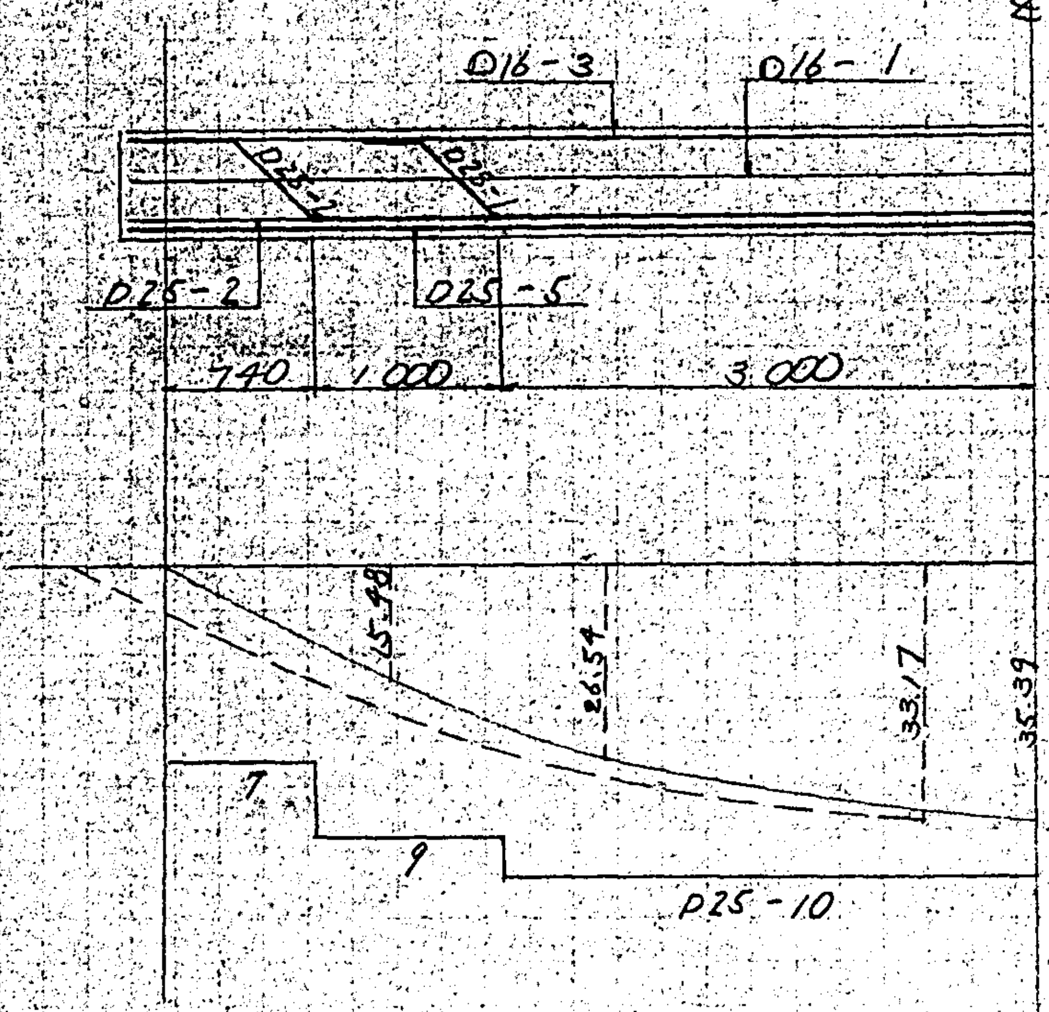
c) Top and Bottom

Minimum section of re-bars

$$A_s = D16 - 1 = 1.99 \text{ cm}^2 > 1.97 \text{ cm}^2$$

Side (one side)

(3) Resisting moment diagram



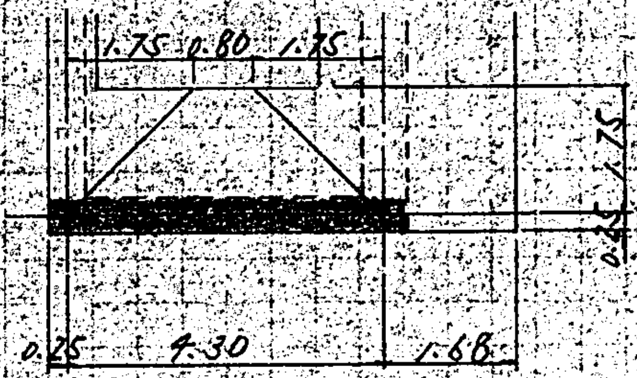
Stirrups D13 - 1 sets in 25.0 ^{cm} ctc

$MR = 1800 \times 0.897 \times 51.3 \times 5.067 \times 10^{-5} = 4.20^{tm}$

$S = 1/40 \quad M = 1/1$

§4. Calculation of Cross beam

(1) Load Calculation



1) Dead load

pavement $1.1\ ^{t}/_{m^3} \times 0.05 = 0.055\ ^{t}/_{m^2}$

Slab $2.5\ '' \times 0.15 = 0.375\ ''$

$0.430\ ^{t}/_{m^2}$

2) pedestrian load

$w = 0.50\ ^{t}/_{m^2}$

3) Dead load + pedestrian load

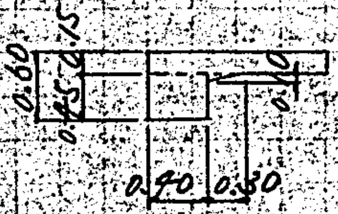
$w = 0.430 + 0.50 = 0.93\ ^{t}/_{m^2}$

4) Uniformly distributed load

$wd_1 = 0.93 \times 1.75 = 1.63\ ^{t}/_{m}$

$wd_2 = 0.93 \times 0.25 = 0.23\ ''$

5) Linear load



$$w_3 = 2.5\,{}^{t}/_{m^3} \times (0.40 \times 0.45$$
$$+ 0.30 \times 0.10 \times 1/2)$$
$$= 0.49\,{}^{t}/_{m}$$

$$w_2 + w_3 = 0.23 + 0.49 = 0.72\,{}^{t}/_{m}$$

(2) Stresses calculation

1) Calculation is made based on the assumption that both supporting slab ends are rigid.

fixed $M_1 = -\frac{1}{12} \times 0.72 \times 4.30^2 = -1.11^{tm}$

$$M_2 = -\frac{1}{12} \times \frac{1}{4.30} \times 1.63 \times 2.55 \times (4.30^2$$
$$+ 1.75^2 + 1.75 \times 0.80) = -1.85^{tm}$$

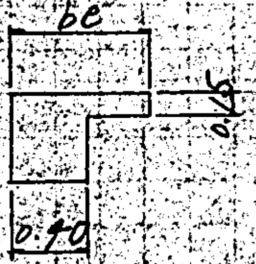
$$\Sigma M = -1.11 - 1.85 = -2.96^{tm}$$

· At the span center point

$$M_1 = (\frac{1}{8} + \frac{1}{24}) \times 1/2 \times 0.72 \times 4.30^2 = 1.11^{tm}$$
$$M_2 = \frac{1.63}{24} \times (3 \times 4.30^2 + 4 \times 1.75^2) = 4.60\ ''$$
$$M_2' = \frac{1}{24} \times \frac{1}{4.30} \times 1.63 \times (4.30^3 - 2 \times 1.75^3) = 1.09\ ''$$

$$\Sigma M = 1.11 + (4.60 + 1.09) \times 1/2 = 3.96^{tm}$$

· Stress Calculation



Effective width

$$be = 0.50 + 0.10 + \frac{0.6 \times 4.30}{8}$$

$$= 0.92^{m}$$

2) Required minimun cross section of re-bars

(i) At the top of support point

$$As = \frac{M}{fsa \cdot j \cdot d} \times \frac{4}{3} = \frac{2.96 \times 10^5}{1800 \times 0.875 \times 52.5} \times \frac{4}{3}$$

$$= 4.77^{cm^2}$$

Hence, D16 - 4 $= 7.94^{cm^2} > 4.77^{cm^2}$

(ii) At the bottom of span center point

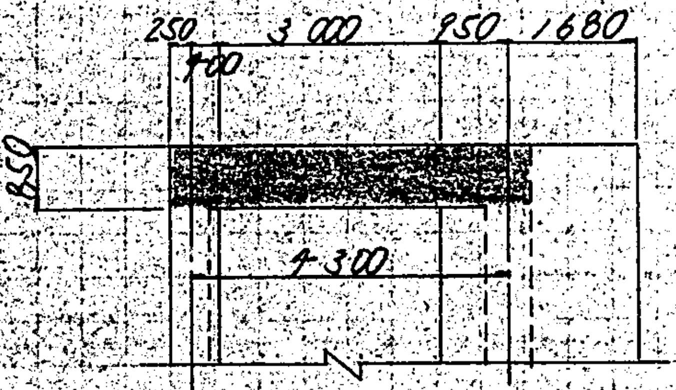
$$As = \frac{3.96 \times 10^5}{1800 \times 0.875 \times 52.0} \times \frac{4}{3} = 6.45^{cm^2}$$

Hence, D16 - 4 $= 7.94^{cm^2} > 6.45^{cm^2}$

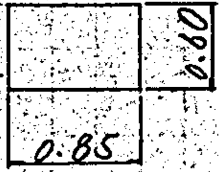
3). Stress calculation

	At the support paint	At the span center paint	
M (tm)	-2.96	3.96	
N (t)			
S (t)			
b (cm)	50	92	
h (cm)	60	60	
d (cm)	52.5	52.0	
d' (cm)	7.5	8	
As (cm^2)	D16 - 4 7.94	D16 - 4 7.94	
p	0.00302	0.00166	
As' (cm^2)			
p'			
e=M/N (cm)			
e=M/N+u (cm)			
e=M/N−u (cm)			
e/h (t)		15	
d/e			
d'/h			
d'/d (t/d)		0.288	
$\overset{M}{Ne}/bd^2$ (kg/cm^2)	2.15	1.59	
k			
c			
j			
1/Lc	8.44	10.7	
1/Ls	362	645	
$\beta=\sigma s/\sigma c$			
σc (kg/cm^2)	18.2	17.1	
σs (kg/cm^2)	780	1030	
τ (kg/cm^2)			
σsa (kg/cm^2)	1800	〃	
σca (kg/cm^2)	90	〃	
τa (kg/cm^2)			
Nomogram number	M - 1	M-47-48	
combination	D+P		

§5 Calculation of beam support stairway



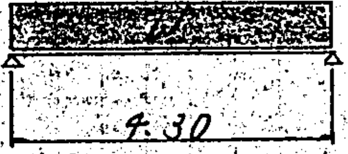
(1) own weight



$w = 2.5\,t/m^3 \times 0.85 \times 0.60$

$= 1.28\,t/m$

(2) Reaction of stairway (Refer. veaduct of platform (north side))



Dead load $w_d = 9.67\,t/m$

pedestrian load $w_p = 1.59$ "

$\Sigma w = 1.28 + 9.67 + 1.59 = 12.54\,t/m$

(3) Moment

i) At the support point

$M = -\frac{1}{12} wl^2 = -\frac{1}{12} \times 12.54 \times 4.30^2 = 19.32^{tm}$

ii) At the span center point

$M = \frac{1}{2} \times (\frac{1}{8} + \frac{1}{24}) wl^2 = \frac{1}{12} wl^2$

$= \frac{1}{12} \times 12.54 \times 4.30^2 = 19.32^{tm}$

(4) Required minimun cross section of re-bars

(i) At the top of support point

$As = \frac{M}{\sigma sa \cdot j \cdot d} \times \frac{4}{3} = \frac{19.32 \times 10^5}{1800 \times 0.875 \times 52.0} \times \frac{4}{3}$

$= 31.45^{cm^2}$

Hence, $D25 - 7 = 35.47^{cm^2} > 31.45^{cm^2}$

(ii) At the span Center Center point

$As = \frac{19.32 \times 10^5}{1800 \times 0.875 \times 51.5} \times \frac{4}{3} = 31.76^{cm^2}$

Hence, $D25 - 7 = 35.47^{cm^2} > 31.76^{cm^2}$

(5) Shearing Stress

$h/2$ point

$$S = 1/2 \times 12.54 \times 4.30 - 12.54 \times 0.55 = 20.06^{t}$$

$$\tau = \frac{20.06 \times 10^{3}}{85 \times 52.0} = 4.54\ ^{kg}/_{cm^2} > 3.9\ ^{kg}/_{cm^2}$$

(6) Calculation of diagonal tension bar

1) Calculation of total shear

$$\Sigma SR = Sc + Sv + Sb$$

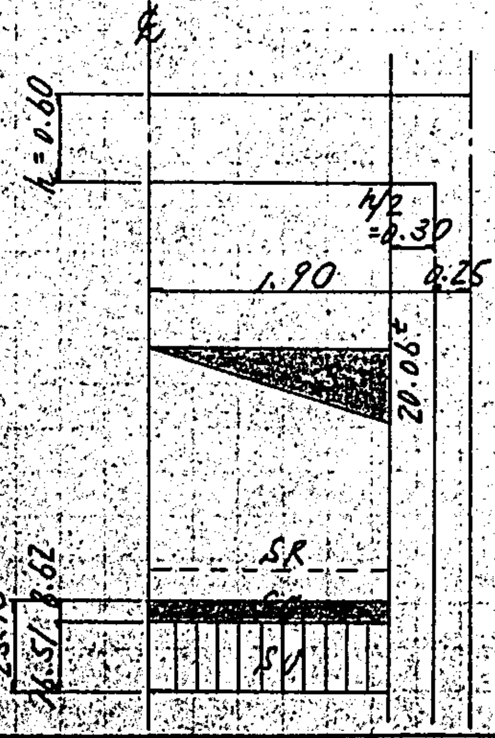
Where,

Sc : Shearing stress beared by concrete (t)

Sv : Shearing stress beared by stirrup (t)

Sb : Shearing stress beared by turned up bars (t)

Assumed, $Sv \geq Sb$



Shearing force diagram

Resisting shearing force diagram

(i) Shearing stress beared by concrete

$Sc = 1/2 \cdot \tau c \cdot b \cdot d$

Where,

τc : 3.9 kg/cm²

b : Width of member (cm)

d : Effective height of member at the examining section (cm)

$Sc = 1/2 \times 3.9 \times 85.0 \times 52.0 \times 10^{-3} = 8.62^{t}$

(ii) Shearing force beared by stirrup

$$Sv = \frac{Av \cdot \sigma sa \cdot d}{1.15 \cdot s}$$

Where,

Av : Total cross section (cm2) of stirrup within the section s,

σsa : Allowable tensile stress of re-bar

$\sigma sa = 1800$ kg/cm²

s : Interval of stirrups measured along the member axis (cm)

Arranged Stirrups D13 - 2 sets 25cm ctc,

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

$$Sv_1 = \frac{5.07 \times 1800 \times 52.0}{1.15 \times 25 \times 10^3} = 16.51^{t}$$

(iii) Shearing stress beared by turned up bars

Disregarded the turned up bars for calculation

(iv) Total shear

$$\Sigma S_R = S_c + S_v + S_b$$

$$\Sigma S_R = 8.62 + 16.51 + 0 = 25.13^{t} > 20.06^{t}$$

Re-bars in axial direction D19-1 bear (one side)

Stress calculation

	At the support point	At the span center point	
M (tm)	19.32	19.32	
N (t)			
S (t)			
b (cm)	85	85	
h (cm)	60	60	
d (cm)	52	51.5	
d' (cm)	8	8.5	
As (cm²)	D25 - 7 = 35.47	D25 - 7 = 35.47	
p	0.00802	0.00810	
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			
M ~~Ne~~/bd² (kg/cm²)	8.41	8.57	
k			
c			
j			
1/Lc	5.96	5.94	
1/Ls	193	192	
β = σs/σc			
σc (kg/cm²)	50.1	50.9	
σs (kg/cm²)	1200	1210	
τ (kg/cm²)			
σsa (kg/cm²)	1800	1800	
σca (kg/cm²)	90	90	
τa (kg/cm²)			
Nomogram number	M - 1		
combination	D + P		

§6. Calculation of Stairway

1. Slab Calculation

1) Load Calculation

pedestrian load		= 0.500 t/m
step	$2.5\,t/m^3 \times 0.33 \times 0.165 \times 1/2 \times \frac{1}{0.33}$	= 0.206 "
pavement	1.1 " × 0.05	= 0.055 "
slab	2.5 " × 0.559	= 1.398 "
		$w' = 2.159\ t/m$

$$l = 11.18^{m} \quad (\alpha = 26^{\circ}5615)$$

$$w = w' \cdot \cos\alpha^2$$

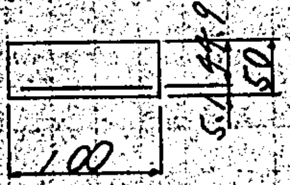
$$= 2.159 \times \left(\frac{10.00}{11.18}\right)^2 = 1.727$$

2) Bending moment

- At the span center point

$$M = \frac{1}{8} \times 1.727 \times 11.18^2 = 26.98^{tm}$$

(3) Calculation of Bending stress



$AS = D25 - 12.5\,ctc = 40.54\ cm^2$

$P = \frac{40.54}{100 \times 44.9} = 0.00903$

Nomogram number M-1

$1/Lc = 5.74 \quad 1/Ls = 128$

$\sigma c = \frac{26.98 \times 10^5}{100 \times 44.9^2} \times 5.74 = 76.8\ kg/cm^2 < 90\ kg/cm^2$

$\sigma s = \text{———} \,{}''\, \text{———} \times 128 = 1710\ {}'' < 1800\ {}''$

Reinforcement at the support of railway cross section shall be 1/6 of that of at the support of railway profile

$AS' = D25 - 12.5^{cm}\,ctc\,(B) = 40.54\ cm^2$

$40.54 \times 1/6 = 6.76\ cm^2$

$AS = D16 - 25.0^{cm}\,ctc = 7.94\ cm^2 > 6.76\ cm^2$

Shearing Stress

$$S\,l/2 = 1/2 \times 1.727 \times 11.18 - 1.727 \times 0.25$$

$$= 9.22^{t}$$

$$\tau = \frac{9.22 \times 10^{3}}{100 \times 44.9} = 2.05\ \mathrm{kg/cm^2} < 3.9\ \mathrm{kg/cm^2}$$