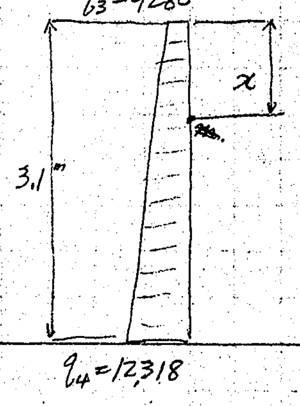
Moment in GH as a simple span.



$$M_x = \frac{l}{6}(q_4+2q_3)x - \frac{q_3}{2}x^2 - \frac{q_4-q_3}{6l}x^3$$

$$= \frac{3.1}{6}(30878)x - 4640x^2 - 163x^3$$

$$= 15950x - 4640x^2 - 163x^3$$

$$= (15950 - 4640x - 163x^2)x$$

x	x^2	15950	$-4640x$	$-163x^2$			M_x
0.5	0.25	15950	− 2320	− 40	13590	× 0.5	= 6800
1.0	1.0	〃	− 4640	− 160	11150	× 1.0	11,150
1.5	2.25	〃	− 6960	− 370	8620	× 1.5	12930
2.0	4.00	〃	− 9280	− 650	6020	× 2.0	12040
2.5	6.25	〃	− 11600	− 1020	3330	× 2.5	8320

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MADE BY K. I. DATE 10-11-6 **FILE NO** 6
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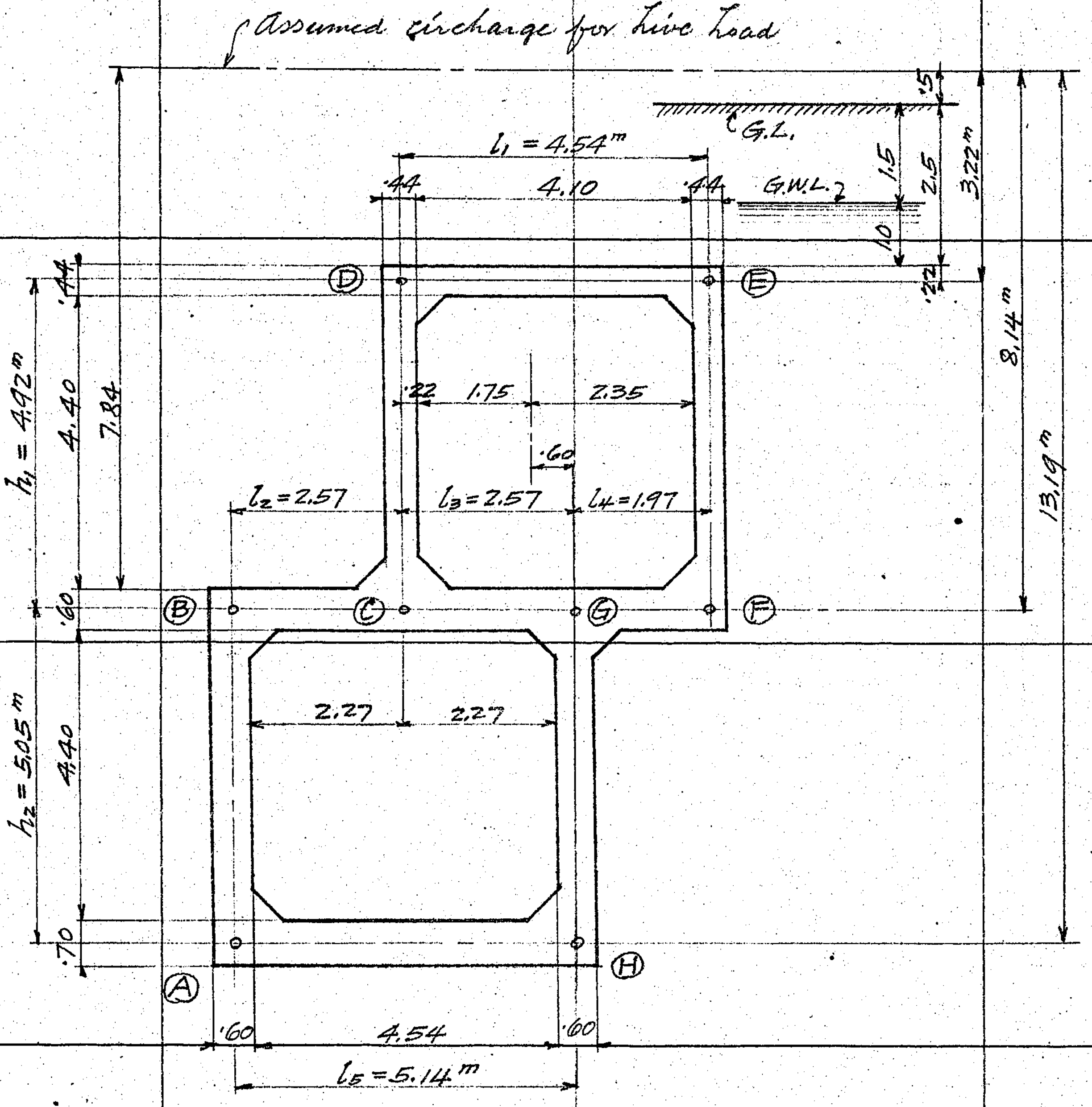
CALCULATIONS FOR
赤坂見附停留場
上下二段式函型隧道 断面A4端 土被 2.5米

不用

断面A4端 土被 2.50米

Cross section of the tonnel assumed as shown on sketch below.



Scale 1:100

Load on Top slab.

Earth filling above ground water level	1.50 @ 1600 =	2400		
" " below " " "	1.00 @ 2000 =	2000		
			4400	
weight of reinforced concrete slab	0.44 @ 2400 =		1060	
			5460	
Live Load on roadway assumed as			800	
Total load on top slab		w_1 =	6260	kg/m2

Load on Middle Floor slab.

Outside of the tonnel. (BC)

Earth filling above ground water level	1.50 @ 1600 =	2400		
" " below " " "	5.84 @ 2000 =	11680		
			14080	
weight of reinforced concrete slab	0.60 @ 2400 =		1440	
			15520	
Live Load on roadway assumed as			800	
Total load on slab		w_2 =	16320	kg/m2

上下二段式函型隧道 断面A4號.

Inside of the tonnel. (CG)
weight of track with ballast assumed as 720
" " concrete floor slab 0.60 @ 2400 = 1440
Dead Load = 2160 kg/m2

Wheel load. Single line of 54 ton Electric car train assumed.
One axle load 13500 kg
Distributed load on slab = $\frac{13500}{1.8 \times 2.4}$ = 3120 kg/m2

Impact coef. = $\frac{50}{2.4+100}$ = 49% 3120×.49 = 1530
4650 kg/m2

Total load on slab 2160 + 4650 = 6,810 kg/m2 = w_3

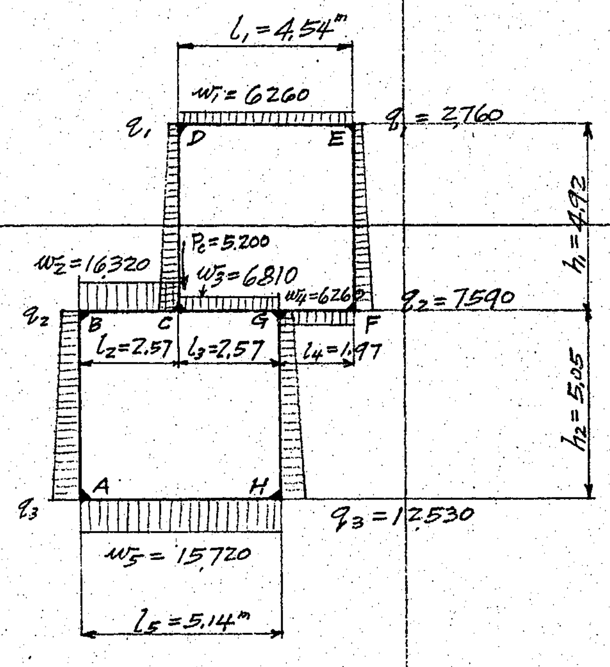
Concentrated load on point C
weight of wall DC Concentrated on point C assumed.
0.44×4.92@2400 = 5,200 = P_c

Load on GF $w_4 = w_1$ = 6260 kg/m2 assumed.

Load on Bottom slab AH.
Load on structure. - $w_1 l_1$ = 6260 × 4.54 = 28,400
$w_2 l_2$ = 16,320 × 2.57 = 42,000
$w_3 l_3$ = 6,810 × 2.57 = 17,500
weight of wall DC, P_c = 5,200
93,100
$w_4 l_4$ = 6260 × 1.97 = - 12,300
80,800 kg
w_5 = 80,800 ÷ 5.14 = 15,720 kg/m2

Earth pressure intensity on walls.
pressure intensity pressure coef. = 0.490 see on page 83.
at D for $\mathcal{J}$ = 20°
2.00 @ 1600 = 3,200
1.22 @ 2000 = 2440
5640 × 0.490 = 2,760 kg/m2

Loading Condition:



at B
2.00 @ 1600 = 3200
6.14 @ 2000 = 12280
15480 × 0.490 = 7,590 kg/m2

at A
2.00 @ 1600 = 3200
11.19 @ 2000 = 22380
25580 × 0.490 = 12,530 kg/m2

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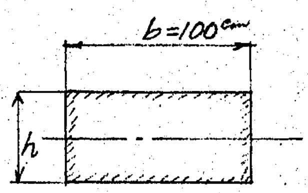
CALCULATIONS FOR

上下二段式函型隧道 断面A4號

Assumed cross section and moment of inertia of each member.



		width b	depth h	h^3	$I = \frac{bh^3}{12}$
Top slab.	DE	100 cm	44 cm	85,184	710,000 cm^4
middle 〃	BC	〃	60	216,000	1,800,000 〃
〃 〃	CG	〃	〃	〃	〃
〃 〃	GF	〃	〃	〃	〃
Bottom 〃	AH	〃	70	343,000	2,860,000 〃
Sidewall	CD	100	44	85,184	710,000 〃
〃 〃	EF	〃	〃	〃	〃
〃 〃	AB	〃	60	216,000	1,800,000 〃
〃 〃	GH	〃	〃	〃	

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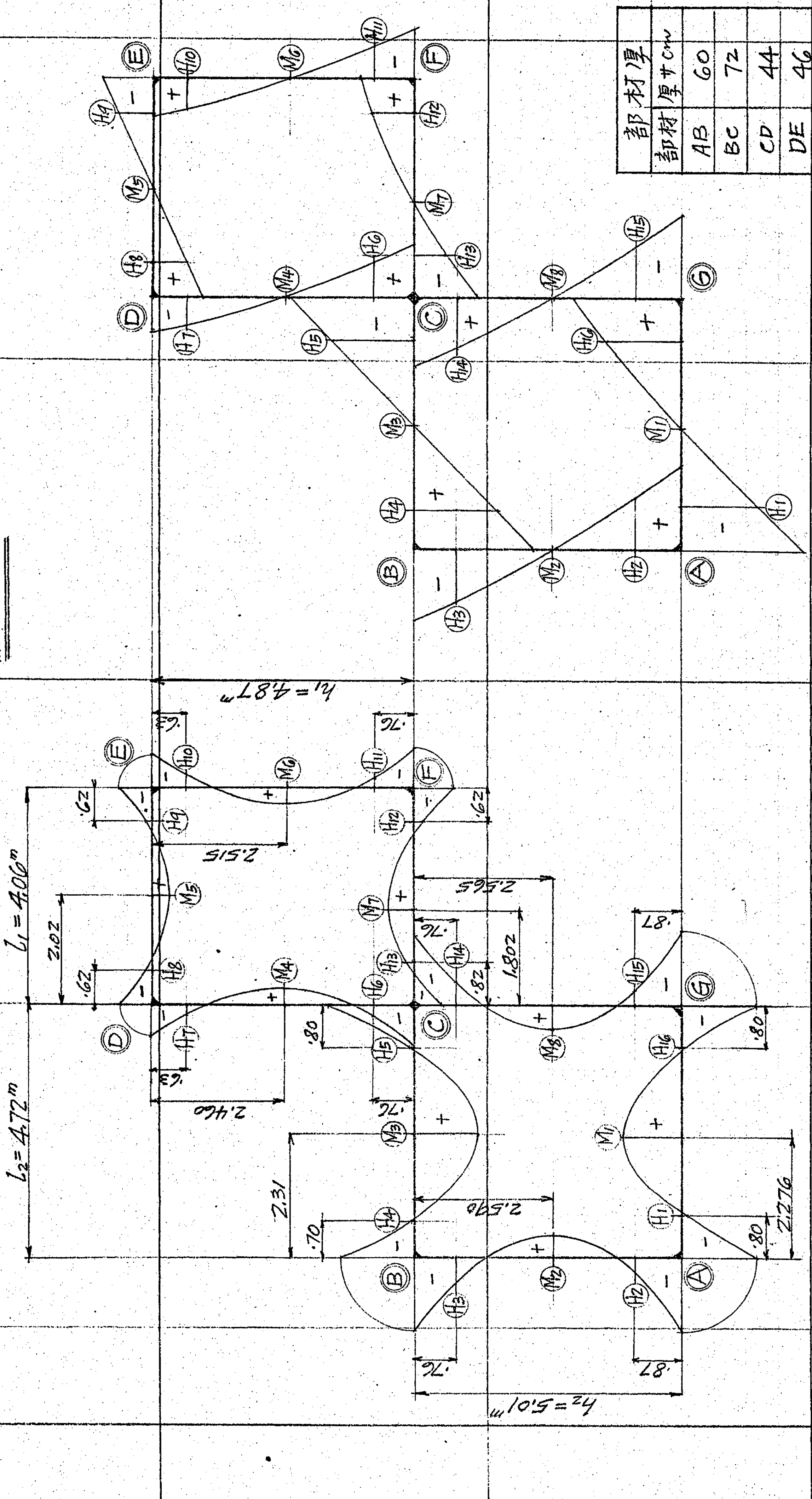
CALCULATIONS FOR

上下二段式函型隧道 断面A5號 土被4.0m

鐵筋混凝土上下二段式函型隧道断面A5號 土被四〇米 其ノ一

部材	部材厚サcm
AB	60
BC	72
CD	44
DE	46
EF	44
FC	60
CG	60
GA	74



土圧 E点 q_1 = 4,150 kg/cm²
F点 q_2 = 8,920 〃
G点 q_3 = 13,840 〃

荷重状態
土被 4.00m
地下水位 地表面下 1.50m
土ノ安息角 φ = 20°-00'
上床荷重 DE w_1 = 9,100 kg/m²
〃 〃 BC w_2 = 19,210 〃
下床 〃 F点 w_3 = 6,890 〃
〃 〃 C,G点 w_4 = 13,970 〃
〃 〃 A点 w_5 = 22,200 〃

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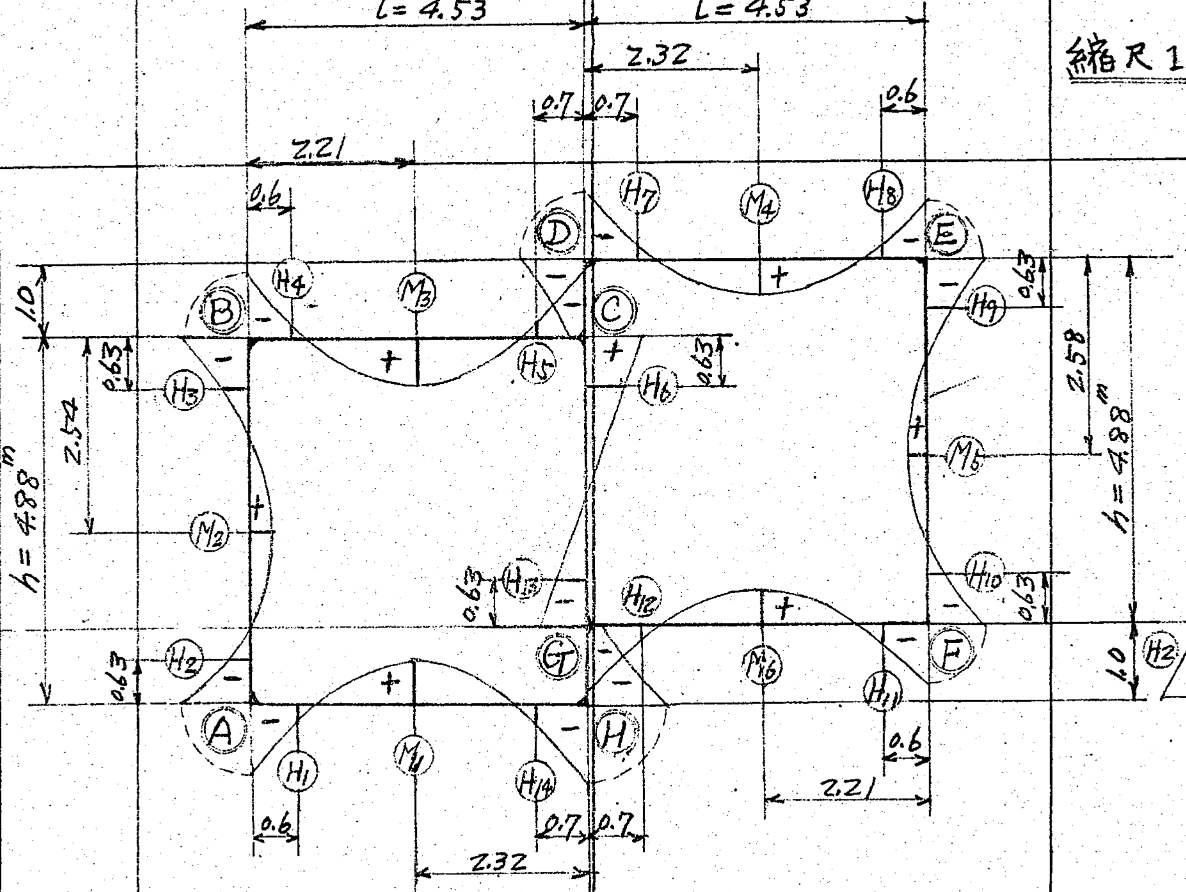
CALCULATIONS FOR
上下二段式函型隧道断面A7號 土被4.5米

鐵筋混凝土上下二段式函型隧道断面A7號 土被四.五米

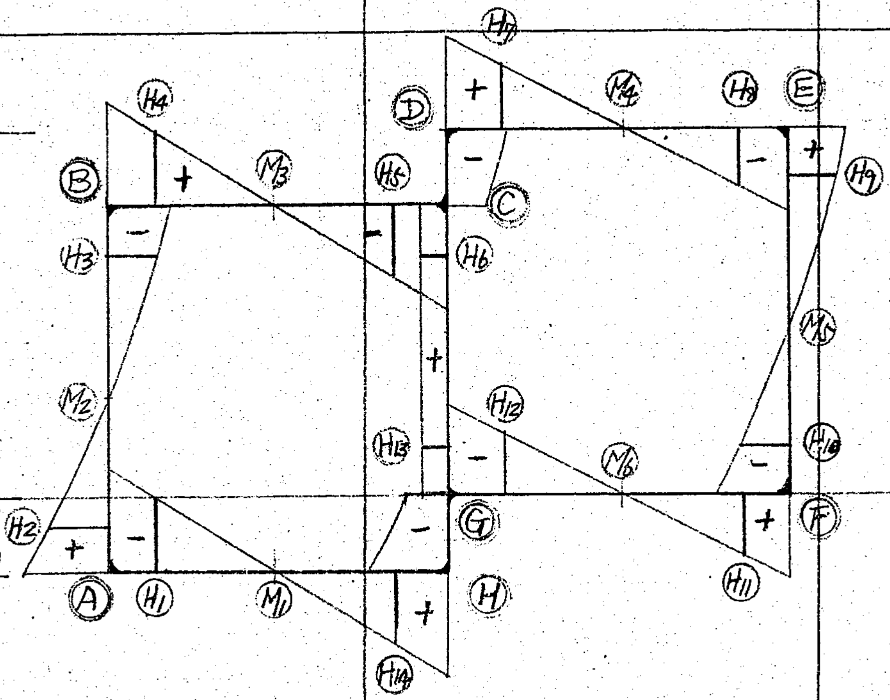
其一

縮尺 1:60

曲ゲモーメント図
尺度 1mm = 2000 kgm



剪断力図
尺度 1mm = 2000 kg.



荷重状態

土被			4.50m
地下水位	地表面下		1.50m
土ノ安息角			20°
上床荷重	DE	W_1 =	10,100 kg/m²
〃 〃	BC	W_2 =	12,100 〃
下床 〃	FG	W_1 =	10,100 〃
〃 〃	AH	W_2 =	12,100 〃
土圧	E点	q_1 =	4,640 〃
〃	B点	q_2 =	5,620 〃
〃	F点	q_3 =	9,422 〃
〃	H点	q_4 =	10,402 〃

部材厚

部材	厚サ cm
AB	40
BC	46
CD	60
DE	46
EF	40
FG	46
GH	60
HA	46
CG	60

各節点ニ於ケル曲ゲモーメント

符號	M kgm	符號	M kgm
M_A	−17800	M_{GC}	−13300
M_B	−17000	M_{GH}	−4000
M_{CB}	−19700	M_H	−20700
M_{CD}	−4500		
M_{CG}	+15200		
M_D	−17200		
M_E	−14800		
M_F	−14900		
M_{GF}	−17300		

各節点ニ於ケル剪断力

符號	S. kg	符號	S. kg
S_{AB}	+21700	S_{ED}	−22300
S_{BA}	−17400	S_{EF}	+15200
S_{BC}	+26800	S_{FE}	−19100
S_{CB}	−28000	S_{FG}	+22300
S_{CD}	−10000	S_{GF}	−23400
S_{DC}	−15200	S_{GH}	−11800
S_{GC}	+7300	S_{HG}	−21700
S_{CG}	+7300	S_{HA}	+28000
S_{DE}	+23400	S_{AH}	−26800

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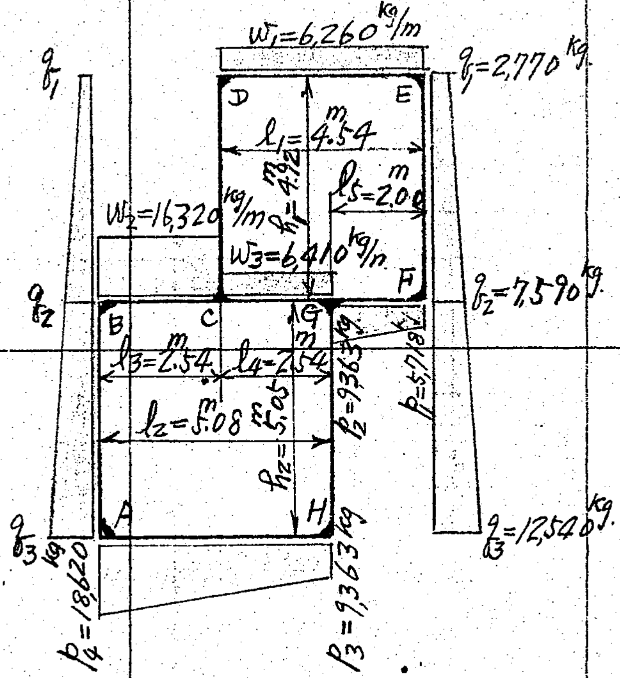
CALCULATIONS FOR
上下二段式函型隧道 断面A4號 土被2.5m 其ノ一

應力表

部材 / 位置		A~B			B-C			C-G				C-D		D-E					E-F			F-G	
		H1	M1	H2	B	H3	H4	C	H12	H11	G	M2	H5	D	H6	M3	H7	E	H8	M4	H9	F	H10
断面	b(cm)	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
	h(cm)	54	54	54	82	60	60	81	60	60	82	44	44	65	44	44	44	65	44	44	44	81	60
	d(cm)	49	49	49	77	55	55	76	55	55	77	39	39	60	39	39	39	60	39	39	39	76	55
	d'(cm)	5	5	5	/	5	5	/	5	5	/	5	5	/	5	5	5	/	5	5	5	/	5
	As(cm²)	28.35	28.35	38.01	40.78	38.01	24.55	43.55	43.55	38.01	40.78	20.11	15.08	20.11	15.08	20.11	15.08	20.11	15.08	20.11	29.06	29.06	29.06
	As'(cm²)	7.09	14.18	7.09	/	12.27	19.01	/	38.01	31.28	/	10.06	5.03	/	5.03	5.03	5.03	/	5.03	10.06	5.03	/	19.01
	U(cm)	59.69	59.69	69.12	71.48	69.12	39.27	73.83	73.83	69.12	71.48	50.27	37.70	50.27	37.70	50.27	37.70	50.27	37.70	50.27	59.81	59.81	59.81
応力	M(kgm)	7,700	6,900	11,300	26,000	3,200	19,900	39,900	19,900	9,800	29,800	6,300	3,800	10,000	2,600	5,500	3,500	11,200	5,000	5,100	1,800	10,200	2,400
	N(kg)	39,600	39,600	39,600	23,600	23,600	23,600	38,100	38,100	38,100	38,100	13,900	13,900	11,000	11,000	11,000	11,000	11,000	14,500	14,500	14,500	14,500	14,500
	S(kg)	18,100	0	18,100	39,600	28,700	8,200	15,800	19,700	27,700	32,000	0	9,100	13,900	10,100	0	10,600	14,500	9,100	0	9,400	14,500	10,400
応力度	σc(kg/cm²)	22.2	20.1	31.8	32.3	/	43.7	37.7	34.5	19.5	38.3	28.0	18.9	23.2	13.1	25.4	17.6	27.4	25.4	23.6	/	14.6	/
	σs(kg/cm²)	122.0	86.0	295.0	684.0	/	1,167.0	602.0	552.0	156.0	708.0	588.0	316.0	637.0	189.0	534.0	334.0	767.0	510.0	405.0	/	307.0	/
	τ(kg/cm²)	4.89	0	4.65	5.97	7.41	1.69	2.48	4.27	5.77	4.89	0	2.75	2.63	3.12	0	3.19	2.74	2.72	0	3.44	2.22	3.56
	τ'(kg/cm²)	/	0	3.36	4.17	5.36	2.15	1.68	2.89	4.17	3.42	/	/	/	/	/	/	/	/	/	2.87	1.85	2.97

部材 / 位置		G-H				H-A				
		G	H13	M5	H14	H	H15	M6	H16	A
断面	b(cm)	100	100	100	100	100	100	100	100	100
	h(cm)	77	54	54	54	92	70	70	70	92
	d(cm)	72	49	49	49	87	65	65	65	87
	d'(cm)	/	5	5	5	/	5	5	5	/
	As(cm²)	38.01	38.01	28.35	28.35	28.35	21.26	28.35	21.26	28.35
	As'(cm²)	/	7.09	14.18	7.09	/	7.09	7.09	7.09	/
	U(cm)	69.12	69.12	59.69	59.69	59.69	44.77	59.69	44.77	59.69
応力	M(kgm)	24,800	10,200	8,100	6,500	23,600	4,700	21,200	2,100	24,600
	N(kg)	31,400	31,400	31,400	31,400	27,200	27,200	27,200	27,200	27,200
	S(kg)	23,600	18,100	0	18,100	31,400	24,700	0	27,600	39,600
応力度	σc(kg/cm²)	36.3	28.4	22.9	19.7	27.1	/	37.4	/	28.2
	σs(kg/cm²)	690.0	312.0	229.0	132.0	649.0	/	823.0	/	690.0
	τ(kg/cm²)	3.84	4.57	0	4.80	4.14	5.86	0	5.76	5.22
	τ'(kg/cm²)	2.78	3.31	/	/	/	/	/	/	/

荷重狀態



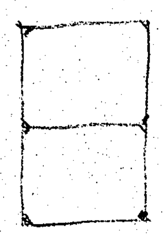
條件

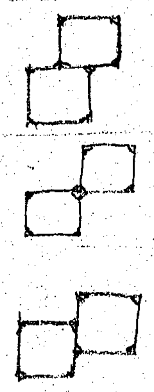
土被 2.5m
地下水位 地表下 1.5m
土ノ重量 地下水位以上 1,600 kg/m³
地下水位以下 2,000 kg/m³
土ノ息角 20°
路面活荷重 800 kg/m²
隧道内電車荷重 54瓲四輪ボギー電車

100
76
103

應力度表

	断面	土被	枚数
	A_1	3.5^m	1
	A_1	3.0	1
	A_1	2.5	1
800	A_2	2.5	1
〃	A_3	2.5	1
〃	A_4	2.5	2 (其一, 其二)
600	A_5	4.0	2 (〃)
〃	A_6	4.5	2 (〃)
〃	A_7	4.5	2 (〃)
	計九個所		計13枚





2.5^m A4-2
(3.) A5-1
5 — 3394

3.0 — 128
1.0 — .601

(A5號 土被 3.0米ノモノハ後廻シ)

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CALCULATIONS FOR

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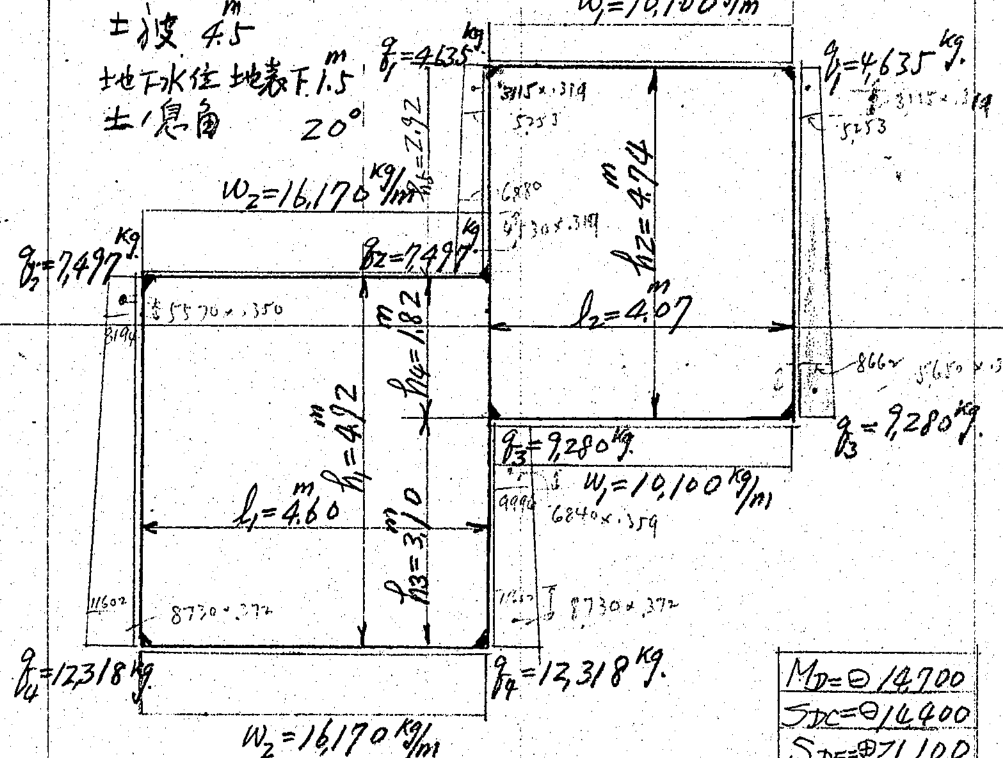
赤坂見付停車場
上下二段式函型隧道
断面 A_6 系 土被 4.5

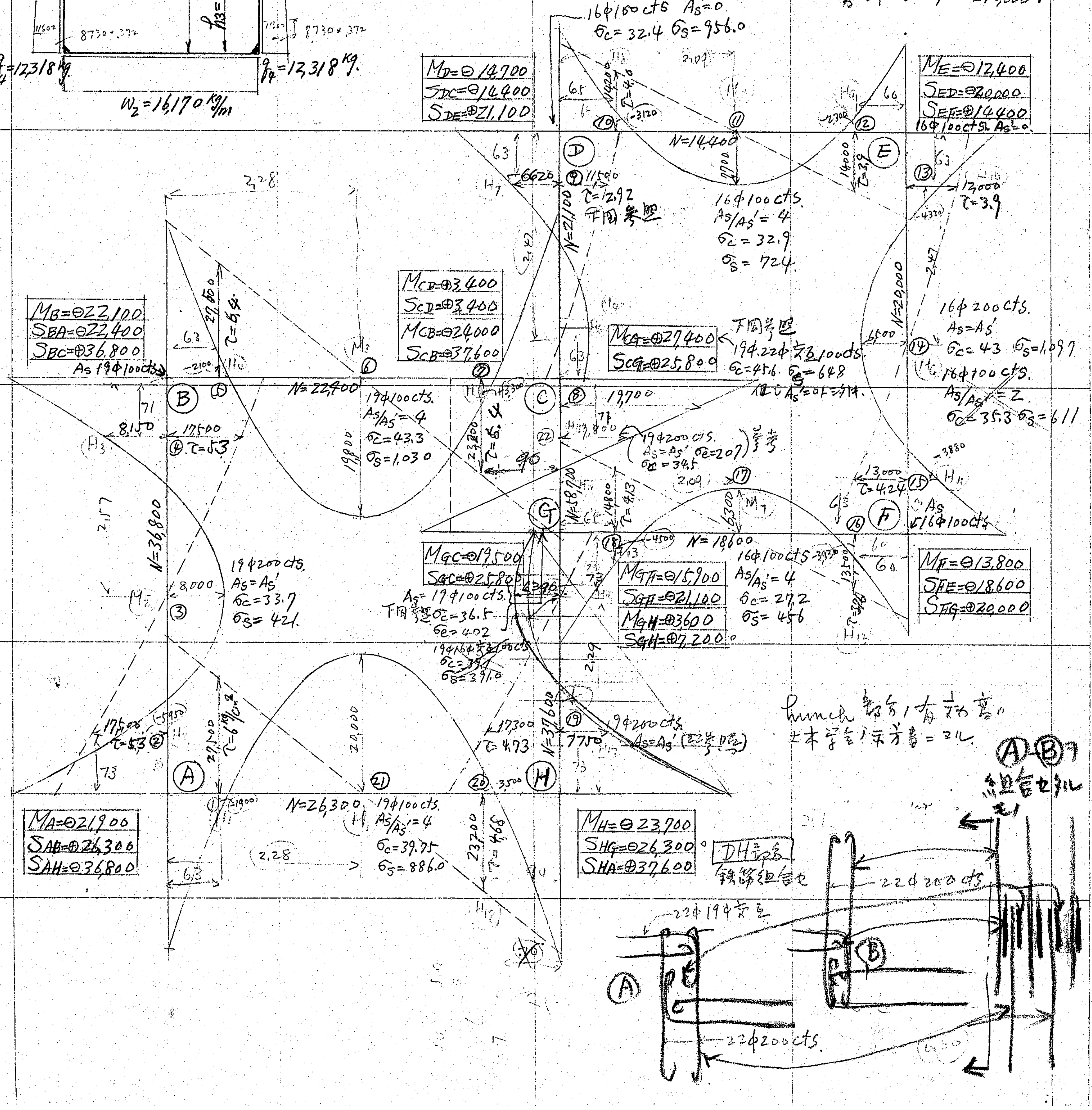
荷重状態



部材厚

A-B	46 cm
B-C	62
C-D	50
D-E	46
E-F	40
F-G	46
G-C	50
G-H	50
H-A	66

彎曲能率 ———
剪断力 - - - -
單位 彎曲能率 kg.m 單位応力 kg/cm²
剪断力 kg.
縮尺 部材長 1/50
彎曲能率 1/6 cm = 1,000 kg.m
剪断力 1 cm = 10,000 kg.



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CALCULATIONS FOR

上下二段式函型隧道断面A_7號土被4.5^m 不用

$$C_{CD} = \frac{h_2^2(2q_1+3q_2)}{60} = \frac{100^2(2 \times 4640+3 \times 5620)}{60} = 435 \text{ kgm}$$

$$C_{DC} = \frac{h_2^2(3q_1+2q_2)}{60} = \frac{100^2(3 \times 4640+2 \times 5620)}{60} = 420 \text{ ''}$$

$$C_{HG} = \frac{h_2^2(2q_3+3q_4)}{60} = \frac{100^2(2 \times 9420+3 \times 10400)}{60} = 835 \text{ ''}$$

$$C_{GH} = \frac{h_2^2(3q_3+2q_4)}{60} = \frac{100^2(3 \times 9420+2 \times 10400)}{60} = 820 \text{ ''}$$

$$C_{AH} = \frac{l^2(2P_2+3P_1)}{60} = \frac{453^2(2 \times 11100+3 \times 12570)}{60} = 20{,}500 \text{ ''}$$

$$C_{HA} = \frac{l^2(3P_2+2P_1)}{60} = \frac{453^2(3 \times 11100+2 \times 12570)}{60} = 20{,}000 \text{ ''}$$

$$C_{GF} = \frac{l^2(2P_3+3P_2)}{60} = \frac{453^2(2 \times 9630+3 \times 11100)}{60} = 17{,}960 \text{ ''}$$

$$C_{FG} = \frac{l^2(3P_3+2P_2)}{60} = \frac{453^2(3 \times 9630+2 \times 11100)}{60} = 17{,}470 \text{ ''}$$

Value of ρ :-

$$\rho_A = \rho_B = \rho_E = \rho_F = 2 \times (k_{AB}+k_{AH}) = 2 \times (0.00109+0.00179) = 0.00576$$
$$\rho_D = \rho_H = 2 \times (k_{DC}+k_{DE}) = 2 \times (0.01800+0.00179) = 0.03958$$
$$\rho_C = \rho_G = 2 \times (k_{CB}+k_{CD}+k_{CG}) = 2 \times (0.00179+0.01800+0.00464) = 0.04886$$

Value of P :-

$$P_A = -C_{AB}+C_{AH} = -16{,}850+20{,}500 = +3{,}650 \text{ kgm}$$
$$P_B = -C_{BC}+C_{BA} = -20{,}700+14{,}940 = -5{,}760 \text{ ''}$$
$$P_C = -C_{CD}+C_{CB} = -435+20{,}700 = +20{,}265 \text{ ''}$$
$$P_D = -C_{DE}+C_{DC} = -17{,}270+420 = -16{,}850 \text{ ''}$$
$$P_E = -C_{EF}+C_{ED} = -13{,}000+17{,}270 = +4{,}270 \text{ ''}$$
$$P_F = -C_{FG}+C_{FE} = -17{,}470+14{,}900 = -2{,}570 \text{ ''}$$
$$P_G = -C_{GH}+C_{GF} = -820+17{,}960 = +17{,}140 \text{ ''}$$
$$P_H = -C_{HA}+C_{HG} = -20{,}000+835 = -19{,}165 \text{ ''}$$

Value of γ :-

$$\gamma_{AH} = \gamma_{ED} = \gamma_{BC} = \gamma_{FG} = \frac{k_{AH}}{\rho_A} = 0.00179 \div 0.00576 = 0.311$$

$$\gamma_{DC} = \gamma_{HG} = \frac{k_{DC}}{\rho_D} = 0.01800 \div 0.03958 = 0.455$$

$$\gamma_{AB} = \gamma_{BA} = \gamma_{EF} = \gamma_{FE} = \frac{k_{AB}}{\rho_A} = 0.00109 \div 0.00576 = 0.189$$

$$\gamma_{CB} = \gamma_{GF} = \frac{k_{CB}}{\rho_C} = 0.00179 \div 0.04886 = 0.037$$

$$\gamma_{CD} = \gamma_{GH} = \frac{k_{CD}}{\rho_C} = 0.01800 \div 0.04886 = 0.369$$

$$\gamma_{DE} = \gamma_{HA} = \frac{k_{DE}}{\rho_D} = 0.00179 \div 0.03958 = 0.045$$

$$\gamma_{CG} = \gamma_{GC} = \frac{k_{CG}}{\rho_C} = 0.00464 \div 0.04886 = 0.095$$

Value of φ :-

$$\varphi_A = \frac{P_A}{\rho_A} = \frac{3650}{0.00576} = 634{,}000 \qquad \varphi_E = \frac{P_E}{\rho_E} = \frac{4270}{0.00576} = 741{,}000$$

$$\varphi_B = \frac{P_B}{\rho_B} = \frac{-5760}{0.00576} = -1{,}000{,}000 \qquad \varphi_F = \frac{P_F}{\rho_F} = \frac{-2570}{0.00576} = -446{,}000$$

$$\varphi_C = \frac{P_C}{\rho_C} = \frac{20265}{0.04886} = 414{,}500 \qquad \varphi_G = \frac{P_G}{\rho_G} = \frac{17140}{0.04886} = 351{,}000$$

$$\varphi_D = \frac{P_D}{\rho_D} = \frac{-16850}{0.03958} = -425{,}700 \qquad \varphi_H = \frac{P_H}{\rho_H} = \frac{-19165}{0.03958} = -494{,}000$$

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CALCULATIONS FOR

上下二段式函型隧道断面A₇號土被45ᵐ

we have final values of φ by trial method with previous values.

$\varphi_A = 1165000$ $\varphi_E = 1151000$
$\varphi_B = -1438700$ $\varphi_F = -857300$
$\varphi_C = 702700$ $\varphi_G = 623200$
$\varphi_D = -797300$ $\varphi_H = -833000$

Bending moment at each support
From the foundamental equation of moment, we have as follow,

$M_{AB} = k_{AB}(2\varphi_A + \varphi_B) + C_{AB} = 0.00109e(2e1165000 - 1438700) + 16850$
$= +970 + 16850 = 17820$ kgm

$M_{AH} = k_{AH}(2\varphi_A + \varphi_H) - C_{AH} = 0.00179e(2e1165000 - 833000) - 20500$
$= +2680 - 20500 = -17820$ kgm

$M_{BC} = k_{BC}(2\varphi_B + \varphi_C) + C_{BC} = 0.00179e(2e-1438700 + 702700) + 20700$
$= -3890 + 20700 = 16810$ kgm

$M_{BA} = k_{BA}(2\varphi_B + \varphi_A) - C_{BA} = 0.00109e(2e-1438700 + 1165000) - 14940$
$= -1870 - 14940 = -16810$ kgm

* $M_{CB} = k_{CB}(2\varphi_C + \varphi_B) - C_{CB} = 0.00179e(2e702700 - 1438700) - 20700$
$= -60 - 20700 = -20760$ kgm

$M_{CD} = k_{CD}(2\varphi_C + \varphi_D) + C_{CD} = 0.0180e(2e702700 - 797300) + 435$
$= 10935 + 435 = 11370$ kgm

$M_{CG} = k_{CG}(2\varphi_C + \varphi_G) - C_{CG} = 0.00464e(2e702700 + 623200) - 0$
$= 9390$ kgm

$M_{DC} = k_{DC}(2\varphi_D + \varphi_C) - C_{DC} = 0.0180e(2e-797300 + 702700) - 420$
$= -16050 - 420 = -16470$ kgm

$M_{DE} = k_{DE}(2\varphi_D + \varphi_E) + C_{DE} = 0.00179e(2e-797300 + 1151000) + 17270$
$= -800 + 17270 = 16470$ kgm

$M_{ED} = k_{ED}(2\varphi_E + \varphi_D) - C_{ED} = 0.00179e(2e1151000 - 797300) - 17270$
$= 2690 - 17270 = -14580$ kgm

$M_{EF} = k_{EF}(2\varphi_E + \varphi_F) + C_{EF} = 0.00109e(2e1151000 - 857300) + 13000$
$= 1580 + 13000 = +14580$ kgm

$M_{FE} = k_{FE}(2\varphi_F + \varphi_E) - C_{FE} = 0.00109e(2e-857300 + 1151000) - 14900$
$= -610 - 14900 = -15510$ kgm

$M_{FG} = k_{FG}(2\varphi_F + \varphi_G) + C_{FG} = 0.00179e(2e-857300 + 623200) + 17470$
$= -1960 + 17470 = 15510$ kgm

$M_{GF} = k_{GF}(2\varphi_G + \varphi_F) - C_{GF} = 0.00179e(2e623200 - 857300) - 17960$
$= 700 - 17960 = -17260$ kgm

$M_{GH} = k_{GH}(2\varphi_G + \varphi_H) + C_{GH} = 0.0180e(2e623200 - 833000) + 820$
$= 7420 + 820 = 8240$ kgm

$M_{GC} = k_{GC}(2\varphi_G + \varphi_C) - C_{GC} = 0.00464e(2e623200 + 702700) - 0$
$= 9020$ kgm

$M_{HG} = k_{HG}(2\varphi_H + \varphi_G) - C_{HG} = 0.0180e(2e-833000 + 623200) - 835$
$= -18515 - 835 = -19350$ kgm

$M_{HA} = k_{HA}(2\varphi_H + \varphi_A) + C_{HA} = 0.00179e(2e-833000 + 1165000) + 20000$
$= -650 + 20000 = +19350$ kgm

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CALCULATIONS FOR

上下二段式函型隧道断面A7號土被4.5m

Then we have

$M_{AB} = M_{AH}$ = - 17,820 kgm		$M_{ED} = M_{EF}$ = - 14,580 kgm	
$M_{BC} = M_{BA}$ = - 16,810 "		$M_{FE} = M_{FG}$ = - 15,510 "	
M_{CB} = - 20,760 "		M_{GF} = - 17,260 "	
M_{CD} = - 11,370 "		M_{GH} = - 8,240 "	
M_{CG} = - 9,390 "		M_{GC} = - 9,020 "	
$M_{DC} = M_{DE}$ = - 16,470 "		$M_{HG} = M_{HA}$ = - 19,350 "	

Positive moment of slab as a simple beam.

For top slab BC,

$$M_x = \frac{w_2 l}{2}x - \frac{1}{2}w_2 x^2$$
$$= \frac{12,100 \times 4.53}{2}x - \frac{12,100}{2}x^2 = 27,400x - 6,050x^2$$

value of M_x for several value of x.

x	$27400x$	$6050x^2$	M_x	
0.453	12,420	1,240	11,180	kgm
0.600	16,440	2,180	14,260	"
0.906	24,830	4,970	19,860	"
1.358	37,220	11,160	26,060	"
1.812	49,640	19,870	29,770	"
2.265	62,030	31,030	31,000	"
0.700	19,180	2,960	16,220	"

For top slab DE,

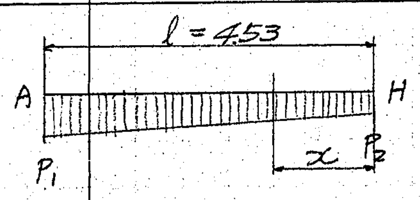
$$M_x = \frac{w_1 l}{2}x - \frac{w_1}{2}x^2$$
$$= \frac{10,100 \times 4.53}{2}x - \frac{10,100}{2}x^2 = 22,880x - 5,050x^2$$

Value of M_x for several value of x

x	$22880x$	$5050x^2$	M_x	
0.453	10,360	1,040	9,320	kgm
0.600	13,730	1,820	11,910	"
0.906	20,720	4,140	16,580	"
1.358	31,080	9,320	21,760	"
1.812	41,450	16,570	24,880	"
2.265	51,820	25,900	25,920	"
0.700	16,020	2,470	13,550	"

For bottom slab AH,

$$M_x = \frac{l}{6}(P_1 + 2P_2)x - \frac{P_1 - P_2}{6l}x^3 - \frac{P_2}{2}x^2$$
$$= \frac{4.53}{6}(12,570 + 2 \times 11,100)x - \frac{12,570 - 11,100}{6 \times 4.53}x^3 - \frac{11,100}{2}x^2$$
$$= 26,230x - 54x^3 - 5,550x^2$$



Value of M_x for several value of x

x	$26230x$	$54x^3$	$5550x^2$	M_x	
0.453	11,880	—	1,140	10,740	kgm
0.800	20,990	30	3,550	17,410	"
0.906	23,780	40	4,560	19,180	"
1.358	35,630	140	10,240	25,250	"
1.812	47,500	320	18,220	28,960	"
2.265	59,400	630	28,470	30,300	"
2.718	71,280	1,080	41,000	29,200	"
3.171	83,200	1,720	55,820	25,660	"
3.624	95,200	2,570	72,900	19,730	"
3.830	100,500	3,030	81,400	16,070	"
4.077	106,900	3,650	92,200	11,050	"

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CALCULATIONS FOR

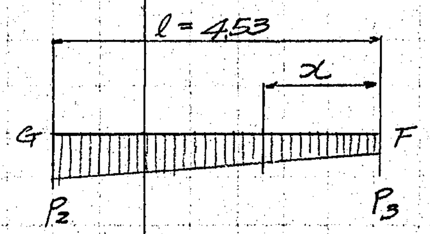
上下二段式函型隧道断面A₇號土被4.5ᵐ

For bottom slab GF,

$$M_x = \frac{l}{6}(P_2+2P_3)x - \frac{P_2-P_3}{6l}x^3 - \frac{P_3}{2}x^2$$

$$= \frac{4.53}{6}(11,100+2\times 9,630)x - \frac{11100-9630}{6\times 4.53}x^3 - \frac{9630}{2}x^2$$

$$= 22,920x - 54x^3 - 4,815x^2$$



x	22920x	54x³	4815x²	Mx
0.453	10,380	–	990	9,390 kgm
0.700	16,040	20	2,360	13,660 "
0.906	20,760	40	3,950	16,770 "
1.358	31,130	140	8,880	22,110 "
1.812	41,520	320	15,800	25,400 "
2.265	51,900	630	24,700	26,570 "
2.718	62,250	1,080	35,560	25,610 "
3.171	72,680	1,720	48,400	22,560 "
3.624	83,050	2,570	63,220	17,260 "
3.730	85,500	2,800	67,000	15,700 "
4.077	93,400	3,650	80,000	9,750 "

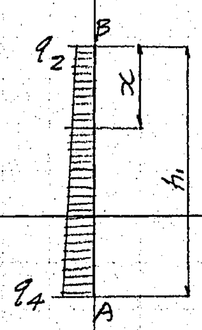
Positive moment of wall as a simple beam

For side wall AB,

$$M_x = \frac{h_1}{6}(q_4+2q_2)x - \frac{q_4-q_2}{6h_1}x^3 - \frac{q_2}{2}x^2$$

$$= \frac{4.88}{6}(10,400+2\times 5,620)x - \frac{10400-5620}{6\times 4.88}x^3 - \frac{5620}{2}x^2$$

$$= 17,600x - 163x^3 - 2,810x^2$$



x	17600x	163x³	2810x²	Mx
0.488	8,580	20	670	7,890 kgm
0.630	11,090	40	1,120	9,930 "
1.464	25,770	510	6,020	19,240 "
1.952	34,350	1,210	10,710	22,430 "
2.440	42,950	2,370	16,720	23,860 "
2.928	51,530	4,080	24,080	23,370 "
3.416	60,100	6,490	32,780	20,830 "
4.150	73,100	11,650	48,400	13,050 "
4.392	77,300	13,820	54,200	9,280 "

For side wall EF,

$$M_x = \frac{h_1}{6}(q_3+2q_1)x - \frac{q_3-q_1}{6h_1}x^3 - \frac{q_1}{2}x^2$$

$$= \frac{4.88}{6}(9420+2\times 4640)x - \frac{9420-4640}{6\times 4.88}x^3 - \frac{4640}{2}x^2$$

$$= 15,200x - 163x^3 - 2,320x^2$$

x	15200x	163x³	2320x²	Mx
0.488	7,420	20	550	6,850 kgm
0.630	9,580	40	920	8,620 "
1.464	22,250	510	4,970	16,770 "
1.952	29,680	1,210	8,840	19,630 "
2.440	37,080	2,370	13,800	20,910 "
2.928	44,500	4,080	19,880	20,540 "
3.416	51,900	6,490	27,050	18,360 "
4.150	63,050	11,650	39,950	11,450 "
4.392	66,680	13,820	44,750	8,110 "

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CALCULATIONS FOR

上下二段式函型隧道断面A7號土被45m

For side wall D.C,

$$M_x = \frac{h_2}{6}(q_2+2q_1)x - \frac{q_2-q_1}{6h_2}x^3 - \frac{q_1}{2}x^2$$

$$= \frac{1.00}{6}(5,620+2\times4,640)x - \frac{5620-4640}{6\times1.00}x^3 - \frac{4,640}{2}x^2$$

$$= 2,480x - 163x^3 - 2,320x^2$$

x	$2,480x$	$163x^3$	$2,320x^2$	M_x
0.250	620	-	140	480 kgm
0.500	1,240	20	580	640 〃
0.750	1,860	70	1,310	480 〃

For side wall GH,

$$M_x = \frac{h_2}{6}(q_4+2q_3)x - \frac{q_4-q_3}{6h_2}x^3 - \frac{q_3}{2}x^2$$

$$= \frac{1.00}{6}(10,400+2\times9,420)x - \frac{10400-9420}{6\times1.00}x^3 - \frac{9420}{2}x^2$$

$$= 4880x - 163x^3 - 4,710x^2$$

x	$4,880x$	$163x^3$	$4,710x^2$	M_x
0.250	1,220	-	290	930 kgm
0.500	2,440	20	1,180	1240 〃
0.750	3,660	70	2,650	940 〃

End shears,

$$S_{BC} = \frac{w_2 l}{2} + \frac{M_{CB}-M_{BC}}{l} = \frac{12,100\times4.53}{2} + \frac{-20,760+16,180}{4.53} = 27,400 - 1,010 = 26,390 \text{ kgs}$$

$$S_{CB} = -(27400 + 1,010) = -28,410 \text{〃}$$

$$S_{DE} = \frac{w_1 l}{2} + \frac{M_{ED}-M_{DE}}{l} = \frac{10,100\times4.53}{2} + \frac{-14,580+16,470}{4.53} = 22,900 + 420 = 23,320 \text{〃}$$

$$S_{ED} = -(22,900 - 420) = -22,480 \text{〃}$$

$$S_{BA} = R_{BA} + \frac{M_{AB}-M_{BA}}{h_1} = \frac{4.88}{6}(10,400+2\times5,620) + \frac{-17,820+16,810}{4.88}$$
$$= 17,600 - 210 = -17,390 \text{〃}$$

$$S_{AB} = \frac{(q_2+q_4)h_1}{2} - S_{BA} = \frac{5,620+10,400}{2}\times4.88 - 17,390$$
$$= 39,100 - 17,390 = 21,710 \text{〃}$$

$$S_{DC} = R_{DC} + \frac{M_{CD}-M_{DC}}{h_2} = \frac{1.00}{6}(5,620+2\times4,640) + \frac{-11,370+16,470}{1.00}$$
$$= 2,490 + 5,100 = -7,590 \text{〃}$$

$$S_{CD} = \frac{(q_1+q_2)h_2}{2} - S_{DC} = \frac{(5620+4640)1.00}{2} - 7,590 = -2,460 \text{〃}$$

$$S_{EF} = R_{EF} + \frac{M_{FE}-M_{EF}}{h_1} = \frac{4.88}{6}(9,420+2\times4,640) + \frac{-15510+14,580}{4.88}$$
$$= 15220 - 190 = 15,030 \text{〃}$$

$$S_{FE} = \frac{(q_1+q_3)h_1}{2} - S_{EF} = \frac{(4640+9,420)4.88}{2} - 15,030 = -19,270 \text{〃}$$

$$S_{FG} = R_{FG} + \frac{M_{GF}-M_{FG}}{l} = \frac{4.53}{6}(11,100+2\times9,630) + \frac{-17,260+15,510}{4.53}$$
$$= 22,910 - 390 = 22,520 \text{〃}$$

$$S_{GF} = \frac{(P_2'+P_3)l}{2} - S_{FG} = \frac{(11,100+9,630)}{2}\times4.53 - 22,520 = -24,480 \text{〃}$$

$$S_{GH} = R_{GH} + \frac{M_{HG}-M_{GH}}{h_2} = \frac{1.00}{6}(10,400+2\times9,420) + \frac{-19,350+8,240}{1.00} = -6,240 \text{〃}$$

$$S_{HG} = \frac{(q_3+q_4)h_2}{2} - S_{GH} = \frac{(10,400+9,420)\times1.00}{2} - 6,240 = (9,910-6,240) = -3,670 \text{〃}$$

$$S_{HA} = R_{HA} + \frac{M_{AH}-M_{HA}}{l} = \frac{4.53}{6}(12,570+2\times11,100) + \frac{-17,820+19,350}{4.53}$$
$$= 26240 + 340 = 26,580 \text{〃}$$

$$S_{AH} = \frac{(P_1+P_2)l}{2} - S_{HA} = \frac{(12,570+11,100)\times4.53}{2} - 26,580 = -27,020 \text{〃}$$

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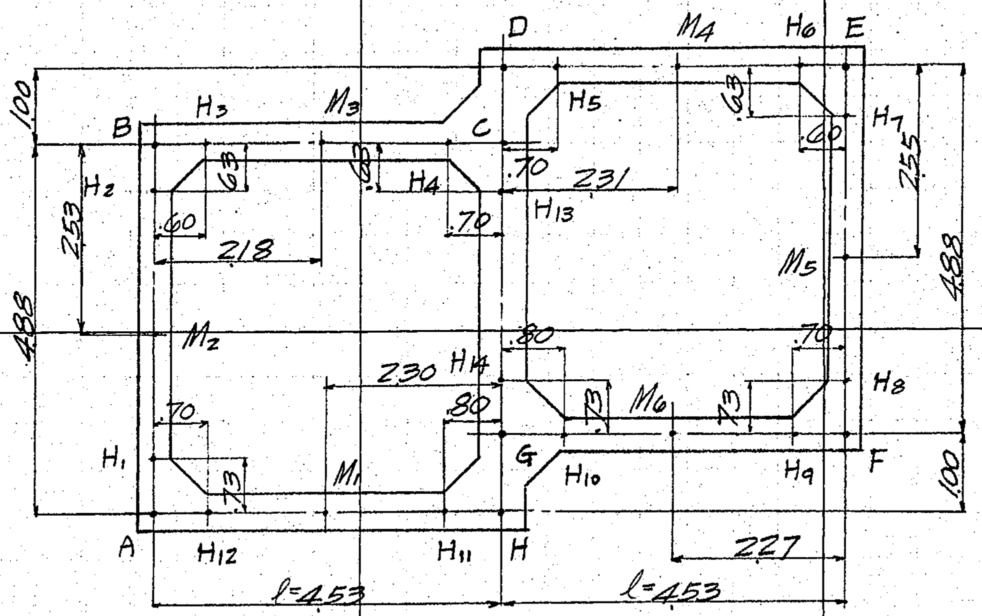
CALCULATIONS FOR

上下二段式函型隧道断面A7號土被4.5m

Moment, shear and thrust at each point.



Bottom slab.

at (M1)

general equation of shear

$S = S_{HA} + \frac{(P_1 - P_2)}{2l} x^2 + P_2 x$

$= 26{,}580 - \frac{(12{,}570 - 11{,}100)}{2 \times 4.53} x^2 - 11{,}100 x$

$= 26{,}580 - 11{,}100 x - 162 x^2$

point of zero shear

$26{,}580 - 11{,}100 x - 162 x^2 = 0$

$x = 2.30^m$

moment $x = 2.30$

$M_s = 26{,}230 x - 54 x^3 - 5{,}550 x^2$

$= 26{,}230 \times 2.30 - 54 \times 2.30^3 - 5{,}550 \times 2.30^2$

$= 30{,}310$ kgm

shear

$S = 0$

thrust

$N = 21{,}710$ kgs

$-17{,}820$

$(19{,}350 - 17{,}820) \times \frac{2.23}{4.53} = -750$

M_s $+30{,}310$

$M = +11{,}740$ kgm

at (H11)

moment $x = 0.80$

$-17{,}820$

$(19{,}350 - 17{,}820) \times \frac{3.73}{4.53} = -1{,}260$

M_s $+17{,}410$

$M = -1{,}670$ kgm

shear

26,580

$11{,}100 \times 0.80 = -8{,}880$

$162 \times 0.80^2 = -100$

$S = 17{,}600$ kgs

thrust $N = 21{,}710$ kgs

at (H12)

moment $x = 3.83$

$-17{,}820$

$1{,}530 \times \frac{0.70}{4.53} = -240$

$M_s = +16{,}070$

$M = -1{,}990$ kgm

shear

26,580

$11{,}100 \times 3.83 = -42{,}500$

$162 \times 3.83^2 = -2{,}380$

$S = -18{,}300$ kgs

thrust $N = 21{,}710$ kgs

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CALCULATIONS FOR

上下二段式函型隧道断面A_7號土被4.5^m

at (M6)

General equation of shear

$S = S_{FG} + \frac{(P_2-P_3)x^2}{2l} + P_3 x$

$= 22{,}520 - \frac{1470}{2\times 4.53}x^2 - 9630x$

$= 22{,}520 - 9{,}630x - 162x^2$

Point of zero shear

$162x^2 + 9{,}630x - 22{,}520 = 0$

$x = 2.27$

Moment $x = 2.27$ m

$M_s = 22920x - 54x^3 - 4815x^2$

$= 22920\times 2.27 - 54\times 2.27^3 - 4815\times 2.27^2$

$= 26{,}590$ kgm

shear $S = 0$

$-15{,}510$

$(17{,}260 - 15{,}510)\times\frac{2.27}{4.53} = -880$

$M_s = 26{,}590$

$M = 10{,}200$ kgm

thrust $N = 19{,}270$ kgs

at (H9)

Moment $x = 0.70$ m

$-15{,}510$

$1750\times\frac{0.70}{4.53} = -270$

$M_s = 13660$

$M = -2{,}120$ kgm

shear

$22{,}520$

$9{,}630\times 0.70 = -6{,}740$

$162\times 0.70^2 = -80$

$S = 15{,}700$ kgs

thrust $N = 19{,}270$ kgs

at (H10)

Moment $x = 3.73$ m

$-15{,}510$

$1{,}750\times\frac{3.73}{4.53} = -1{,}440$

$M_s = 15{,}700$

$M = -1{,}250$ kgm

shear

$22{,}520$

$9{,}630\times 3.73 = -35{,}920$

$162\times 3.73^2 = -2{,}250$

$S = -15{,}650$ kgs

thrust $N = 19{,}270$ kgs

Top slab

at (M3)

Moment $x = 2.18$ m

$M_s = 27{,}400x - 6{,}050x^2$

$= 27{,}400\times 2.18 - 6{,}050\times 2.18^2 = 30{,}950$ kgm

shear $S = 0$

3950

$-16{,}810$

$(20{,}760 - 16{,}810)\times\frac{2.18}{4.53} = -1{,}900$

$M_s = 30950$

$M = 12{,}240$ kgm

thrust $N = 17{,}390$ kgs

at (H3)

Moment $x = 0.60$ m

$-16{,}810$

$3{,}950\times\frac{0.60}{4.53} = -520$

$M_s = 11{,}910$

$M = -5{,}420$ kgm

shear

$26{,}390$

$12{,}100\times 0.60 = -7{,}260$

$S = 19{,}130$ kgs

thrust $N = 17{,}390$ kgs

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CALCULATIONS FOR
上下二段式函型隧道断面A7號土被4.5m

at (H4)

moment $x = 3.83$ m

$$3950 \times \frac{383}{453} = -3340$$

-16810
- 3340
Ms = 16220
M = - 3930 kgm

shear

-28410
$12100 \times 0.70 =$ + 8470
S = - 19940 kg

thrust N = 17390 kg

at (M4)

moment $x = 2.31$ m

$M_s = 22880x - 5050x^2$
$= 22880 \times 2.31 - 5050 \times 2.31^2$
$= 25890$ kgm

1890
-14580
$(16470-14580) \times \frac{222}{453} = -930$
Ms = 25890
M = 10380 kgm

shear S = 0

thrust N = 15030 kg

at (H5)

moment $x = 0.70$ m

-14580
$1890 \times \frac{383}{453} = -1600$
Ms = 13550
M = - 2630 kgm

shear

23320
$10100 \times 0.70 =$ - 7070
S = 16250 kg

thrust N = 15030 kg

at (H6)

moment $x = 3.93$ m

-14580
$1890 \times \frac{0.60}{4.53} = -250$
Ms = 11910
M = -2920 kgm

shear

-22480
$10100 \times 0.60 =$ + 6060
S = -16420 kg

thrust N = 15030 kg

Side wall.

at (M2)

general equation of shear

$$S = S_{BA} + \frac{(q_4 - q_2)}{2h}x^2 - q_2 x$$
$$= 17390 - \frac{(10400-5620)}{2 \times 4.88}x^2 - 5620x$$
$$= 17390 - 5620x - 490x^2$$

Point of zero shear
$17390 - 5620x - 490x^2 = 0$
$x = 2.53$ m

Moment $x = 2.53$ m

$M_s = 17600x - 163x^3 - 2810x^2$
$= 17600 \times 2.53 - 163 \times 2.53^3 - 2810 \times 2.53^2$
$= 23880$ kgm

-16810
$(17820-16810) \times \frac{253}{488} = -520$
Ms = 23880
M = 6550 kgm

shear S = 0

thrust N = 26390 kg

at (H1)

moment $x = 4.15$ m

-16810
$1010 \times \frac{415}{488} = -860$
Ms = 13050
M = - 4620 kgm

shear

-17390
$5620 \times 4.15 =$ + 23330
$490 \times 4.15^2 =$ + 8440
S = 14380 kg

thrust N = 26390 kg

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CALCULATIONS FOR

上下二段式函型隧道断面A7號土被4.5m

at (H2)

moment $x = 0.63m$

-16810
$1010 \times \frac{0.63}{4.88} = -130$
$M_s = 9930$
$M = -7010$ kgm

shear
-17390
$5620 \times 0.63 = +3540$
$490 \times 0.63^2 = +190$
$S = -13660$ kgs

thrust $N = 26390$ kgs

at (M5)

general equation of shear

$S = S_{EF} + \frac{(8_3-8_1)}{2h_1}x^2 + 8_1 x$
$= 15030 - \frac{(9420-4640)}{2 \times 4.88}x^2 - 4640x$
$= 15030 - 4640x - 490x^2$

Point of zero shear
$15030 - 4640x - 490x^2 = 0$
$x = 2.55m$

moment $x = 2.55m$
$M_s = 15200x - 163x^3 - 2320x^2$
$= 15200 \times 2.55 - 163 \times 2.55^3 - 2320 \times 2.55^2$
$= 20990$ kgm

930
-14580
$(15510 - 14580) \times \frac{2.55}{4.88} = -490$
$M_s = 20990$
$M = 5920$ kgm

shear $S = 0$

thrust $N = 22480$ kgs

at (H7)

moment $x = 0.63^m$

-14580
$930 \times \frac{0.63}{4.88} = -120$
$M_s = 8620$
$M = -6080$ kgm

shear
15030
$4640 \times 0.63 = -2920$
$490 \times 0.63^2 = -190$
$S = 11920$ kgs

thrust $N = 22480$ kgs

at (H8)

moment $x = 4.15m$

-14580
$930 \times \frac{4.15}{4.88} = -790$
$M_s = 11450$
$M = -3920$ kgm

shear
$+15030$
$4640 \times 4.15 = -19260$
$490 \times 4.15^2 = -8440$
$S = -12670$ kgs

thrust $N = 22480$ kgs

Center wall

at (H13)

moment $x = 0.63m$
$9390 + 9020 = -18410$
$18410 \times \frac{0.63}{3.83} = +3030$
9390
$M = -6360$ kgm

shear $S = 0$

thrust
28410
23320
$N = 51730$ kgs

at (H14)

moment
$18410 \times \frac{0.73}{3.83} = +3510$
-9020
$M = -5510$ kgm

shear $S = 0$

thrust $N = 51730$ kgs

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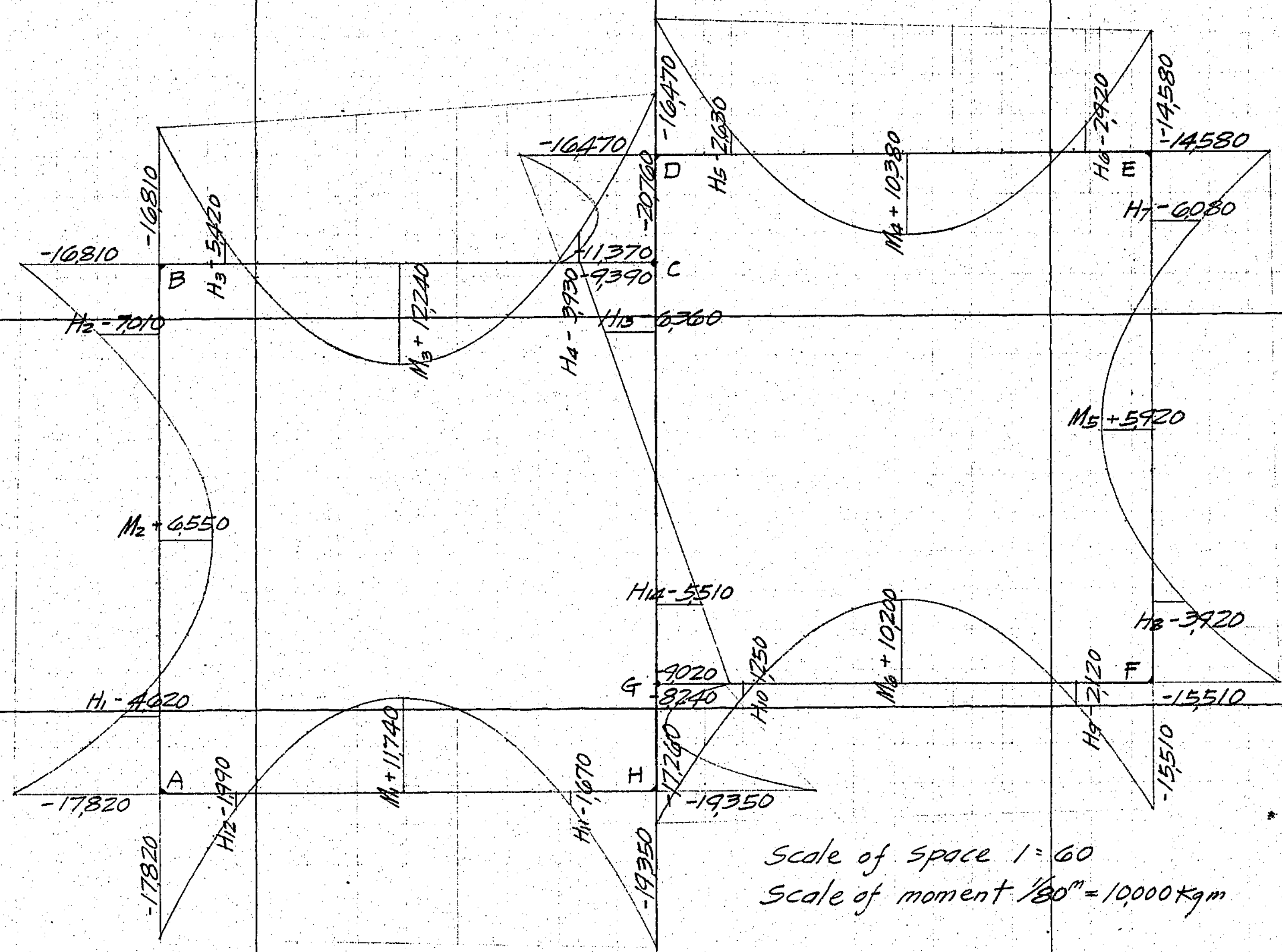
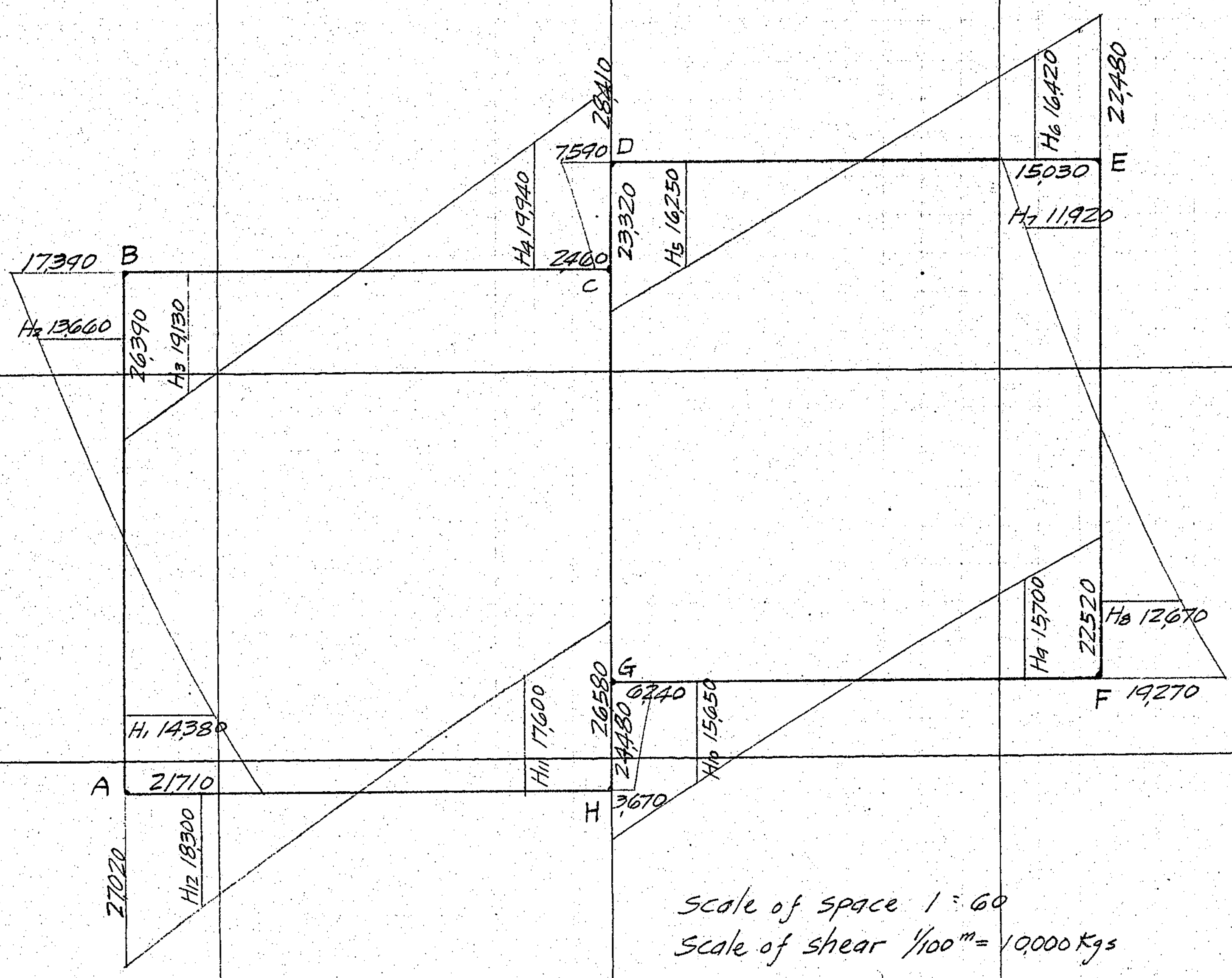
CALCULATIONS FOR

上下二段式函型隧道断面A_7號土被4.5^m

Moment diagram



Shear diagram



増田淳氏関係資料
(独立行政法人 土木研究所蔵)

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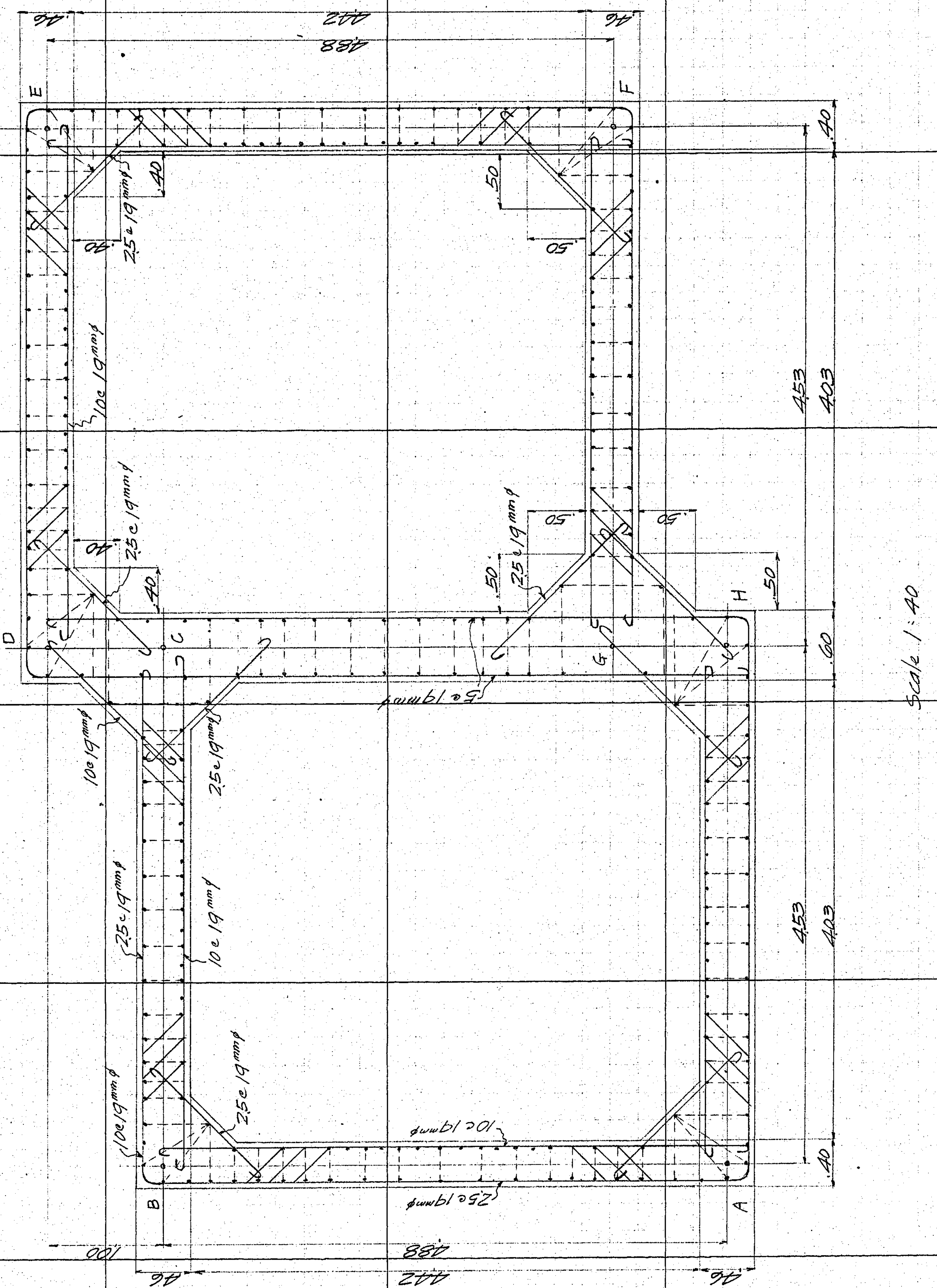
CALCULATIONS FOR

上下二段式函型隧道断面A7號土被4.5m

Assumed cross section and reinforcement for each member.



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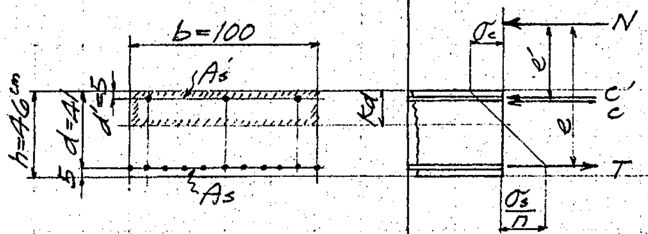
CALCULATIONS FOR

上下二段式函型隧道断面A7號土被4.5m

Unit stress calculations. 柴田直光著,"NOMOGRAM FOR REINFORCED CONCRETE"参照

Top slab BC

at (M3) $M = +12240$ kgm, $N = 17390$ kgs, $S = 0$



$h = 46$ cm, $b = 100$ cm, $d' = 5$ cm, $d = 41$ cm
$A_s = 10 \text{ c } 19^{mm\phi} = 28.4 \text{ cm}^2$, $A_s' = 2.5 \text{ c } 19^{mm\phi} = 7.1 \text{ cm}^2$
$p_0 = \frac{A_s}{bh} = \frac{28.4}{100 \times 46} = 0.00618$
$p_0' = \frac{A_s'}{bh} = \frac{7.1}{100 \times 46} = 0.00154$
$\frac{d}{h} = \frac{41}{46} = 0.891$, $\frac{d'}{h} = \frac{5}{46} = 0.109$
$\frac{u}{h} = 0.524$, $u = 24.1$ cm, $d - u = 16.9$ cm

$\frac{M}{N} = \frac{12240}{17390} \times 100 = 70.4$
16.9
$e = 87.3$ cm
$e' = e - 36 = 51.3$ cm, $\frac{e'}{e} = \frac{51.3}{87.3} = 0.588$

$p = \frac{A_s}{bd} = \frac{28.4}{100 \times 41} = 0.00693$ $\frac{d'}{d} = \frac{5}{41} = 0.122$
$p' = \frac{A_s'}{bd} = \frac{7.1}{100 \times 41} = 0.00173$
$k = 0.43$, $\frac{Ne}{bd^2\sigma_c} = 0.202$

$\sigma_c = \frac{17390 \times 87.3}{0.202 \times 100 \times 41^2} = 44.7$ kg/cm²

$\sigma_s = n\sigma_c \frac{1-k}{k} = 15 \times 44.7 \times \frac{1-0.43}{0.43} = 889$ kg/cm²
$\tau = 0$

at (H3) $M = -5420$ kgm, $N = 17390$ kgs, $S = 19130$ kgs

$h = 46$ cm, $b = 100$ cm, $d' = 5$ cm, $d = 41$ cm
$A_s = 7.5 \text{ c } 19^{mm\phi} = 21.3 \text{ cm}^2$, $A_s' = 2.5 \text{ c } 19^{mm\phi} = 7.1 \text{ cm}^2$
$p_0 = \frac{A_s}{bh} = \frac{21.3}{100 \times 46} = 0.00463$,
$p_0' = \frac{A_s'}{bh} = 0.00154$, $\frac{d}{h} = 0.891$, $\frac{d'}{h} = 0.109$
$\frac{u}{h} = 0.516$, $u = 23.7$ cm, $d - u = 17.3$ cm

$\frac{M}{N} = \frac{5420}{17390} \times 100 = 31.2$
17.3
$e = 48.5$ cm
$e' = e - 36 = 12.5$ cm, $\frac{e'}{e} = \frac{12.5}{48.5} = 0.258$

$p = \frac{A_s}{bd} = \frac{21.3}{100 \times 41} = 0.00519$, $p' = 0.00173$, $\frac{d'}{d} = 0.122$

$k = 0.50$, $\frac{Ne}{bd^2\sigma_c} = 0.226$, $j = 1 - \frac{k}{3} = 1 - 0.167 = 0.833$

$\sigma_c = \frac{17390 \times 48.5}{100 \times 41^2 \times 0.226} = 22.2$ kg/cm²

$\sigma_s = n\sigma_c \frac{1-k}{k} = 15 \times 22.2 \times \frac{1-0.50}{0.50} = 333$ kg/cm²

$\tau = \frac{S}{bjd} = \frac{19130}{100 \times 0.833 \times 41} = 5.6$ kg/cm² use bent up bars

at (H4) $M = -3930$ kgm, $N = 17390$ kgs, $S = 19940$ kgs

$h = 49$ cm, $b = 100$ cm, $d' = 5$ cm, $d = 44$ cm
$A_s = 7.5 \text{ c } 19^{mm\phi} = 21.3 \text{ cm}^2$, $A_s' = 2.5 \text{ c } 19^{mm\phi} = 7.1 \text{ cm}^2$
$p_0 = \frac{21.3}{100 \times 49} = 0.00435$, $p_0' = \frac{7.1}{100 \times 49} = 0.00145$
$\frac{d}{h} = \frac{44}{49} = 0.898$, $\frac{d'}{h} = \frac{5}{49} = 0.102$

$\frac{M}{N} = \frac{3930}{17390} \times 100 = 22.6$ cm
18.7
$e = 41.3$ cm, $e' = e - 39 = 2.3$ cm

$\frac{u}{h} = 0.516$, $u = 25.3$ cm, $d - u = 18.7$ cm

$p = \frac{21.3}{100 \times 44} = 0.00484$ $\frac{e'}{e} = \frac{2.3}{41.3} = 0.056$
$p' = \frac{7.1}{100 \times 44} = 0.00161$
$\frac{d'}{d} = \frac{5}{44} = 0.114$, $k = 0.602$
$j = 1 - \frac{k}{3} = 0.799$, $\frac{Ne}{bd^2\sigma_c} = 0.258$

$\sigma_c = \frac{17390 \times 41.3}{100 \times 44^2 \times 0.258} = 14.4$ kg/cm²
$\sigma_s = 15 \times 14.4 \times \frac{1-0.602}{0.602} = 143$ "
$\tau = \frac{19940}{100 \times 0.799 \times 44} = 5.7$ kg/cm²

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CALCULATIONS FOR

上下二段式函型隧道断面A_7號土被4.5^m

web reinforcement

use 3-set of bent up bars 2.5 - 19$^{mm\phi}$ = 7.1 cm^2
allowable tension for one set = 7.1 × 1200 = 8,520 kgs
vertical shear carried by one set
= 8,520 × sec 45° = 8,520 × 1.4142 = 12,020 kgs
spacing of bent up bars being taken as 20 cm (horizontal)

$\frac{12020}{0.20} = 60,100$ kg/lin. m of vertical shear

at Ⓑ $M = -16,810$ kgm, $N = 17,390$ kgs, $S = 26,390$ kgs

$h = 66$ cm, $b = 100$ cm, $d' = 5$ cm, $d = 61$ cm
$A_s = 10 \times 19^{mm\phi} = 28.4$ cm^2, $A_s' = 2.5 \times 19^{mm\phi} = 7.1$ cm^2
$p_0 = \frac{A_s}{bh} = \frac{28.4}{100 \times 66} = 0.00440$
$p_0' = \frac{A_s'}{bh} = \frac{7.1}{100 \times 66} = 0.00108$
$\frac{d}{h} = \frac{61}{66} = 0.924$, $\frac{d'}{h} = \frac{5}{66} = 0.076$
$\frac{u}{h} = 0.520$ $u = 34.3$ cm, $d - u = 61 - 34.3 = 26.7$ cm

$\frac{M}{N} = \frac{16810}{17390} \times 100 = 96.7$ $e' = e - 56 = 67.4$ cm, $\frac{e'}{e} = \frac{67.4}{123.4} = 0.546$
$\quad 26.7$
$e = 123.4$ cm
$p = \frac{A_s}{bd} = \frac{28.4}{100 \times 61} = 0.00466$ $\frac{d'}{d} = \frac{5}{61} = 0.082$
$p' = \frac{A_s'}{bd} = \frac{7.1}{100 \times 61} = 0.00116$
$k = 0.378$, $j = 1 - \frac{k}{3} = 0.874$, $\frac{Ne}{bd^2\sigma_c} = 0.177$

$\sigma_c = \frac{17390 \times 123.4}{100 \times 61^2 \times 0.177} = 32.6$ kg/cm^2

$\sigma_s = 15 \times 32.6 \times \frac{1 - 0.378}{0.378} = 805$ kg/cm^2

$\tau = \frac{26390}{100 \times 0.874 \times 61} = 4.9$ kg/cm^2 use bent up bars

at Ⓒ $M = -20,760$ kgm, $N = 17,390$ kgs $S = 28,410$ kgs

$h = 96$ cm, $b = 100$ cm, $d' = 5$ cm, $d = 91$ cm
$A_s = 10 \times 19^{mm\phi} = 28.4$ cm^2, $A_s' = 2.5 \times 19^{mm\phi} = 7.1$ cm^2
$p_0 = \frac{A_s}{bh} = \frac{28.4}{100 \times 96} = 0.00296$
$p_0' = \frac{A_s'}{bh} = \frac{7.1}{100 \times 96} = 0.00074$
$\frac{d}{h} = \frac{91}{96} = 0.948$, $\frac{d'}{h} = \frac{5}{96} = 0.052$
$\frac{u}{h} = 0.514$, $u = 49.4$ cm, $d - u = 91 - 49.4 = 41.6$ cm

$\frac{M}{N} = \frac{20760}{17390} \times 100 = 119.4$
$\quad 41.6$ $e' = e - 86 = 75.0$ cm, $\frac{e'}{e} = \frac{75.0}{161.0} = 0.466$
$e = 161.0$ cm
$p = \frac{A_s}{bd} = \frac{28.4}{100 \times 91} = 0.00312$ $\frac{d'}{d} = \frac{5}{91} = 0.055$
$p' = \frac{A_s'}{bd} = \frac{7.1}{100 \times 91} = 0.00078$
$k = 0.345$, $j = 1 - \frac{k}{3} = 0.885$, $\frac{Ne}{bd^2\sigma_c} = 0.163$

$\sigma_c = \frac{17390 \times 161.0}{100 \times 91^2 \times 0.163} = 20.7$ kg/cm^2

$\sigma_s = 15 \times 20.7 \times \frac{1 - 0.345}{0.345} = 590$ kg/cm^2

$\tau = \frac{28410}{100 \times 0.885 \times 91} = 3.5$ kg/cm^2

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CALCULATIONS FOR

上下二段式函型隧道断面A_7號土被4.5ᵐ

Top slab DE

at (M4) . $M = +10,380$ kgm, $N = 15,030$ kgs, $S = 0$

$h = 46$ cm, $b = 100$ cm, $d' = 5$ cm, $d = 41$ cm

$A_s = 10 \text{c} 19^{mm\phi} = 28.4\ cm^2$, $A_s' = 2.5 \text{c} 19^{mm\phi} = 7.1\ cm^2$

$u = 24.1$ cm, $d - u = 16.9$ cm

$\frac{M}{N} = \frac{10,380}{15,030} \times 100 = 69.1$
$\underline{16.9}$
$e = 86.0$ cm

$e' = e - 36 = 50.0$ cm, $\frac{e'}{e} = \frac{50.0}{86.0} = 0.582$, $\frac{d'}{d} = 0.122$

$P = 0.00693$, $P' = 0.00173$, $k = 0.43$, $\frac{Ne}{bd^2\sigma_c} = 0.202$

$\sigma_c = \frac{15,030 \times 86.0}{100 \times 41^2 \times 0.202} = 38.1\ kg/cm^2$

$\sigma_s = 15 \text{c} 38.1 \times \frac{1 - 0.43}{0.43} = 758\ kg/cm^2$

$\tau = 0$

at (H5) $M = -2,630$ kgm, $N = 15,030$ kgs, $S = 16,250$ kgs

$h = 46$ cm, $b = 100$ cm, $d' = 5$ cm, $d = 41$ cm

$A_s = 7.5 \text{c} 19^{mm\phi} = 21.3\ cm^2$, $A_s' = 2.5 \text{c} 19^{mm\phi} = 7.1\ cm^2$

$u = 23.7$ cm $d - u = 17.3$ cm

$\frac{M}{N} = \frac{2630}{15,030} \times 100 = 17.5$ cm
$\underline{17.3}$
$e = 34.8$ cm

$e' = 36 - 34.8 = 1.2$ cm

$\frac{e'}{e} = \frac{1.2}{34.8} = 0.035$

$P = 0.00519$, $P' = 0.00173$, $\frac{d'}{d} = 0.122$, $k = 0.70$, $j = 1 - \frac{k}{3} = 0.767$

$\frac{Ne}{bd^2\sigma_c} = 0.288$

$\sigma_c = \frac{15,030 \times 34.8}{100 \times 41^2 \times 0.288} = 10.8\ kg/cm^2$

$\sigma_s = 15 \times 10.8 \times \frac{1 - 0.767}{0.767} = 49.2$ 〃

$\tau = \frac{16250}{100 \times 0.767 \times 41} = 5.6$ 〃 use bent up bars

at (H6) . $M = -2,920$ kgm, $N = 15,030$ kgs, $S = 16,420$ kgs

$h = 46$ cm, $b = 100$ cm, $d' = 5$ cm, $d = 41$ cm

$A_s = 7.5 \text{c} 19^{mm\phi} = 21.3\ cm^2$, $A_s' = 2.5 \text{c} 19^{mm\phi} = 7.1\ cm^2$

$u = 23.7$ cm, $d - u = 17.3$ cm

$\frac{M}{N} = \frac{2,920}{15,030} \times 100 = 19.4$
$\underline{17.3}$
$e = 36.7$ cm

$e' = e - 36 = 0.7$ cm, $\frac{e'}{e} = \frac{0.7}{36.7} = 0.019$

$P = 0.00519$, $P' = 0.00173$, $\frac{d'}{d} = 0.122$, $k = 0.648$, $j = 1 - \frac{k}{3} = 0.784$

$\frac{Ne}{bd^2\sigma_c} = 0.274$

$\sigma_c = \frac{15,030 \times 36.7}{100 \times 41^2 \times 0.274} = 12.0\ kg/cm^2$

$\sigma_s = 15 \times 12.0 \times \frac{1 - 0.648}{0.648} = 97.8\ kg/cm^2$

$\tau = \frac{16420}{100 \times 0.784 \times 41} = 5.1$ 〃 use bent up bars

at (D) $M = -16,470$ kgm, $N = 15,030$ kgs, $S = 23,320$ kgs

$h = 69$ cm, $b = 100$ cm, $d' = 5$ cm, $d = 64$ cm

$A_s = 10 \text{c} 19^{mm\phi} = 28.4\ cm^2$, $A_s' = 2.5 \text{c} 19^{mm\phi} = 7.1\ cm^2$

$P_0 = \frac{A_s}{bh} = \frac{28.4}{100 \times 69} = 0.00412$

$P_0' = \frac{A_s'}{bh} = \frac{7.1}{100 \times 69} = 0.00103$

$\frac{d}{h} = \frac{64}{69} = 0.928$, $\frac{d'}{h} = \frac{5}{69} = 0.072$

$\frac{u}{h} = 0.518$, $u = 35.8$ cm, $d - u = 28.2$ cm

$\frac{M}{N} = \frac{16470}{15,030} \times 100 = 109.6$
$\underline{28.2}$
$e = 137.8$

$e' = e - 59 = 78.8$ cm, $\frac{e'}{e} = 0.572$

$P = \frac{A_s}{bd} = \frac{28.4}{100 \times 64} = 0.00444$ $\frac{d'}{d} = 0.078$

$P' = \frac{A_s'}{bd} = \frac{7.1}{100 \times 64} = 0.00111$

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CALCULATIONS FOR

上下二段式函型隧道断面A_7號土被4.5m

$k = 0.368$, $j = 1 - \frac{k}{3} = 0.877$, $\frac{Ne}{bd^2\sigma_c} = 0.175$

$\sigma_c = \frac{15030 \times 137.8}{100 \times 64^2 \times 0.175} = 28.9$ kg/cm²

$\sigma_s = 15 \times 28.9 \times \frac{1-0.368}{0.368} = 732$ kg/cm²

$\tau = \frac{23320}{100 \times 0.877 \times 64} = 4.2$ kg/cm²

at (E) $M = -14{,}580$ kgm, $N = 15{,}030$ kg, $S = 22{,}480$ kg

$h = 66$ cm, $b = 100$ cm, $d' = 5$ cm, $d = 61$ cm

$A_s = 10 \text{c} 19^{mm\phi} = 28.4$ cm², $A_s' = 25 \text{c} 19^{mm\phi} = 7.1$ cm²

$u = 34.3$ cm, $d - u = 26.7$ cm

$\frac{M}{N} = \frac{14580}{15030} \times 100 = 97.0$

$\underline{26.7}$

$e = 123.7$ cm

$e' = e - 56 = 67.7$ cm $\quad \frac{e'}{e} = 0.547$

$p = 0.00466$, $p' = 0.00116$, $\frac{d'}{d} = 0.082$

$k = 0.378$, $j = 0.874$, $\frac{Ne}{bd^2\sigma_c} = 0.177$

$\sigma_c = \frac{15030 \times 123.7}{100 \times 61^2 \times 0.177} = 28.2$ kg/cm²

$\sigma_s = 15 \times 28.2 \times \frac{1-0.378}{0.378} = 696$ 〃

$\tau = \frac{22480}{100 \times 0.874 \times 61} = 4.2$ kg/cm²

Bottom slab AH

at (M_1) $M = +11{,}740$ kgm, $N = 21{,}710$ kg, $S = 0$

$h = 46$ cm, $b = 100$ cm, $d' = 5$ cm, $d = 41$ cm

$A_s = 10 \text{c} 19^{mm\phi} = 28.4$ cm², $A_s' = 25 \text{c} 19^{mm\phi} = 7.1$ cm²

$u = 24.1$ cm, $d - u = 16.9$ cm

$\frac{M}{N} = \frac{11740}{21710} \times 100 = 54.1$

$\underline{16.9}$

$e = 71.0$ cm

$e' = e - 36 = 35.0$ cm $\quad \frac{e'}{e} = 0.493$

$p = 0.00693$, $p' = 0.00173$, $\frac{d'}{d} = 0.122$, $k = 0.455$, $\frac{Ne}{bd^2\sigma_c} = 0.211$

$\sigma_c = \frac{21710 \times 71.0}{100 \times 41^2 \times 0.211} = 43.5$ kg/cm²

$\sigma_s = 15 \times 43.5 \times \frac{1-0.455}{0.455} = 782$ kg/cm²

$\tau = 0$

at (H_{11}) $M = -1{,}670$ kgm, $N = 21{,}710$ kg, $S = 17{,}600$ kg

$h = 46$ cm, $b = 100$ cm, $d' = 5$ cm, $d = 41$ cm

$A_s = 7.5 \text{c} 19^{mm\phi} = 21.3$ cm², $A_s' = 25 \text{c} 19^{mm\phi} = 7.1$ cm²

$u = 23.7$ cm, $d - u = 17.3$ cm

$\frac{M}{N} = \frac{1670}{21710} \times 100 = 7.7$ cm $= e$

$46 \times 100 = 4600$
$15 \times 28.4 = \underline{426}$
$A_i = 5026$ cm²

$\frac{100 \times 46^3}{12} = 811{,}000$
$15 \times 21.3 \times 17.3^2 = 95{,}600$
$15 \times 7.1 \times 18.7^2 = \underline{27{,}300}$
$I_i = 933{,}900$ cm⁴

$\sigma_c = \frac{N}{A_i} + \frac{Ne}{I_i} u = \frac{21710}{5026} + \frac{21710 \times 7.7}{933900} \times 23.7 = 8.6$ kg/cm²

$\sigma_c' = \frac{21710}{5026} - \frac{21710 \times 7.7}{933900} \times 22.3 = 0.3$ kg/cm²

$\tau = \frac{17600}{100 \times 46} = 3.8$ kg/cm²

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CALCULATIONS FOR

上下二段式函型隧道断面A_7號土被4.5m

at (H12) $M = -1990$ kgm, $N = 21710$ kgs, $S = 18300$ kgs

$h = 46$ cm, $b = 100$ cm, $d' = 5$ cm, $d = 41$ cm

$A_s = 7.5 \text{c} 19^{mm\phi} = 21.3 \text{ cm}^2$, $A_s' = 2.5 \text{c} 19^{mm\phi} = 7.1 \text{ cm}^2$

$u = 23.7$ cm, $d - u = 17.3$ cm

$\frac{M}{N} = \frac{1990}{21710} \times 100 = 9.2 \text{ cm} = e$

$A_i = 5026 \text{ cm}^2$, $I_i = 933900 \text{ cm}^4$

$\sigma_c = \frac{N}{A_i} + \frac{Ne}{I_i}u = \frac{21710}{5026} + \frac{21710 \times 9.2}{933900} \times 23.7 = 9.4 \text{ kg/cm}^2$

$\sigma_c' = \frac{21710}{5026} - \frac{21710 \times 9.2}{933900} \times 22.3 = +0.5 \text{ kg/cm}^2$

$\sigma_s = 15 \text{c} 0.5 = 7.5 \text{ kg/cm}^2$ $\tau = \frac{18300}{100 \times 46} = 4.0 \text{ kg/cm}^2$

Bottom slab FG

at (M6) $M = +10200$ kgm, $N = 19270$ kgs, $S = 0$

$h = 46$ cm, $b = 100$ cm, $d' = 5$ cm, $d = 41$ cm

$A_s = 10 \text{c} 19^{mm\phi} = 28.4 \text{ cm}^2$, $A_s' = 2.5 \text{c} 19^{mm\phi} = 7.1 \text{ cm}^2$

$u = 24.1$ cm, $d - u = 16.9$ cm

$\frac{M}{N} = \frac{10200}{19270} \times 100 = 53.0$

$\underline{16.9}$

$e = 69.9$ cm $\qquad e' = e - 36 = 33.9$ cm, $\frac{e'}{e} = 0.485$

$P = 0.00693$, $P' = 0.00173$, $\frac{d'}{d} = 0.122$, $k = 0.458$, $\frac{Ne}{bd^2\sigma_c} = 0.212$

$\sigma_c = \frac{19270 \times 69.9}{100 \times 41^2 \times 0.212} = 37.8 \text{ kg/cm}^2$

$\sigma_s = 15 \times 37.8 \times \frac{1 - 0.458}{0.458} = 664 \text{ kg/cm}^2$

$\tau = 0$

at (H9) $M = -2120$ kgm, $N = 19270$ kgs, $S = 15700$ kgs

$h = 46$ cm, $b = 100$ cm, $d' = 5$ cm, $d = 41$ cm

$A_s = 7.5 \text{c} 19^{mm\phi} = 21.3 \text{ cm}^2$, $A_s' = 2.5 \text{c} 19^{mm\phi} = 7.1 \text{ cm}^2$

$u = 23.7$ cm, $d - u = 17.3$ cm

$\frac{M}{N} = \frac{2120}{19270} \times 100 = 11.0 \text{ cm} = e$

$A_i = 5026 \text{ cm}^2$, $I_i = 933900 \text{ cm}^4$

$\sigma_c = \frac{N}{A_i} + \frac{Ne}{I_i}u = \frac{19270}{5026} + \frac{19270 \times 11.0}{933900} \times 23.7 = 9.2 \text{ kg/cm}^2$

$\sigma_c' = \frac{19270}{5026} - \frac{19270 \times 11.0}{933900} \times 22.3 = +1.2 \text{ kg/cm}^2$

$\sigma_s = 15 \text{c} 1.2 = 18.0 \text{ kg/cm}^2$ $\tau = \frac{15700}{100 \times 46} = 3.4 \text{ kg/cm}^2$

at (H10) $M = -1250$ kgm, $N = 19270$ kgs, $S = 15650$ kgs

$h = 49$ cm, $b = 100$ cm, $d' = 5$ cm, $d = 44$ cm

$A_s = 7.5 \text{c} 19^{mm\phi} = 21.3 \text{ cm}^2$, $A_s' = 2.5 \text{c} 19^{mm\phi} = 7.1 \text{ cm}^2$

$u = 25.3$ cm, $d - u = 18.7$ cm

$\frac{M}{N} = \frac{1250}{19270} \times 100 = 6.5 \text{ cm} = e$

$49 \times 100 = 4900$ $\qquad \frac{100 \times 49^3}{12} = 980000$

$15 \text{c} 28.4 = \underline{426}$ $\qquad 15 \times 21.3 \times 18.7^2 = 111700$

$A_i = 5326 \text{ cm}^2$ $\qquad 15 \times 7.1 \times 20.3^2 = \underline{43900}$

$I_i = 1135600 \text{ cm}^4$

$\sigma_c = \frac{N}{A_i} + \frac{Ne}{I_i}u = \frac{19270}{5326} + \frac{19270 \times 6.5}{1135600} \times 25.3 = 6.4 \text{ kg/cm}^2$

$\sigma_c' = \frac{19270}{5326} - \frac{19270 \times 6.5}{1135600} \times 23.7 = 1.0 \text{ kg/cm}^2$

$\tau = \frac{15650}{100 \times 49} = 3.2 \text{ kg/cm}^2$

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CALCULATIONS FOR

上下二段式函型隧道断面A_7號土被4.5^m

at Ⓐ $M = -17{,}820\,kgm,\ N = 21{,}710\,kgs,\ S = 27{,}020\,kgs$

$h = 69\,cm,\ b = 100\,cm,\ d' = 5\,cm,\ d = 64\,cm$

$A_s = 10 e\ 19^{mm\phi} = 28.4\,cm^2,\ A_s' = 2.5 e\ 19^{mm\phi} = 7.1\,cm^2$

$u = 35.8\,cm,\ d - u = 28.2\,cm$

$\frac{M}{N} = \frac{17820}{21{,}710} \times 100 = 82.1$
$\quad\quad 28.2$
$e = 110.3\,cm$

$e' = e - 59 = 51.3\,cm,\quad \frac{e'}{e} = 0.465$

$P = 0.00444,\ P' = 0.00111,\quad \frac{d'}{d} = 0.078,\quad k = 0.395,\quad j = 1 - \frac{k}{3} = 0.868$

$\frac{Ne}{bd^2\sigma_c} = 0.184$

$\sigma_c = \frac{21{,}710 \times 110.3}{100 \times 64^2 \times 0.184} = 31.8\ kg/cm^2$

$\sigma_s = 15 \times 31.8 \times \frac{1 - 0.395}{0.395} = 730\ kg/cm^2$

$\tau = \frac{27{,}020}{100 \times 0.868 \times 64} = 4.9\ kg/cm^2$ use bent up bars

at Ⓗ $M = -19{,}350\,kgm,\ N = 21{,}710\,kgs,\ S = 26{,}580\,kgs$

$h = 73\,cm,\ b = 100\,cm,\ d' = 5\,cm,\ d = 68\,cm$

$A_s = 10 e\ 19^{mm\phi} = 28.4\,cm^2,\ A_s' = 2.5 e\ 19^{mm\phi} = 7.1\,cm^2$

~~$P_0 = \frac{A_s}{bh} = \frac{28.4}{100 \times 73} = 0.00389$~~

$P_0' = \frac{A_s'}{bh} = \frac{7.1}{100 \times 73} = 0.00097$

$\frac{d}{h} = \frac{68}{73} = 0.934,\quad \frac{d'}{h} = \frac{5}{73} = 0.068$

$\frac{u}{h} = 0.518,\quad u = 37.8\,cm\quad d - u = 30.2\,cm$

$\frac{M}{N} = \frac{19350}{21{,}710} \times 100 = 89.1$
$\quad\quad 30.2$
$e = 119.3\,cm$

$e' = e - 63 = 56.3\,cm,\quad \frac{e'}{e} = 0.472$

$P = \frac{A_s}{bd} = \frac{28.4}{100 \times 68} = 0.00418$

~~$P' = \frac{A_s'}{bd} = \frac{7.1}{100 \times 68} = 0.00104$~~

$\frac{d'}{d} = 0.074,\quad k = 0.383,\quad j = 1 - \frac{k}{3} = 0.872$

$\frac{Ne}{bd^2\sigma_c} = 0.181$

$\sigma_c = \frac{21{,}710 \times 119.3}{100 \times 68^2 \times 0.181} = 31.0\ kg/cm^2$

$\sigma_s = 15 \times 31.0 \times \frac{1 - 0.383}{0.383} = 749\ kg/cm^2$

$\tau = \frac{26{,}580}{100 \times 0.872 \times 68} = 4.5\ kg/cm^2$

at Ⓕ $M = -15{,}510\,kgm,\ N = 19{,}270\,kgs,\ S = 22{,}520\,kgs$

$h = 69\,cm,\ b = 100\,cm,\ d' = 5\,cm,\ d = 64\,cm$

$A_s = 10 e\ 19^{mm\phi} = 28.4\,cm^2,\ A_s' = 2.5 e\ 19^{mm\phi} = 7.1\,cm^2$

$u = 35.8\,cm,\ d - u = 28.2\,cm$

$\frac{M}{N} = \frac{15510}{19{,}270} \times 100 = 80.5$
$\quad\quad 28.2$
$e = 108.7\,cm$

$e' = e - 59 = 49.7\,cm,\quad \frac{e'}{e} = 0.457$

$\frac{d'}{d} = 0.078,\quad k = 0.398,\quad j = 1 - \frac{k}{3} = 0.867$

$P = 0.00444,\ P' = 0.00111,$

$\frac{Ne}{bd^2\sigma_c} = 0.186$

$\sigma_c = \frac{19{,}270 \times 108.7}{100 \times 64^2 \times 0.186} = 27.5\ kg/cm^2$

$\sigma_s = 15 \times 27.5 \times \frac{1 - 0.398}{0.398} = 624\ kg/cm^2$

$\tau = \frac{22{,}520}{100 \times 0.867 \times 64} = 4.1\ kg/cm^2$

at Ⓖ $M = -17{,}260\,kgm,\ N = 19{,}270\,kgs,\ S = 24{,}480\,kgs$

$h = 99\,cm,\ b = 100\,cm,\ d' = 5\,cm,\ d = 94\,cm$

$A_s = 10 e\ 19^{mm\phi} = 28.4\,cm^2,\ A_s' = 2.5 e\ 19^{mm\phi} = 7.1\,cm^2$

$P_0 = \frac{A_s}{bh} = \frac{28.4}{100 \times 99} = 0.00287$

$P_0' = \frac{A_s'}{bh} = \frac{7.1}{100 \times 99} = 0.00072$

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CALCULATIONS FOR

上下二段式函型隧道断面A7號土被4.5m

$\frac{d}{h}=0.950$, $\frac{d'}{h}=0.091$

$\frac{u}{h}=0.514$ $u=50.9$ cm ; $d-u=94-50.9=43.1$ cm

$\frac{M}{N}=\frac{17260}{19270}\times 100=89.6$

$\quad 43.1$

$e=132.7$ cm

$e'=e-89=43.7$ cm , $\frac{e'}{e}=0.329$

$\frac{d'}{d}=\frac{5}{94}=0.053$, $k=0.379$, $j=1-\frac{k}{3}=0.874$

$p=\frac{A_s}{bd}=\frac{28.4}{100\times 94}=0.00302$ $\frac{Ne}{bd^2\sigma_c}=0.173$

$p'=\frac{A_s'}{bd}=\frac{7.1}{100\times 94}=0.00076$

$\sigma_c=\frac{19270\times 132.7}{100\times 94^2\times 0.173}=16.7$ kg/cm²

$\sigma_s=15\times 16.7\times\frac{1-0.379}{0.379}=410$ kg/cm²

$\tau=\frac{24480}{100\times 0.874\times 94}=3.0$ 〃

Side wall AB

at (M2) $M=+6{,}550$ kgm , $N=26{,}390$ kgs , $S=0$

$h=40$cm , $b=100$cm , $d'=5$cm , $d=35$cm

$A_s=10$ c $19^{mm\phi}=28.4$ cm² , $A_s'=2.5$ c $19^{mm\phi}=7.1$ cm²

$P_o=\frac{A_s}{bh}=\frac{28.4}{100\times 40}=0.00710$

$P_o'=\frac{A_s'}{bh}=\frac{7.1}{100\times 40}=0.00178$

$\frac{d}{h}=\frac{35}{40}=0.875$, $\frac{d'}{h}=\frac{5}{40}=0.125$

$\frac{M}{N}=\frac{6550}{26390}\times 100=28.4$

$\quad 14.0$

$e=42.4$ cm

$\frac{u}{h}=0.526$ $u=21.0$ cm , $d-u=14.0$ cm

$e'=e-30=12.4$ cm , $\frac{e'}{e}=0.292$

$p=\frac{A_s}{bd}=\frac{28.4}{100\times 35}=0.00811$ $\frac{d'}{d}=\frac{5}{35}=0.143$

$p'=\frac{A_s'}{bd}=\frac{7.1}{100\times 35}=0.00203$ $k=0.555$, $\frac{Ne}{bd^2\sigma_c}=0.247$

~~$\sigma_c=\frac{26390\times 424}{100\times 35^2\times 0.247}=37.0$ kg/cm²~~

$\sigma_s=15\times 37.0\times\frac{1-0.555}{0.555}=445$ kg/cm²

$\tau=0$

at (H1) $M=-4{,}620$ kgm , $N=26{,}390$ kgs , $S=14{,}380$ kgs

$h=40$cm , $b=100$cm , $d'=5$cm , $d=35$cm

$A_s=7.5$ c $19^{mm\phi}=21.3$ cm² , $A_s'=2.5$ c $19^{mm\phi}=7.1$ cm²

$P_o=\frac{A_s}{bh}=\frac{21.3}{100\times 40}=0.00532$

$P_o'=\frac{A_s'}{bh}=\frac{7.1}{100\times 40}=0.00178$

$\frac{d}{h}=0.875$, $\frac{d'}{h}=0.125$

$\frac{u}{h}=0.519$, $u=20.8$ cm , $d-u=14.2$ cm

$\frac{M}{N}=\frac{4620}{26390}\times 100=17.5$

$\quad 14.2$

$e=31.7$ cm

$e'=e-30=1.7$ cm , $\frac{e'}{e}=\frac{1.7}{31.7}=0.054$

$\frac{d'}{d}=0.143$, $k=0.657$, $j=1-\frac{k}{3}=0.781$

$p=\frac{A_s}{bd}=\frac{21.3}{100\times 35}=0.00609$ $\frac{Ne}{bd^2\sigma_c}=0.276$

$p'=0.00203$

$\sigma_c=\frac{26390\times 31.7}{100\times 35^2\times 0.276}=24.8$ kg/cm²

~~$\sigma_s=15\times 24.8\times\frac{1-0.657}{0.657}=194$ kg/cm²~~

$\tau=\frac{14380}{100\times 0.781\times 35}=5.3$ kg/cm² use bent up bars

at (H2) $M=-7{,}010$ kgm , $N=26{,}390$ kgs , $S=13{,}660$ kgs

$h=40$cm , $b=100$cm , $d'=5$cm , $d=35$cm

$A_s=7.5$ c $19^{mm\phi}=21.3$ cm² , $A_s'=2.5$ c $19^{mm\phi}=7.1$ cm²

$u=20.8$ cm , $d-u=14.2$ cm

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$\frac{M}{N} = \frac{7010}{26390} \times 100 = 26.6$ $e' = e - 30 = 10.8\,cm$, $\frac{e'}{e} = 0.265$

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$e = 40.8\,cm$ $\frac{d'}{d} = 0.143$, $k = 0.523$, $j = 1 - \frac{k}{3} = 0.826$

$p = 0.00609$, $p' = 0.00203$,

$\frac{Ne}{bd^2\sigma_c} = 0.237$

$\sigma_c = \frac{26390 \times 40.8}{100 \times 35^2 \times 0.237} = 36.9\,kg/cm^2$

$\sigma_s = 15 \times 36.9 \times \frac{1-0.523}{0.523} = 504\,kg/cm^2$

~~$\tau = \frac{13660}{100 \times 0.826 \times 35} = 47\,kg/cm^2$ use bent up bars~~

at Ⓐ $M = -17{,}820\,kgm$, $N = 26{,}390\,kgs$, $S = 21{,}710\,kgs$

$h = 64\,cm$, $b = 100\,cm$, $d' = 5\,cm$, $d = 59\,cm$

$A_s = 10 - 19^{mm\phi} = 28.4\,cm^2$, $A_s' = 2.5 - 19^{mm\phi} = 7.1\,cm^2$

$P_0 = \frac{A_s}{bh} = \frac{28.4}{100 \times 64} = 0.00444$

$P_0' = \frac{A_s'}{bh} = \frac{7.1}{100 \times 64} = 0.00111$

$\frac{d}{h} = \frac{59}{64} = 0.922$, $\frac{d'}{h} = \frac{5}{64} = 0.078$

$\frac{u}{h} = 0.520$, $u = 33.3\,cm$, $d - u = 25.7\,cm$

$\frac{M}{N} = \frac{17820}{26390} \times 100 = 67.7$ $e' = e - 54 = 39.4\,cm$, $\frac{e'}{e} = 0.422$

25.7

$e = 93.4\,cm$ $\frac{d'}{d} = \frac{5}{59} = 0.085$, $k = 0.415$, $j = 1 - \frac{k}{3} = 0.862$

$p = \frac{A_s}{bd} = \frac{28.4}{100 \times 59} = 0.00481$ $\frac{Ne}{bd^2\sigma_c} = 0.193$

$p' = \frac{A_s'}{bd} = \frac{7.1}{100 \times 59} = 0.00120$

$\sigma_c = \frac{26390 \times 93.4}{100 \times 59^2 \times 0.193} = 36.7\,kg/cm^2$

$\sigma_s = 15 \times 36.7 \times \frac{1-0.415}{0.415} = 776\,kg/cm^2$

$\tau = \frac{21710}{100 \times 0.862 \times 59} = 4.3\,kg/cm^2$

at Ⓑ $M = -16{,}810\,kgm$, $N = 26{,}390\,kgs$, $S = 17{,}390\,kgs$

$h = 61\,cm$, $b = 100\,cm$, $d' = 5\,cm$, $d = 56\,cm$

$A_s = 10 - 19^{mm\phi} = 28.4\,cm^2$, $A_s' = 2.5 - 19^{mm\phi} = 7.1\,cm^2$

$P_0 = \frac{A_s}{bh} = \frac{28.4}{100 \times 61} = 0.00466$

$P_0' = \frac{A_s'}{bh} = \frac{7.1}{100 \times 61} = 0.00116$

$\frac{d}{h} = \frac{56}{61} = 0.918$, $\frac{d'}{h} = \frac{5}{61} = 0.082$

$\frac{u}{h} = 0.520$, $u = 31.7\,cm$, $d - u = 24.3\,cm$

$\frac{M}{N} = \frac{16810}{26390} \times 100 = 63.7$ $e' = e - 51 = 37.0\,cm$, $\frac{e'}{e} = 0.420$

24.3 $\frac{d'}{d} = 0.089$, $k = 0.422$, $j = 1 - \frac{k}{3} = 0.859$

$e = 88.0\,cm$

$p = \frac{A_s}{bd} = \frac{28.4}{100 \times 56} = 0.00507$ $\frac{Ne}{bd^2\sigma_c} = 0.198$

$p' = \frac{A_s'}{bd} = \frac{7.1}{100 \times 56} = 0.00127$

$\sigma_c = \frac{26390 \times 88.0}{100 \times 56^2 \times 0.198} = 37.4\,kg/cm^2$

$\sigma_s = 15 \times 37.4 \times \frac{1-0.422}{0.422} = 768\,kg/cm^2$

$\tau = \frac{17390}{100 \times 56 \times 0.859} = 3.6\,kg/cm^2$

Side wall EF

at (M_E) $M = +5920\,kgm$, $N = 22480\,kgs$, $S = 0$

$h = 40\,cm$, $b = 100\,cm$, $d' = 5\,cm$, $d = 35\,cm$

$A_s = 10 - 19^{mm\phi} = 28.4\,cm^2$, $A_s' = 2.5 - 19^{mm\phi} = 7.1\,cm^2$

$u = 21.0\,cm$, $d - u = 14.0\,cm$

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$\frac{M}{N} = \frac{5920}{22480} \times 100 = 26.4$ $e' = e - 30 = 10.4\,cm$, $\frac{e'}{e} = 0.258$

$\underline{14.0}$

$e = 40.4\,cm$ $\frac{d'}{d} = 0.143$

$p = 0.00811$, $p' = 0.00203$, $k = 0.570$, $\frac{Ne}{bd^2\sigma_c} = 0.253$

$\sigma_c = \frac{22480 \times 40.4}{100 \times 35^2 \times 0.253} = 29.3\ kg/cm^2$

$\sigma_s = 15 \times 29.3 \times \frac{1-0.570}{0.570} = 332\ kg/cm^2$

$\tau = 0$

at (H₇) $M = -6080\,kgm$, $N = 22480\,kgs$, $S = 11920\,kgs$

$h = 40\,cm$, $b = 100\,cm$, $d' = 5\,cm$, $d = 35\,cm$

$A_s = 7.5 \text{ c } 19^{mm\phi} = 21.3\,cm^2$, $A_s' = 2.5 \text{ c } 19^{mm\phi} = 7.1\,cm^2$

$u = 20.8\,cm$, $d - u = 14.2\,cm$

$\frac{M}{N} = \frac{6080}{22480} \times 100 = 27.1$ $e' = e - 30 = 11.3$, $\frac{e'}{e} = 0.224$

$\underline{14.2}$

$e = 41.3\,cm$ $\frac{d'}{d} = 0.143$, $k = 0.545$, $\frac{Ne}{bd^2\sigma_c} = 0.244$

$p = 0.00609$, $p' = 0.00203$, $j = 1 - \frac{k}{3} = 0.818$

$\sigma_c = \frac{22480 \times 41.3}{100 \times 35^2 \times 0.244} = 31.1\ kg/cm^2$

$\sigma_s = 15 \times 31.1 \times \frac{1-0.545}{0.545} = 381\ kg/cm^2$

$\tau = \frac{11920}{100 \times 0.818 \times 35} = 4.2\ kg/cm^2$

at (H₈) $M = -3920\,kgm$, $N = 22480\,kgs$, $S = 12670\,kgs$

$h = 40\,cm$, $b = 100\,cm$, $d' = 5\,cm$, $d = 35\,cm$

$A_s = 7.5 \text{ c } 19^{mm\phi} = 21.3\,cm^2$, $A_s' = 2.5 \text{ c } 19^{mm\phi} = 7.1\,cm^2$

$u = 20.8\,cm$, $d - u = 14.2\,cm$

$\frac{M}{N} = \frac{3920}{22480} \times 100 = 17.5$ $e' = e - 30 = 1.7\,cm$, $\frac{e'}{e} = 0.054$

$\underline{14.2}$ $\frac{d'}{d} = 0.143$, $k = 0.657$, $j = 0.781$

$e = 31.7\,cm$

$p = 0.00609$, $p' = 0.00203$, $\frac{Ne}{bd^2\sigma_c} = 0.276$

$\sigma_c = \frac{22480 \times 31.7}{100 \times 35^2 \times 0.276} = 21.1\ kg/cm^2$

$\sigma_s = 15 \times 21.1 \times \frac{1-0.657}{0.657} = 165\ kg/cm^2$

$\tau = \frac{12670}{100 \times 0.781 \times 35} = 4.6\ kg/cm^2$ use bent up bars

at (E) $M = -14580\,kgm$, $N = 22480\,kgs$, $S = 15030\,kgs$

$h = 61\,cm$, $b = 100\,cm$, $d' = 5\,cm$, $d = 56\,cm$

$A_s = 10 \text{ c } 19^{mm\phi} = 28.4\,cm^2$, $A_s' = 2.5 \text{ c } 19^{mm\phi} = 7.1\,cm^2$

$u = 31.7\,cm$, $d - u = 24.3\,cm$

$\frac{M}{N} = \frac{14580}{22480} \times 100 = 64.9$ $e' = e - 51 = 38.2\,cm$, $\frac{e'}{e} = 0.428$

$\underline{24.3}$ $\frac{d'}{d} = 0.089$, $k = 0.421$, $j = 1 - \frac{k}{3} = 0.860$

$e = 89.2\,cm$

$p = 0.00507$, $p' = 0.00127$, $\frac{Ne}{bd^2\sigma_c} = 0.198$

$\sigma_c = \frac{22480 \times 89.2}{100 \times 56^2 \times 0.198} = 32.3\ kg/cm^2$

$\sigma_s = 15 \times 32.3 \times \frac{1-0.421}{0.421} = 666\ kg/cm^2$

$\tau = \frac{15030}{100 \times 0.860 \times 56} = 3.1\ kg/cm^2$

at (F) $M = -15510\,kgm$, $N = 22480\,kgs$, $S = 19270\,kgs$

$h = 64\,cm$, $b = 100\,cm$, $d' = 5\,cm$, $d = 59\,cm$

$A_s = 10 \text{ c } 19^{mm\phi} = 28.4\,cm^2$, $A_s' = 2.5 \text{ c } 19^{mm\phi} = 7.1\,cm^2$

$u = 33.3\,cm$, $d - u = 25.7\,cm$

$\frac{M}{N} = \frac{15510}{22480} \times 100 = 69.0$ $e' = e - 54 = 40.7\,cm$, $\frac{e'}{e} = 0.430$

$\underline{25.7}$

$e = 94.7\,cm$ $\frac{d'}{d} = 0.085$

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CALCULATIONS FOR

上下二段式函型隧道断面A7號土被4.5m

$P=0.00481$, $P'=0.00120$, $k=0.415$, $j=0.862$, $\frac{Ne}{bd^2\sigma_c}=0.193$

$\sigma_c=\frac{22480\times947}{100\times59^2\times0.193}=31.7\ ^{kg}/_{cm^2}$

$\sigma_s=15\times31.7\cdot\frac{1-0.415}{0.415}=670\ ^{kg}/_{cm^2}$

$\tau=\frac{19270}{100\times0.862\times59}=3.7\ ^{kg}/_{cm^2}$

Center wall CG

at (H13) $M=-6360$ kgm, $N=51730$ kg, $S=0$

$h=60$ cm, $b=100$ cm, $d'=5$ cm, $d=55$ cm

$A_s=A_s'=5\text{-}19^{mm\phi}=14.2\ cm^2$

$\frac{M}{N}=\frac{6360}{51730}\times100=12.3\ cm=e$

$60\times100=6000$ $\qquad \frac{100\times60^3}{12}=1800000$

$15\text{-}28.4=426$ $\qquad 15\text{-}28.4\times25^2=266000$

$A_i=6426\ cm^2$ $\qquad I_i=2066000\ cm^4$

$\sigma_c=\frac{N}{A_i}+\frac{Ne}{I_i}\times\frac{h}{2}=\frac{51730}{6426}+\frac{51730\times12.3}{2066000}\times30=17.3\ ^{kg}/_{cm^2}$

$\sigma_c'=\frac{51730}{6426}-\frac{51730\times12.3}{2066000}\times30=+1.1\ ^{kg}/_{cm^2}$

$\sigma_s=15\times1.1=16.5\ ^{kg}/_{cm^2}$

$\tau=0$

at (H14) $M=-5510$ kgm, $N=51730$ kg, $S=0$

$h=60$ cm, $b=100$ cm, $d'=5$ cm, $d=55$ cm

$A_s=A_s'=5\text{-}19^{mm\phi}=14.2\ cm^2$

$\frac{M}{N}=\frac{5510}{51730}\times100=10.7\ cm=e$

$A_i=6426\ cm^2$, $I_i=2066000\ cm^4$

$\sigma_c=\frac{N}{A_i}+\frac{Ne}{I_i}\times\frac{h}{2}=\frac{51730}{6426}+\frac{51730\times10.7}{2066000}\times30=16.1\ ^{kg}/_{cm^2}$

$\sigma_c'=\frac{51730}{6426}-\frac{51730\times10.7}{2066000}\times30=0.0\ ^{kg}/_{cm^2}$

$\tau=0$

at (C) $M=-9390$ kgm, $N=51730$ kg, $S=0$

$h=81$ cm, $b=100$ cm, $d'=5$ cm, $d=76$ cm

$A_s=5\text{-}19^{mm\phi}=14.2\ cm^2$, $A_s'=2.5\text{-}19^{mm\phi}=7.1\ cm^2$

$P_0=\frac{A_s}{bh}=\frac{14.2}{100\times81}=0.00175$

$P_0'=\frac{A_s'}{bh}=\frac{7.1}{100\times81}=0.00088$

$\frac{d}{h}=\frac{76}{81}=0.938$, $\frac{d'}{h}=\frac{5}{76}=0.066$

$\frac{u}{h}=0.506$, $u=41.0$ cm

$81\times100=8100$ $\qquad \frac{100\times81^3}{12}=4432000$

$15\text{-}21.3=319$ $\qquad 15\text{-}14.2\times35^2=261000$

$A_i=8419\ cm^2$ $\qquad 15\text{-}7.1\times36^2=138000$

$I_i=4831000\ cm^4$

$\frac{M}{N}=\frac{9390}{51730}\times100=18.2\ cm=e$

$\sigma_c=\frac{N}{A_i}+\frac{Ne}{I_i}u=\frac{51730}{8419}+\frac{51730\times18.2}{4831000}\times41=14.1\ ^{kg}/_{cm^2}$

$\sigma_c'=+1.7\ ^{kg}/_{cm^2}$

$\sigma_s=15\times1.7=25.5\ ^{kg}/_{cm^2}$

$\tau=0$

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CALCULATIONS FOR

上下二段式函型隧道断面A_7號土被4.5m

at Ⓖ $M = -9020$ kgm, $N = 51{,}730$ kgs, $S = 0$

$h = 84\,cm,\ b = 100\,cm,\ d' = 5\,cm,\ d = 79\,cm$

$A_s = 5\text{c}\,19^{mm\phi} = 14.2\,cm^2,\ A_s' = 2.5\text{c}\,19^{mm\phi} = 7.1\,cm^2$

$p_0 = \frac{A_s}{bh} = \frac{14.2}{100 \times 84} = 0.00169$

$p_0' = \frac{A_s'}{bh} = \frac{7.1}{100 \times 84} = 0.00085$

$\frac{d}{h} = \frac{79}{84} = 0.941,\quad \frac{d'}{h} = \frac{5}{84} = 0.060$

$\frac{u}{h} = 0.506,\ u = 42.5\,cm$

$84 \times 100 = 8{,}400$

$15 \text{c} 21.3 = \underline{319}$

$A_i = 8{,}719\,cm^2$

$\frac{100 \times 84^3}{12} = 4{,}940{,}000$

$15\text{c}\,14.2 \times 37.5^2 = 300{,}000$

$15\text{c}\,7.1 \times 36.5^2 = \underline{142{,}000}$

$I_i = 5{,}382{,}000\,cm^4$

$\frac{M}{N} = \frac{9020}{51{,}730} \times 100 = 17.5\,cm = e$

$\sigma_c = \frac{N}{A_i} + \frac{N.e}{I_i} u = \frac{51{,}730}{8{,}719} + \frac{51{,}730 \times 17.5}{5{,}382{,}000} \times 42.5 = 13.1\ kg/cm^2$

$\sigma_c' = \frac{51{,}730}{8{,}719} - \frac{51730 \times 17.5}{5382{,}000} \times 41.5 = +1.0\ kg/cm^2$

$\sigma_s = 15 \times 1.0 = 15.0\ kg/cm^2$

$\tau = 0$

不用　不用

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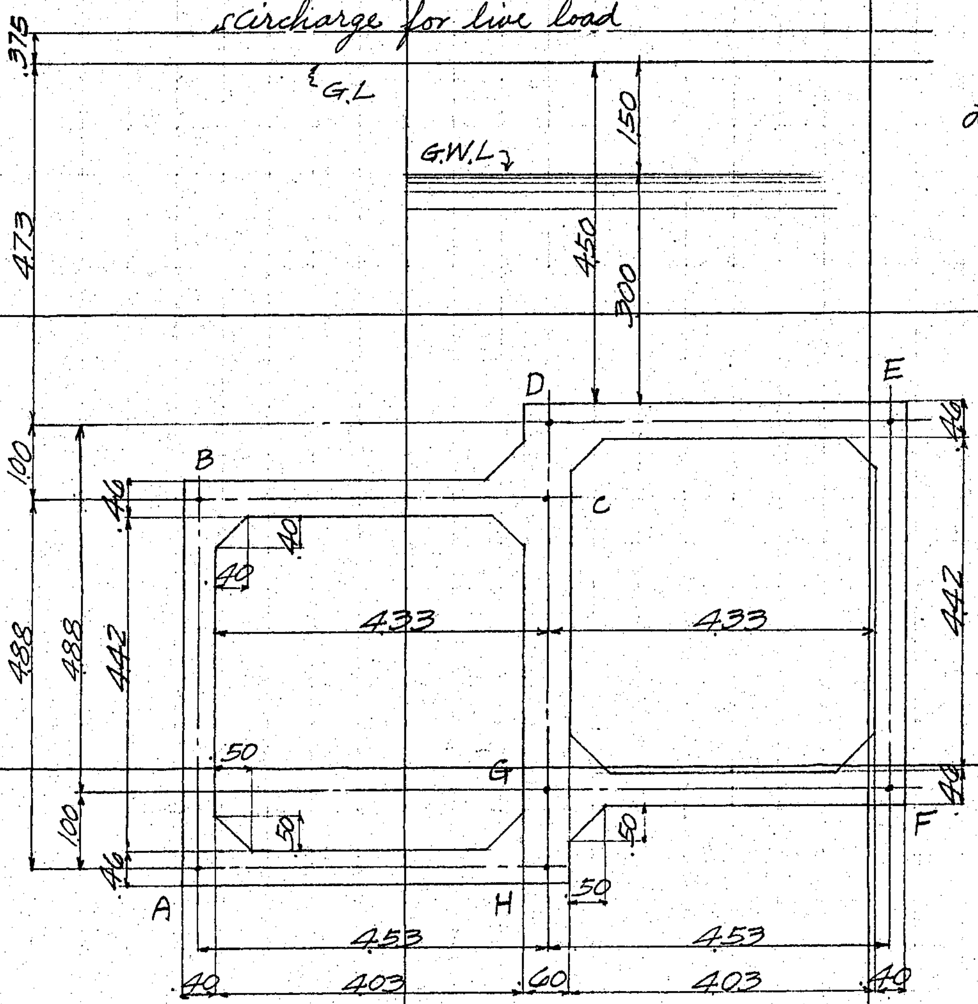
CALCULATIONS ~~FOR~~
赤坂見付停車場
上下二段式函型隧道断面A₇號土被4.5ᵐ

断面A₇號 土被4.5ᵐ

Cross section of the tonnel assumed as following sketch.



Load on top slab (right)
Earth filling above ground water level　1.50ᵐ × 1,600 = 2,400
Earth filling below ground water level　3.00ᵐ × 2,000 = 6,000
Weight of concrete slab　.46 × 2,400 = 1,100
　9,500 kg/m²

Live load　600
w_1 = 10,100 kg/m²

Load on top slab (left)
　9,500
Earth filling　1.00ᵐ × 2,000 = 2,000
　11,500 kg/m²

Live load　600
w_2 = 12,100 kg/m²

Earth pressure on side wall
Angle of repose of earth assumed as $\varphi = 20°$
Earth pressure coeff. $k = \frac{1-\sin\varphi}{1+\sin\varphi} = \frac{1-0.34202}{1+0.34202} = 0.490$　$\sin 20° = 0.34202$

Circharge of live load　600 ÷ 1,600 = 0.375ᵐ of earth

Pressure intensity at D & E
0.490 × 1,600 × 1.875 = 1,470
0.490 × 2,000 × 3.230 = 3,170
q_1 = 4,640 kg/m²

Pressure intensity at B & C
0.490 × 2,000 × 1.000 = 980
4,640
q_2 = 5,620 kg/m²

Pressure intensity at F & G
0.490 × 2,000 × 3.880 = 3,800
5620
q_3 = 9,420 kg/m²

Pressure intensity at A & H
0.490 × 2,000 × 1.000 = 980
9,420
q_4 = 10,400 kg/m²

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CALCULATIONS FOR

上下二段式函型隧道断面A7號土被4.5m

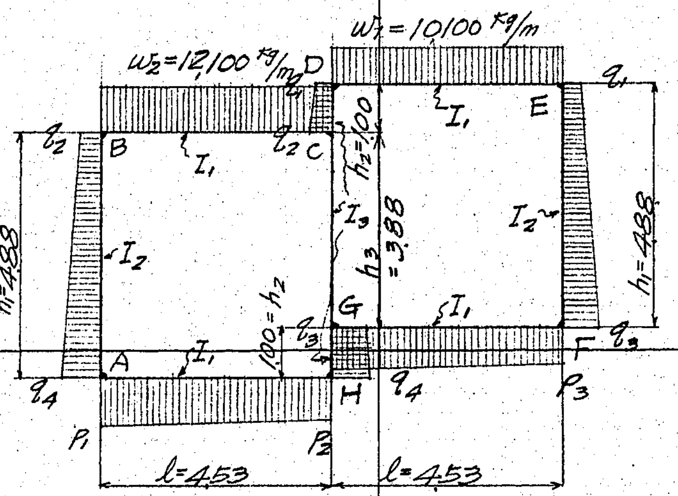
Pressure intensity on bottom slab
Moment at A due to vertical load

$12{,}100 \times 4.53 = 54{,}800 \times 2.265 = 124{,}100$
$10{,}100 \times 4.53 = \underline{45{,}800} \times 6.795 = \underline{311{,}100}$
$100{,}600 \times 4.33^m \qquad 435{,}200$

Eccentricity $e = 4.53 - 4.33 = 0.20^m$

intensity $p = \dfrac{100{,}600}{1.0 \times 9.06}\left(1 \pm \dfrac{6 \times 0.20}{9.06}\right) = 12{,}570 = p_1$
$9{,}630 = p_3$
$11{,}100 = p_2$

Loading condition



assumed section and moment of inertia
Top and bottom slab
$1.00 \times .46 = 0.46\ m^2$

moment of inertia $\dfrac{1.00 \times .46^3}{12} = 0.00811 m^4 = I_1$

Side wall
$1.00 \times .40 = 0.40\ m^2$

moment of inertia $\dfrac{1.00 \times .40^3}{12} = 0.00533 m^4 = I_2$

Center and partition wall
$1.00 \times .60 = 0.60\ m^2$

moment of inertia $\dfrac{1.00 \times .60^3}{12} = 0.01800 m^4 = I_3$

Notation as follow,
$k = I/l$ for member shown by suffix,
C = Bending moment of propped beam for member by suffix,
$\rho = 2 \times$ value of k for assembled members at point shown by suffix,
P = summary of value c at point shown by suffix,
$\gamma = k/\rho$ for member shown by suffix,

Value of k :–

$k_{AB} = k_{BA} = k_{EF} = k_{FE} = \dfrac{I_2}{h_1} = \dfrac{0.00533}{4.88} = 0.00109\ m^3$

$k_{AH} = k_{HA} = k_{BC} = k_{CB} = k_{GF} = k_{FG} = k_{DE} = k_{ED} = \dfrac{I_1}{l} = \dfrac{0.00811}{4.53} = 0.00179\ m^3$

$k_{CD} = k_{DC} = k_{GH} = k_{HG} = \dfrac{I_3}{h_2} = \dfrac{0.01800}{1.000} = 0.01800\ m^3$

$k_{CG} = k_{GC} = \dfrac{I_3}{h_3} = \dfrac{0.01800}{3.88} = 0.00464\ m^3$

Value of C :–

$C_{BC} = C_{CB} = \dfrac{w_2 l^2}{12} = \dfrac{12{,}100 \times 4.53^2}{12} = 20{,}700$ kgm

$C_{DE} = C_{ED} = \dfrac{w_1 l^2}{12} = \dfrac{10{,}100 \times 4.53^2}{12} = 17{,}270$ kgm

$C_{AB} = \dfrac{h_1^2(2q_2 + 3q_4)}{60} = \dfrac{4.88^2(2 \times 5620 + 3 \times 10400)}{60} = 16{,}850$ kgm

$C_{BA} = \dfrac{h_1^2(3q_2 + 2q_4)}{60} = \dfrac{4.88^2(3 \times 5620 + 2 \times 10400)}{60} = 14{,}940$ kgm

$C_{FE} = \dfrac{h_1^2(2q_1 + 3q_3)}{60} = \dfrac{4.88^2(2 \times 4640 + 3 \times 9420)}{60} = 14{,}900$ kgm

$C_{EF} = \dfrac{h_1^2(3q_1 + 2q_3)}{60} = \dfrac{4.88^2(3 \times 4640 + 2 \times 9420)}{60} = 13{,}000$ kgm

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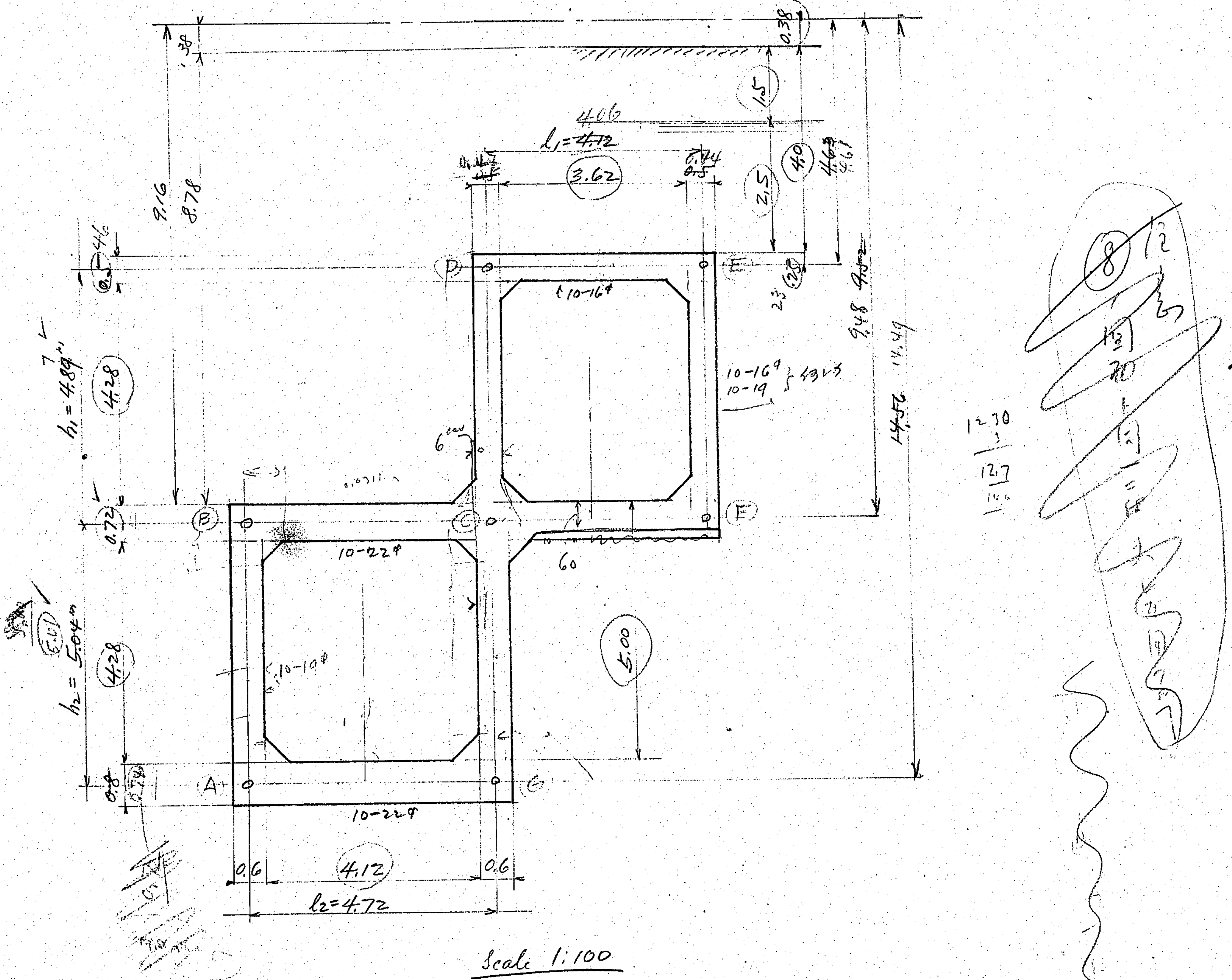
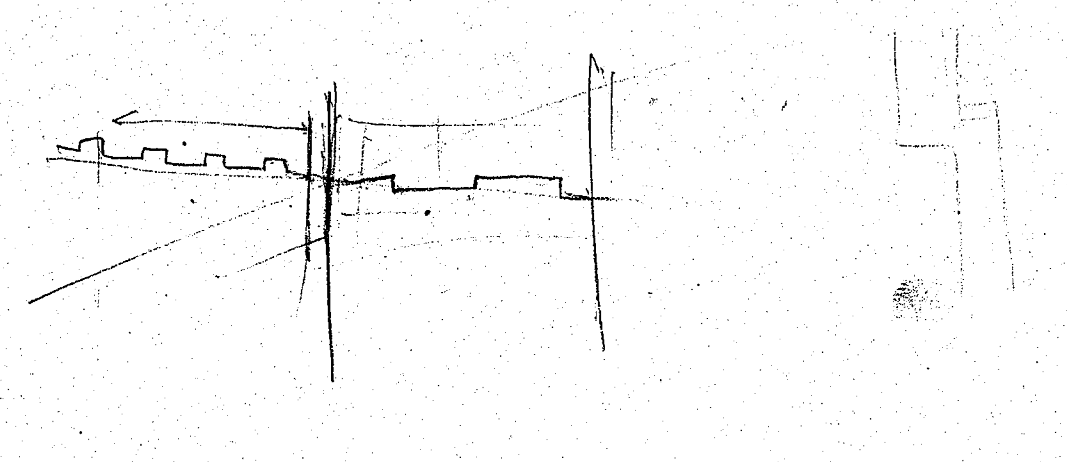
CALCULATIONS FOR (A5 土被 ...)

A5 土被 6.0, L = 600





Load on Top floor.

Earth fill. 1.50 @ 1600 = 2400
" 2.50 @ 2000 = 5000
7400

wt. of slab. 0.5 @ 2400 = 1200
8600

L.L. 600
w_1 = 9200 kg/m²

Load on middle floor.

Earth fill. 2400
7.28 @ 2000 = 14560
16960

wt. of slab 0.72 @ 2400 = 1730
18690

L.L. 600
w_2 = 19290 kg/m²

Load on bott. floor.

for CF $w_3 = w_1$ = 9200 kg/m²

for AG $w_4 = w_2$ = 19290 "

Side pressure at E.

0.38 @ 1600 = 600
7400
8000 × 0.49 = 3930 = q_1

at F
600
16960
17570 × 0.49 = 8610 = q_2

at G
600
2400
12.680 × 2000 = 25360
28370 × 0.49 = 13900 = q_3

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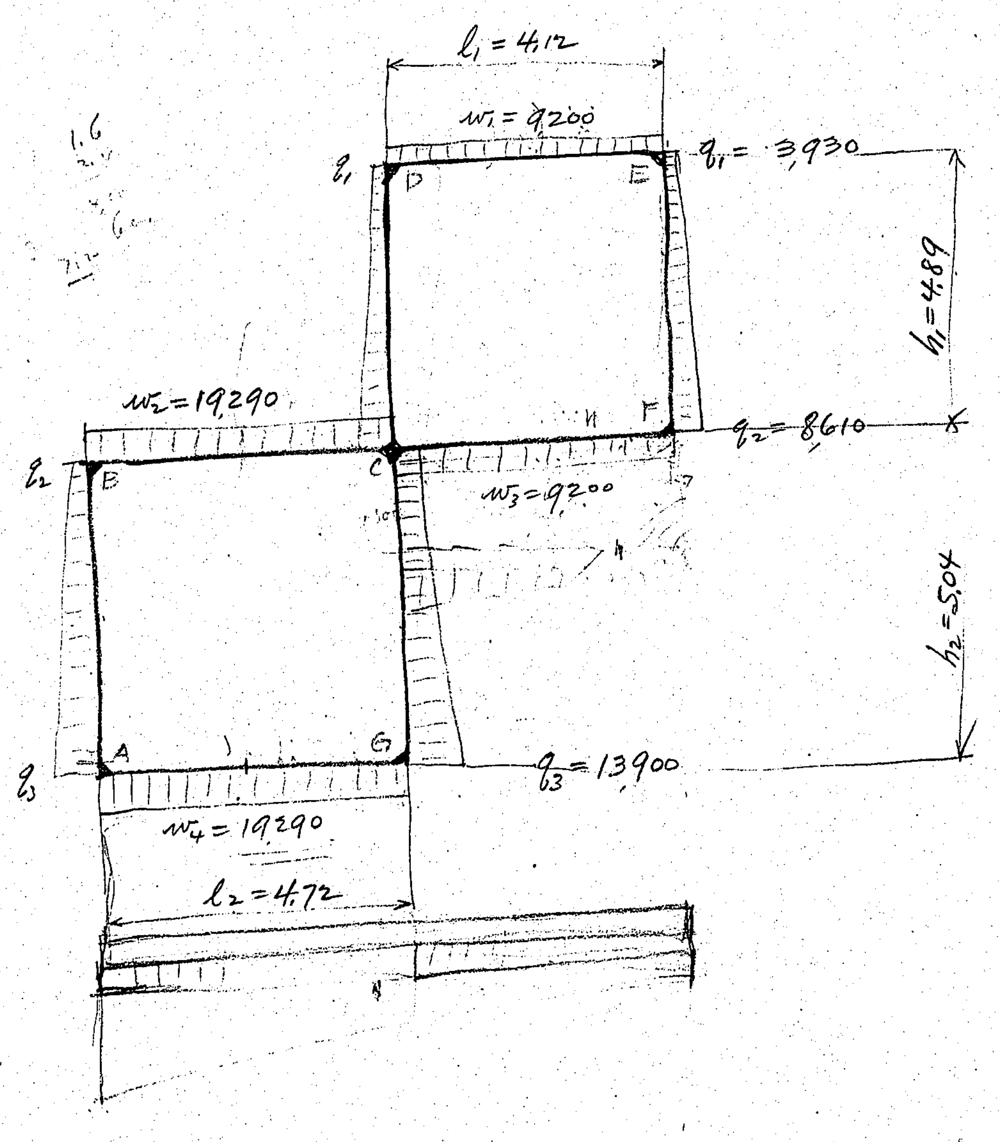
CALCULATIONS FOR



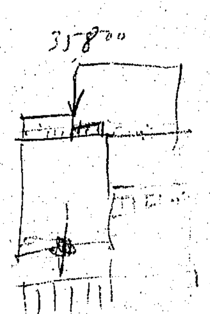
moment.

DE $\oplus$ $\frac{wl_1^2}{16} = +9700$

$\ominus$ $\frac{\text{"}}{15.8} = -9900$

AG. $\oplus$ $\frac{w_2 l_2^2}{16.} = +27900$

$\ominus$ $\frac{\text{"}}{15.8} = -27200$



Thrust.

DE. 9200 × 2.06 = 19000

AB. 19290 × 2.36 = 45500

DE. 3930 × 2.45 = 9640

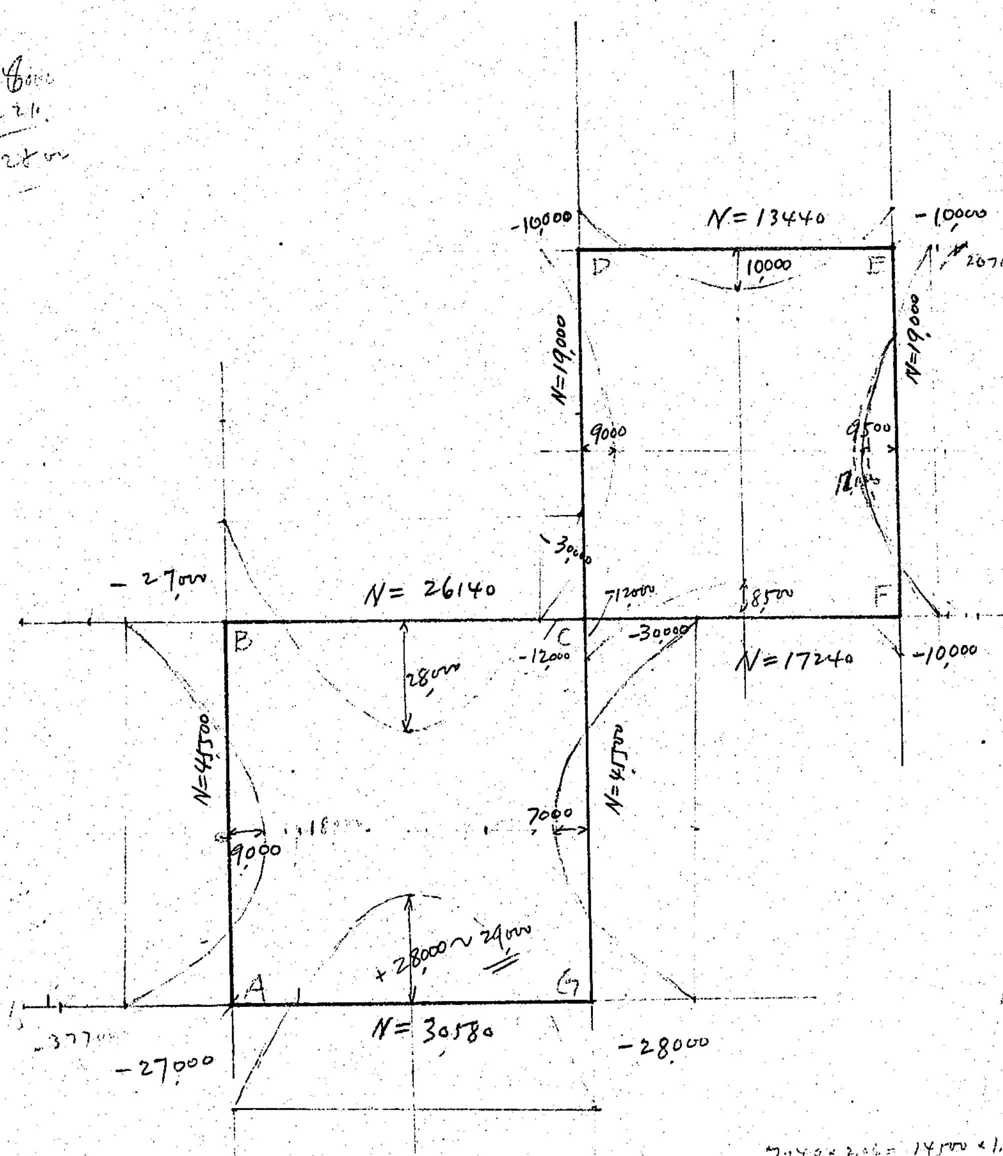
$\frac{4680}{2×3}$ × 4.89 = 3800

13440

CF. 9640
76—
17240

BC. 8610 × 2.52 = 2170
$\frac{5290 × 5.04}{6}$ = 4440
26140

AB. 2170
8880
30580



$\frac{19290 × 4.72^2}{2}$ = 215,000

9200 × 4.12 × 6.78 = 257,000

$\frac{472000}{128900}$ = 3.66 m

91000
37900
128900

e = 4.42 − 3.66 = 0.76 m

$\sigma = \frac{128900}{8.84}\left(1 \pm \frac{6 × 0.76}{8.84}\right)$

$= 14600(1 \pm 0.516) = \frac{22100}{7060}$

7040 × 2.06 = 14500 × 1.37 = 19870
7060 × 4.12 = 29200 × 2.06 = 60100
43700 79970
9200 × 9.12 = 37900 × 2.06 = 78100

7040
7060
14100

10580

地震

$\varphi' = \varphi - \tan^{-1} k = 25° - 15° 15' = 9° 45'$ $\sin\varphi' = \sin 9° 45' = 0.16935$

$K_1 = (1 + k_v)\frac{1-\sin\varphi'}{1+\sin\varphi'} = 1.10 \times \frac{0.831}{1.169} = 0.782$

Earth pressure at E. $7400 \times 0.782 = 5780 = q_1$) 9500
at F $16960 \times 0.782 = 13230 = q_2$
at G $27760 \times 0.782 = 21700 = q_3$) 17470

neg. m. $\frac{17470 \times 5.04^2}{20.5} = +21700$ } say 20000

Ⓐ + Ⓑ $\frac{17470 \times 5.04^2}{11.8} = -37700$ $\frac{17470 \times 5.04^2}{8} = 55500 - 37700 = +17800$

(E + F) $\frac{9500 \times 4.89^2}{11.0} = -20700$ $\frac{9500 \times 4.89^2}{8} = 28500 - 20700 = +7800$

Unit stresses.

DE. (p00) $M = 10{,}000$ kgm, $N = 13440$ kg

$\frac{M}{N} = \frac{10000 \times 100}{13440} = 75$ cm $b = 100$ $h = ~~50~~ 46$

$u = 52 \times ~~50~~ 46 = ~~26~~ 24$ $d = ~~41~~$ 41 $d' = 5$

$d - u = ~~19~~$ 17 $A_s = 10 - 16\phi = 20.1$

$e = ~~94~~$ 92 $A_s' = 2.5 - 1 = 5.0$

$e' = ~~54~~$ 56 $p = 20.1/~~4500~~ 4100 = .00~~447~~ 490$

$e'/e = ~~54~~ 56/~~94~~ 92 = ~~.574~~ .61$ $p' = .00~~112~~ 123$

$\frac{Ne}{bd^2} = \frac{13440 \times 92^2}{100 \times 41^2} = ~~6.240~~ 7.35$ $d'/d = 5/41 = ~~.111~~ .122$

$k = ~~.373~~ .380$ $\frac{Ne}{bd^2 \sigma_c} = ~~.176~~ .178$

$\sigma_c = \frac{~~6.24~~ 7.35}{~~.176~~ .178} = ~~35.5~~ 41.3$

$\sigma_s = 15 \times ~~35.5~~ 41.3 \frac{~~.625~~ .62}{~~.375~~ .38} = ~~890~~ 1,010$

haunch $S = 19000 \times \frac{1.41}{2.06} = 13000$

$\tau = \frac{13000}{100 \times .7 \times ~~45~~ 41} = ~~4.1~~ 4.5$

$\tau_0 = \frac{13000}{50.3 \times 7.5 \times .7 \times ~~45~~ 41} = ~~11.0~~ 12.0$

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CALCULATIONS FOR

EF (pos) M = 9500 kgm. N = 1900 kg.

M/N = 9500×100 / 1900 = 50.

d−u = ~~19~~ 17

e = 69

e' = ~~29~~ 33

e'/e = ~~29~~/69 = .42 .492

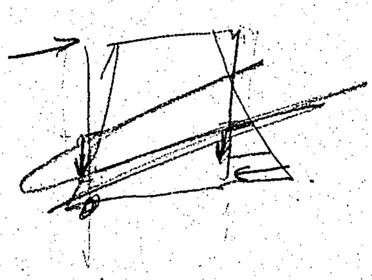
Ne/bd² = 1900×~~69~~ 67 / 100×~~45~~² 39² = 6.~~47~~ 8.34

k = .48 Ne/bd²σc = .22

σc = ~~6.47~~ 8.34 / .22 = 29.5 38.8

σs = 15×29.5×.52/.48 = ~~480~~ 670

b=100, h=~~50~~ 44
d=~~45~~ 39, d'=5
As = 10−19φ = 28.4
As' = 2.5—" = 7.1
p = 28.4/~~4500~~ 3900 = .00~~632~~ 729
p' = .00~~157~~ 182
d'/d = 5/~~45~~ 39 = .111 .128



地震

M/N = 12000×100 / 20000 = 60.
17
e = 77
e' = 43
e'/e = 43/77 = 0.56
Ne/bd² = 20000×77 / 100×39² = ~~7.94~~ 10.12
k = .44 Ne/bd²σc = .206
σc = ~~7.94~~ 10.12/.206 = ~~38~~ 49.1
σs = 15×~~38~~ 49.1×.56/.44 = 940

M/N = 18000×100 / 20000 = 90
17
e = 107
e' = 73
e'/e = 73/107 = .682
Ne/bd² = 20000×107 / 100×39² = 14.1
k = .42 Ne/bd²σc = .198
σc = 14.1/.198 = 71.3
σs = 15×71.3×.58/.42 = 1480

AG. (pos) M = 28000, N = 30580 kg

M/N = 28000×100 / 30580 = 92
33
e = 125
e' = e−64 = 61
e'/e = 61/125 = ~~.540~~ .488
Ne/bd² = 30580×125 / 100×69² = ~~8.76~~ 8.03
k = .42 Ne/bd²σc = .198
σc = ~~8.76~~ 8.03/.198 = ~~45~~ 40.6
σs = 15×40.6×.58/.42 = 840

b = 100, h = ~~70~~ 74
d = ~~65~~ 69, d' = 5
As = 10−22φ = 38.0
As' = 2.5—" = 9.5
p = 38/~~6500~~ 6900 = 0.00~~585~~ 551
p' = 0.00~~146~~ 138
d'/d = 5/~~65~~ 69 = .077 .073

15×~~44~~ = 38
69−38 = 31

hanch.

S = 45500 × 1.56/2.36 = 30100

τ = 30100 / 100×.7×69 = 6.2

τ0 = 30100 / 6.91×7.5×.7×69 = 12.0

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CALCULATIONS FOR

βC (pos.) M = 28000 kgm N = 26140 kg

$\frac{M}{N} = \frac{28000 \times 100}{26140} = 107$

+30

e = 137

e' = 137 - 62 = 75

e'/e = 75/137 = .547

$\frac{Ne}{bd^2} = \frac{26140 \times 137}{100 \times 67^2} = 7.98$

72×1/2 = 37
67 − 37 = 30

b = 100, h = 72
d = 67 d' = 5
As = 10−22φ = 38.
As' = 2.5− " = 9.5
p = 38/6700 = 0.00568
p' = .00142
d'/d = 5/67 = .075

k = .405 $\frac{Ne}{bd^2\sigma_c}$ = .196

σ_c = 7.98/.196 = 40.8

$\sigma_s = 40.8 \times 15 \frac{.595}{.405} = 900$

βB. M = 10000 N = 41500

$\frac{M}{N} = \frac{10000 \times 100}{41500} = 22$

+24

e = 46

e' = 50 − 46 = 4

60×1/2 = 31
55 − 31 = 24

b = 100, h = 60
d = 55 d' = 5
As = 10−19φ = 28.4
As' = 2.5− " = 7.1
p = 28.4/5500 = 0.00517
p' = .00129
d'/d = 5/55 = .091

地震

M = 18000, N = 50000

$\frac{M}{N}$ = 18000×100 / ... = 36

24

e = 60

e' = 6... − ... ...

e'/e = ... .167

$\frac{Ne}{bd^2}$ = 50000 × 60 / 100 × 55² 9.92

k = .53 $\frac{Ne}{bd^2\sigma_c}$ = .232

σ_c = 9.92/.232 = 42.5

$\sigma_s = 15 \times 42.5 \cdot \frac{.47}{.53} = 565$

haunch

S = 30580 × (7.3)/2.6 = 20300 kg

$\tau = \frac{20300}{100 \times .7 \times 55} = 5.3$

$\tau_0 = \frac{20300}{5.97 \times 7.5 \times .7 \times 55} = 11.8$

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CALCULATIONS FOR

野石 A5 土被 4.0m

75 / 148 / 22 / 245 — 75 / 169 / 64 / 308 — 75.0 / 169.3 / 65.1 / 309.4

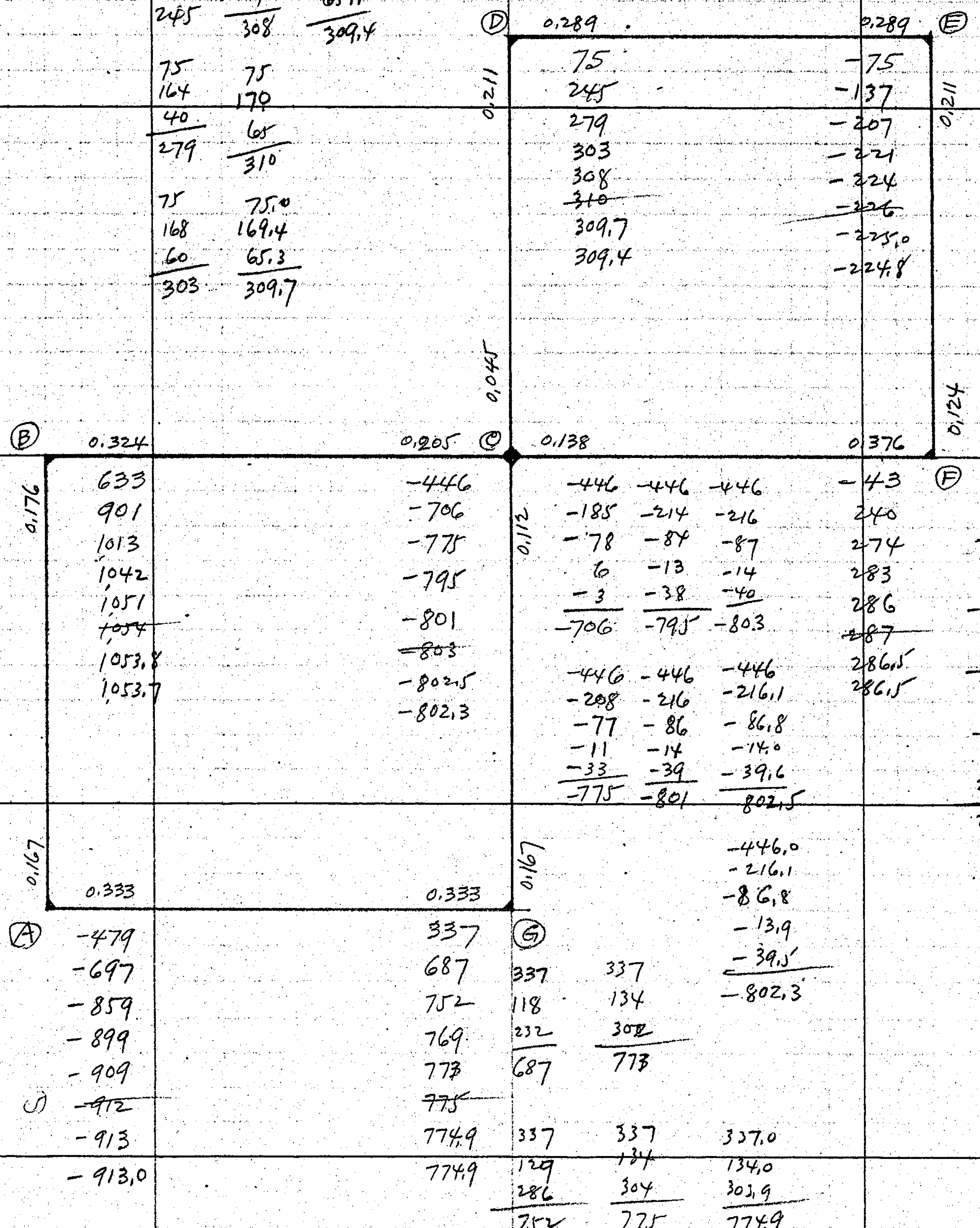
75 / 164 / 40 / 279 — 75 / 170 / 65 / 310

75 / 168 / 60 / 303 — 75.0 / 169.4 / 65.3 / 309.7

-75 / -71 / 9 / -137 — -75 / -89 / -60 / -224 — -75.0 / -89.4 / -60.4 / -224.8

-75 / -81 / -51 / -207 — -75 / -90 / -61 / -226

-75 / -88 / -58 / -221 — -75.0 / -89.5 / -60.5 / -225.0



633 / 123 / 145 / 901 — 633 / 161 / 260 / 1054

633 / 151 / 229 / 1013 — 633 / 160.7 / 260.1 / 1053.8

633 / 158 / 251 / 1042 — 633.0 / 160.7 / 260.0 / 1053.7

633 / 164 / 258 / 1051

-479 / -112 / -106 / -697 — -479 / -257 / -176 / -912

-479 / -229 / -151 / -859 — -479 / -258 / -176 / -913

-479 / -251 / -169 / -899 — -479.0 / -258.0 / -176.0 / -913.0

-479 / -256 / -174 / -909

-43 / 17 / 266 / 240 — -43 / 28 / 301 / 286 — -43.0 / 27.9 / 301.6 / 286.5

-43 / 26 / 291 / 274 — -43 / 28 / 302 / 287

-43 / 27 / 299 / 283 — -43.0 / 27.9 / 301.6 / 286.5

337 / 118 / 232 / 687 — 337 / 134 / 302 / 773

337 / 129 / 286 / 752 — 337 / 134 / 304 / 775 — 337.0 / 134.0 / 303.9 / 774.9

337 / 133 / 299 / 769 — 337.0 / 134.0 / 303.9 / 774.9

-446.0 / -216.1 / -86.8 / -13.9 / -39.5 / -802.3

(10)

不用

断面内ノ土砂の量

A

上下二段式函型隧道 断面 A7 端 土被 4.5m

point of zero shear in side wall AB.

$S_m = S_{BA} + q_2 x + \frac{q_4 - q_2}{2h} x^2 = -17600 + 5620x + 490x^2$

$490x^2 + 5620x - 17600 = 0$

$x = \frac{-5620}{980} \pm \frac{\sqrt{5620^2 + 4 \times 490 \times 17600}}{980} = 2.56^m$ from B.

point of zero shear in side wall EF.

$S_m = S_{EF} - q_1 x - \frac{q_3 - q_1}{2h} x^2 = 15100 - 4640x - 490x^2$

$490x^2 + 4640x - 15100 = 0$

$x = \frac{-4640}{980} \pm \frac{\sqrt{4640^2 + 4 \times 490 \times 15100}}{980} = 2.56^m$ from E

Moment at end of haunches.

at (H1) $M = S_{AH} x + M_{AH} - \frac{w_2 x^2}{2} = 24800 \times 0.60 - 20200 - 6050 \times 0.60^2$
$= 14880 - 20200 - 2180 = -7500$ kgm

(M1) $M = 24800 \times 2.05 - 20200 - 6050 \times 2.05^2$
$= 50800 - 20200 - 25400 = 5200$ "

(H14) $M = 24800 \times 3.83 - 20200 - 6050 \times 3.83^2$
$= 95000 - 20200 - 88700 = -13900$ "

(H4) $M = 24800 \times 0.60 - 20000 - 6050 \times 0.6^2$
$= 14880 - 20000 - 2180 = -7300$ kgm

(M3) $M = 50800 - 20000 - 25400 = 5400$ "

(H5) $M = \quad = -13700$ "

(H12) $M = S_{GF} x + M_{GF} - \frac{w_1}{2} x^2 = 25400 \times 0.70 - 28700 - 5050 \times 0.7^2$
$= 17780 - 28700 - 2480 = -13400$ "

(M6) $M = 25400 \times 2.51 - 28700 - 5050 \times 2.51^2$
$= 63750 - 28700 - 31800 = 3250$ "

(H11) $M = 25400 \times 3.93 - 28700 - 5050 \times 3.93^2$
$= 99800 - 28700 - 78000 = -6900$ "

(H7) $M = 25400 \times 0.70 - 28100 - 5050 \times 0.7^2$
$= 17780 - 28100 - 2480 = -12800$ -[illegible]

(M4) $M = \quad 3850$ +6[illegible]

(H8) $M = \quad -6300$ -[illegible]

B

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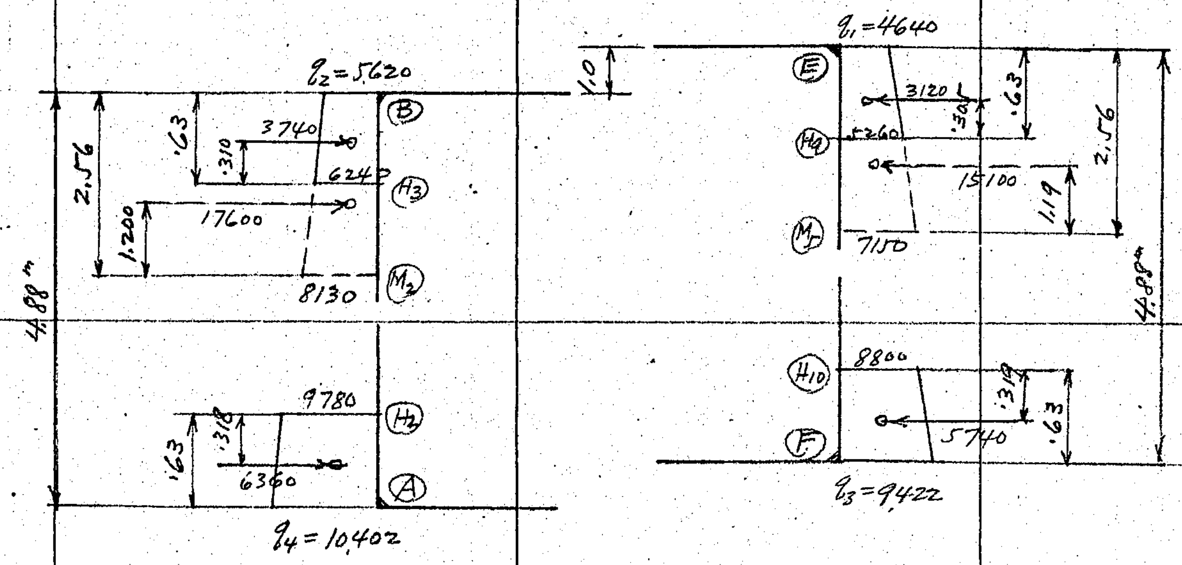
$q_3 - q_1$, $q_4 - q_2$ } = 4,782 kg/m²

Increment

4782 ÷ 488 = 980 kg/m²/lin m.

980 × 0.63 = 620
980 × 2.56 = 2510



at (H2) M = $S_{AB}\,x + M_{AB} - 6360 \times .318$ = 21500 × 0.63 − 20200 − 6360 × 0.318
= 13550 − 20200 − 2020 = −8670 kgm

(M2) M = 17600 × 2.56 − 20000 − 17600 × 1.20
= 45040 − 20,000 − 21,110 = 3930 "

(H3) M = 17600 × 0.63 − 20000 − 3740 × 0.310
= 11005 − 20000 − 1160 = −10,000 "

(H4) M = 15100 × 0.63 − 16800 − 3120 × .305
= 9510 − 16800 − 950 = −8,240 "

(M5) M = 15100 × 2.560 − 16800 − 15100 × 1.19
= 38650 − 16800 − 17970 = 3880 "

(H10) M = 19100 × 0.630 − 17500 − 5740 × .319
= 12030 − 17500 − 1830 = −7300 "

Unit stress calculations.
Bottom slab AH

at (M_1) $M_1 = 5200$ kgm, $N = 21500$ kg, $S = 0$

$d/h = 41/46 = 0.891$
$d'/h = 5/46 = 0.109$ $u = .523 \times 46 = 24.1$
$p_0 = 28.4/4600 = 0.00617$ $d - u = 16.9$ cm
$p_0' = 0.00154$

$\frac{M}{N} = \frac{5200 \times 100}{21500} = 24.2$ cm
$d - u = 16.9$
$e = 41.1$ cm
$e' = e - 36 = 5.1$
$e'/e = 0.124$
$\frac{Ne}{bd^2} = \frac{21500 \times 41.1}{100 \times 41^2} = 5.25$
$k = 0.61$, $\frac{Ne}{bd^2\sigma_c} = 0.262$
$\sigma_c = 5.25 \div 0.262 = 20.0$ kg/cm²
$\sigma_s = 15 \times 20.0 \times \frac{.39}{.61} = 192$ "

$b = 100$ cm, $h = 46$ cm
$d = 41$ ", $d' = 5$ "
$A_s = 10 - 19\phi = 28.4$ cm²
$A_s' = 2.5 -$ " $= 7.1$ "
$p = 28.4/4100 = 0.00692$
$p' = 0.00173$
$d'/d = 5/41 = 0.122$

at (H_1) $M = -7500$ kgm, $N = 21500$ kg, $S = 17700$ kg

$\frac{M}{N} = \frac{7500 \times 100}{21500} = 34.9$ cm
$d - u = 17.3$
$e = 52.2$ cm
$e' = e - 36 = 16.2$
$e'/e = 0.310$
$\frac{Ne}{bd^2} = \frac{21500 \times 52.2}{100 \times 41^2} = 6.67$
$k = 0.48$, $\frac{Ne}{bd^2\sigma_c} = 0.22$
$\sigma_c = 6.67 \div 0.22 = 30.3$ kg/cm²
$\sigma_s = 15 \times 30.3 \times \frac{.52}{.48} = 492$ "
$\tau = \frac{17700}{100 \times .84 \times 41} = 5.1$ "
$\tau_0 = \frac{17700}{59.7 \times 7.5 \times .84 \times 41} = 11.5$ "

$b = 100$ cm, $h = 46$ cm
$d = 41$ ", $d' = 5$ "
$A_s = 7.5 - 19\phi = 21.3$ cm²
$A_s' = 2.5 -$ " $= 7.1$ "
$p = 21.3/4100 = 0.00520$
$p' = 0.00173$
$d'/d = 0.122$

at (H_{14}) $M = -13900$ kgm, $N = 21500$ kg, $S = 21500$ kg

$d/h = 41/46 = 0.891$
$d'/h = 5/46 = 0.109$ $u = 0.50 \times 46 = 23.0$
$p_0 = 0.00617$ $d - u = 18.0$
$p_0' = 0.00617$

$\frac{M}{N} = \frac{13900 \times 100}{21500} = 64.7$ cm
$d - u = 18.0$
$e = 82.7$ cm
$e' = e - 36 = 46.7$ "
$e'/e = 0.564$
$\frac{Ne}{bd^2} = \frac{21500 \times 82.7}{100 \times 41^2} = 10.55$
$k = 0.405$, $\frac{Ne}{bd^2\sigma_c} = 0.240$
$\sigma_c = 10.55 \div 0.240 = 43.9$ kg/cm²
$\sigma_s = 15 \times 43.9 \times \frac{.595}{.405} = 967$
$\tau = \frac{21500}{100 \times .865 \times 41} = 6.1$
$\tau_0 = \frac{21500}{59.7 \times .865 \times 41} = 10.1$

$b = 100$ cm, $h = 46$ cm
$d = 41$ ", $d' = 5$ "
$A_s = 10 - 19\phi = 28.4$ cm²
$A_s' = 10 -$ " $= 28.4$ "
$p = 0.00692$
$p' = 0.00692$
$d'/d = 0.122$

D

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at (H) $M_{HA} = -32000$ kgm, $N = 21500$ kg, $S = 30000$ kg

$d/h = 64/69 = 0.928$
$d'/h = 5/69 = 0.073$ $u = .506 \times 69 = 34.9$ cm
$p_0 = 0.00551$ $d-u = 29.1$
$p_0' = 0.00412$

$\frac{M}{N} = \frac{32000 \times 100}{21500} = 149.0$ cm
$d-u = 29.1$
$e = 178.1$ cm
$e' = e-59 = 119.1$
$e'/e = 0.666$
$\frac{Ne}{bd^2} = \frac{21500 \times 178.1}{100 \times 64^2} = 9.33$
$k = 0.370$, $\frac{Ne}{bd^2\sigma_c} = .213$

$b = 100$ cm, $h = 46 + \frac{70}{3} = 69$ cm
$d = 64$ cm, $d' = 5$ "
$A_s = 10-22^\phi = 38.0$ cm²
$A_s' = 10-19^\phi = 28.4$ "
$p = 0.00594$
$p' = 0.00444$
$d'/d = 0.078$

$\sigma_c = 9.33 \div 0.213 = 43.8$ kg/cm²
$\sigma_s = 15 \times 43.8 \times \frac{.630}{.370} = 1118$ "
$\tau = \frac{30000}{100 \times .867 \times 64} = 5.4$ "
$\tau_0 = \frac{30000}{69.1 \times .867 \times 64} = 7.8$ "

at (A) $M_{AH} = -20200$ kgm, $N = 21500$ kg, $S = 24800$ kg

$d/h = 0.924$
$d'/h = 0.076$ $u = 0.516 \times 66 = 34.1$
$p_0 = 0.00431$ $d-u = 26.9$
$p_0' = 0.00108$

$\frac{M}{N} = \frac{20200 \times 100}{21500} = 94.0$ cm
$d-u = 26.9$
$e = 120.9$ cm
$e' = e-56 = 64.9$
$e'/e = 0.537$
$\frac{Ne}{bd^2} = \frac{21500 \times 120.9}{100 \times 61^2} = 6.98$
$K = 0.385$ $\frac{Ne}{bd^2\sigma_c} = 0.182$

$b = 100$ cm, $h = 46 + \frac{60}{3} = 66$ cm
$d = 61$ ", $d' = 5$
$A_s = 10-19^\phi = 28.4$ cm²
$A_s' = 2.5-$ " $= 7.1$
$p = 0.00466$
$p' = 0.00117$
$d'/d = 0.082$

$\sigma_c = 6.98 \div 0.182 = 38.4$ kg/cm²
$\sigma_s = 15 \times 38.4 \times \frac{.615}{.385} = 920$ "
$\tau = \frac{24800}{100 \times .872 \times 61} = 4.7$ "
$\tau_0 = \frac{24800}{59.7 \times .872 \times 61} = 7.8$ "

Top slab BC.
at (M_3) $M_3 = 5400$ kgm, $N = 17600$ kg, $S = 0$

See (M_1) – – –

$\frac{M}{N} = \frac{5400 \times 100}{17600} = 30.7$ cm
$d-u = 16.9$
$e = 47.6$ cm
$e' = e-36 = 11.6$ "
$e'/e = 0.244$
$\frac{Ne}{bd^2} = \frac{17600 \times 47.6}{100 \times 41^2} = 4.99$
$K = 0.540$, $\frac{Ne}{bd^2\sigma_c} = 0.240$

$b = 100$ cm, $h = 46$ cm
$d = 41$ ", $d' = 5$ "
$A_s = 10-19^\phi = 28.4$ cm
$A_s' = 2.5-$ " $= 7.1$ "
$p = 0.00692$
$p' = 0.00173$
$d'/d = 0.122$

$\sigma_c = 4.99 \div 0.240 = 20.8$ kg/cm²
$\sigma_s = 15 \times 20.8 \times \frac{.46}{.54} = 266$ "

E

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at (H4) M = -7300 kgm, N = 17600 kg, S = 17700 kg. — section same as for (H1)

$\frac{M}{N} = \frac{7300 \times 100}{17600} = 41.5$ cm
d-u = 17.3
e = 58.8 cm
e' = e - 36 = 22.8 ·
e'/e = 0.388
$\frac{Ne}{bd^2} = \frac{17600 \times 58.8}{100 \times 41^2} = 6.15$
k = 0.450 , $\frac{Ne}{bd^2 \sigma_c} = 0.210$

$\sigma_c = 6.15 \div 0.21 = 29.3$ kg/cm²
$\sigma_s = 15 \times 29.3 \times \frac{.55}{.45} = 537$ ·
$\tau = \frac{17700}{100 \times .85 \times 41} = 5.1$ ·
$\tau_0 = \frac{17700}{59.7 \times 7.5 \times .85 \times 41} = 11.3$ ·

at (H5) M = 13700 kgm, N = 17600 kg, S = 21500 kg

b = 100 cm, h = 46 cm
d = 41 ·, d' = 5 ·
As = 10-19φ = 28.4 cm²
As' = 5 - · · = 14.2
p = 0.00693
p' = 0.00346
d'/d = 0.122

d/h = 0.891
d'/h = 0.109
p0 = 0.00617
p0' = 0.00309
u = 0.513 × 46 = 23.6 cm
d-u = 17.4 ·

$\frac{M}{N} = \frac{13700 \times 100}{17600} = 77.9$ cm
d-u = 17.4
e = 95.3 cm
e' = e - 36 = 59.3 ·
e'/e = 0.622
$\frac{Ne}{bd^2} = \frac{17600 \times 95.3}{100 \times 41^2} = 9.97$
k = 0.410 , $\frac{Ne}{bd^2 \sigma_c} = 0.213$

$\sigma_c = 9.97 \div 0.213 = 46.7$ kg/cm²
$\sigma_s = 15 \times 46.7 \times \frac{.59}{.41} = 1008$ ·
$\tau = \frac{21500}{100 \times .863 \times 41} = 6.1$ ·
$\tau_0 = \frac{21500}{59.7 \times .863 \times 41} = 10.2$ ·

at (B) M_{BC} = -20000 kgm, N = 17600 kg, S = 24800 kg — section same as for (A)

$\frac{M}{N} = \frac{20000 \times 100}{17600} = 113.6$ cm
d-u = 26.9
e = 140.5 cm
e' = e - 56 = 84.5 ·
e'/e = 0.601
$\frac{Ne}{bd^2} = \frac{17600 \times 140.5}{100 \times 61^2} = 6.65$
k = 0.370 , $\frac{Ne}{bd^2 \sigma_c} = 0.177$

$\sigma_c = 6.65 \div 0.177 = 37.6$ kg/cm²
$\sigma_s = 15 \times 37.6 \times \frac{.63}{.37} = 961$ ·
$\tau = \frac{24800}{100 \times .877 \times 61} = 4.6$ ·
$\tau_0 = \frac{24800}{59.7 \times .877 \times 61} = 7.8$ ·

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at C. $M_{CB} = -31900$ kgm, $N = 17600$ kg, $S = 30000$ kg

$b = 100$ cm, $h = 46 + \frac{70+80}{3} = 96$ cm
$d = 91$", $d' = 5$"
$A_s = 10-19\phi = 28.4$ cm²
$A_s' = 2.5-$ 〃 $=$ 7.1 〃
$p =$ 0.00312
$p' =$ 0.00078
$d'/d =$ 0.055

$d/h = 0.948$
$d'/h = 0.052$
$p_0 = 0.00296$
$p_0' = 0.00074$

$u = 0.512 \times 96 = 49.1$
$d - u =$ 41.9 cm

$\frac{M}{N} = \frac{31900 \times 100}{17600} = 181.2$ cm
$d - u = 41.9$
$e = 223.1$ cm
$e' = e - 86 = 137.1$
$e'/e = 0.614$
$\frac{Ne}{bd^2} = \frac{17600 \times 223.1}{100 \times 91^2} = 4.74$
$k = 0.320$, $\frac{Ne}{bd^2\sigma_c} = 0.153$

$\sigma_c = 4.74 \div 0.153 = 31.0$ kg/cm²
$\sigma_s = 15 \times 31 \times \frac{.68}{.32} = 987$ 〃
$\tau = \frac{30000}{100 \times .893 \times 91} = 3.7$ 〃
$\tau_0 = \frac{30000}{59.7 \times .893 \times 91} = 6.2$ 〃

Bottom slab FG.

at (M6) $M_6 = 3300$ kgm, $N = 19200$ kg, $S = 0$ — section same as for M_1

$\frac{M}{N} = \frac{3300 \times 100}{19200} = 17.2$
$d - u = 16.9$
$e = 34.1$ cm
$e' = 36 - e = 1.9$ 〃
$e'/e = 0.056$
$\frac{Ne}{bd^2} = \frac{19200 \times 34.1}{100 \times 41^2} = 3.47$
$k = 0.74$, $\frac{Ne}{bd^2\sigma_c} = 0.298$

$\sigma_c = 3.47 \div 0.298 = 11.7$ kg/cm²
$\sigma_s = 15 \times 11.7 \times \frac{.26}{.74} = 62$

at (H11) $M = -6900$ kgm, $N = 19200$ kg, $S = 14300$ kg — section same as for H_1

$\frac{M}{N} = \frac{6900 \times 100}{19200} = 36.0$
$d - u = 17.3$
$e = 53.3$ cm
$e' = e - 36 = 17.3$
$e'/e = 0.325$
$\frac{Ne}{bd^2} = \frac{19200 \times 53.3}{100 \times 41^2} = 6.09$
$k = 0.47$, $\frac{Ne}{bd^2\sigma_c} = 0.217$

$\sigma_c = 6.09 \div 0.217 = 28.0$ kg/cm²
$\sigma_s = 15 \times 28.0 \times \frac{.53}{.47} = 474$
$\tau = \frac{14300}{100 \times .843 \times 41} = 4.1$
$\tau_0 = \frac{14300}{59.7 \times 7.5 \times .843 \times 41} = 9.2$

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at (H12) M = −13400 kgm, N = 19200 kg, S = 18300 kg — section same as for H5

$\frac{M}{N} = \frac{13400 \times 100}{19200} = 69.8$ cm
$d-u = 17.4$
$e = 87.2$ cm
$e' = e - 36 = 51.2$ "
$e'/e = 0.587$
$\frac{Ne}{bd^2} = \frac{19200 \times 87.2}{100 \times 41^2} = 9.95$
$k = 0.415$, $\frac{Ne}{bd^2 \sigma_c} = 0.214$

$\sigma_c = 9.95 \div 0.214 = 46.5$ kg/cm²
$\sigma_s = 15 \times 46.5 \times \frac{.585}{.415} = 982$ "
$\tau = \frac{18300}{100 \times .862 \times 41} = 5.2$ "
$\tau_0 = \frac{18300}{59.7 \times .862 \times 41} = 8.7$ "

at (F) M_{FG} = −17500 kgm, N = 19200 kg, S = 20400 kg — section same as for (A)

$\frac{M}{N} = \frac{17500 \times 100}{19200} = 91.2$ cm
$d-u = 26.9$
$e = 118.1$ cm
$e' = e - 56 = 62.1$
$e'/e = 0.525$
$\frac{Ne}{bd^2} = \frac{19200 \times 118.1}{100 \times 61^2} = 6.09$
$k = 0.385$, $\frac{Ne}{bd^2 \sigma_c} = 0.182$

$\sigma_c = 6.09 \div 0.182 = 33.5$ kg/cm²
$\sigma_s = 15 \times 33.5 \times \frac{.615}{.385} = 802$ "
$\tau = \frac{20400}{100 \times .872 \times 61} = 3.8$ "
$\tau_0 = \frac{20400}{59.7 \times .872 \times 61} = 6.4$ "

at (G) M_{GF} = −32000 kgm, N = 19200 kg, S = 25400 kg — Section same as for C

$\frac{M}{N} = \frac{32000 \times 100}{19200} = 166.8$
$d-u = 41.9$
$e = 208.7$ cm
$e' = e - 86 = 122.7$ "
$e'/e = 0.589$
$\frac{Ne}{bd^2} = \frac{19200 \times 208.7}{100 \times 91^2} = 4.84$
$k = 0.32$, $\frac{Ne}{bd^2 \sigma_c} = 0.153$
$\sigma_c = 4.84 \div 0.153 = 31.6$ kg/cm²
$\sigma_s = 15 \times 31.6 \times \frac{.68}{.32} = 1008$ "
$\tau = \frac{25400}{100 \times .893 \times 91} = 3.1$ "
$\tau_0 = \frac{25400}{59.7 \times .893 \times 91} = 5.2$ "

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CALCULATIONS FOR

Top Slab DE

at (M4) $M_4 = 3900$ kgm, $N = 15100$ kg, $S = 0$ — Section same as for M_3

$\frac{M}{N} = \frac{3900 \times 100}{15100} = 25.8$ cm

$d - u = 16.9$

$e = 42.7$ cm

$e' = e - 36 = 6.7$ "

$e'/e = 0.157$

$\frac{Ne}{bd^2} = \frac{15100 \times 42.7}{100 \times 41^2} = 3.84$

$k = 0.59$ $\frac{Ne}{bd^2\sigma_c} = 0.256$

$\sigma_c = 3.84 \div .256 = 15.0$ kg/cm²

$\sigma_s = 15 \times 15.0 \times \frac{.41}{.59} = 156$ "

at (H8) $M = -6300$ kgm, $N = 15100$ kg, $S = 14300$ kg — Section same as for H_4.

$\frac{M}{N} = \frac{6300 \times 100}{15100} = 41.7$ cm

$d - u = 17.3$

$e = 59.0$ cm

$e' = e - 36 = 23.0$ "

$e'/e = 0.390$

$\frac{Ne}{bd^2} = \frac{15100 \times 59.0}{100 \times 41^2} = 5.30$

$k = 0.45$, $\frac{Ne}{bd^2\sigma_c} = 0.210$

$\sigma_c = 5.30 \div 0.210 = 25.3$ kg/cm²

$\sigma_s = 15 \times 25.3 \times \frac{.55}{.45} = 464$ "

$\tau = \frac{14300}{100 \times .85 \times 41} = 4.1$ "

$\tau_0 = \frac{14300}{5.97 \times 7.5 \times .85 \times 41} = 9.2$ "

at (H7) $M = -12800$ kgm, $N = 15100$ kg, $S = 18300$ kg — Section same as for H_5.

$\frac{M}{N} = \frac{12800 \times 100}{15100} = 84.7$ cm

$d - u = 17.4$

$e = 102.1$ cm

$e' = e - 36 = 66.1$ "

$e'/e = 0.647$

$\frac{Ne}{bd^2} = \frac{15100 \times 102.1}{100 \times 41^2} = 9.18$

$k = 0.405$, $\frac{Ne}{bd^2\sigma_c} = 0.210$

$\sigma_c = 9.18 \div 0.21 = 43.7$ kg/cm²

$\sigma_s = 15 \times 43.7 \times \frac{.595}{.405} = 964$ "

$\tau = \frac{18300}{100 \times .865 \times 41} = 5.2$ "

$\tau_0 = \frac{18300}{59.7 \times .865 \times 41} = 8.6$ "

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CALCULATIONS FOR

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at (E) $M_{ED} = -16800$ kgm, $N = 15100$ kg, $S = 20400$ kg — section same as for A

$\frac{M}{N} = \frac{16800 \times 100}{15100} = 111.2$

$d-u = 26.9$

$e = 138.1$ cm

$e' = e - 56 = 82.1$

$e'/e = 0.595$

$\frac{Ne}{bd^2} = \frac{15100 \times 138.1}{100 \times 61^2} = 5.60$

$k = 0.370$, $\frac{Ne}{bd^2\sigma_c} = 0.177$

$\sigma_c = 5.60 \div 0.177 = 31.7$ kg/cm²

$\sigma_s = 15 \times 31.7 \times \frac{.63}{.37} = 810$

$\tau = \frac{20400}{100 \times .877 \times 61} = 3.8$

$\tau_0 = \frac{20400}{59.7 \times .877 \times 61} = 6.4$

at (D) $M_{DE} = -28100$ kgm, $N = 15100$ kg, $S = 25400$ kg — $b = 100$ cm, $h = 46 + \frac{70}{3} = 69$ cm

$d/h = 0.928$
$d'/h = 0.073$
$p_0 = 0.00551$
$p_0' = 0.00206$

$u = 0.517 \times 69 = 36.6$ cm
$d - u = 27.4$

$\frac{M}{N} = \frac{28100 \times 100}{15100} = 186.3$ cm

$d-u = 27.4$

$e = 213.7$ cm

$e' = e - 59 = 154.7$

$e'/e = 0.724$

$\frac{Ne}{bd^2} = \frac{15100 \times 213.7}{100 \times 64^2} = 7.88$

$k = 0.370$, $\frac{Ne}{bd^2\sigma_c} = 0.187$

$\sigma_c = 7.88 \div 0.187 = 42.1$ kg/cm²

$\sigma_s = 15 \times 42.1 \times \frac{.630}{.370} = 1076$

$\tau = \frac{25400}{100 \times .877 \times 64} = 4.5$

$\tau_0 = \frac{25400}{69.1 \times .877 \times 64} = 6.6$

$d = 64$ cm, $d' = 5$ cm
$A_s = 10 - 22\phi = 38.0$ cm²
$A_s' = 5 - 19\phi = 14.2$
$p = 0.00594$
$p' = 0.00222$
$d'/d = 0.078$

Side wall AB

at (M2) $M_2 = 3900$ kgm $N = 24800$ kg, $S = 0$ — $b = 100$ cm, $h = 40$ cm

$u = 0.526 \times 40 = 21.0$ cm

$\frac{M}{N} = \frac{3900 \times 100}{24800} = 15.7$ cm

$d-u = 14.0$

$e = 29.7$ cm

$e' = 30 - 29.7 = 0.3$

$e'/e = 0.010$

$\frac{Ne}{bd^2} = \frac{24800 \times 29.7}{100 \times 35^2} = 6.01$

$k = 0.740$, $\frac{Ne}{bd^2\sigma_c} = 0.300$

$\sigma_c = 6.01 \div 0.30 = 20.1$ kg/cm²

$\sigma_s = 15 \times 20.1 \times \frac{.26}{.74} = 106$

$d = 35$, $d' = 5$
$A_s = 10 - 19\phi = 28.4$ cm²
$A_s' = 25 - 〃 = 7.1$
$p = 0.00811$
$p' = 0.00203$
$d'/d = 0.143$

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CALCULATIONS FOR

at (H2) M = -8,700 kgm, N = 24800 kg, S = 15,200 kg.

b = 100 cm, h = 40 cm
d = 35 ", d' = 5 "
Same as for M_2

$\frac{M}{N} = \frac{8700 \times 100}{24800} = 35.1$ cm
d-u = 14.0
e = 49.1 cm
e' = e - 30 = 19.1 "
e'/e = 0.389
$\frac{Ne}{bd^2} = \frac{24800 \times 49.1}{100 \times 35^2} = 9.95$
k = .515 $\frac{Ne}{bd^2\sigma_c} = .234$
$\sigma_c = 9.95 \div 0.234 = 42.5$ kg/cm²
$\sigma_s = 15 \times 42.5 \times \frac{.485}{.515} = 600$ "
$\tau = \frac{15900}{100 \times .828 \times 35} = 5.5$ "
$\tau_0 = \frac{15900}{59.7 \times .828 \times 35} = 9.2$ "

at (H3) M = -10,000 kgm, N = 24800 kg, S = 13300 kg.

d/h = 0.875
d'/h = 0.125
p_0 = 0.00710
p_0' = 0.00355

u = 0.519 × 40 = 20.8 cm
d-u = 14.2

b = 100 cm, h = 40 cm
d = 35 ", d' = 5 "
A_s = 10-19φ = 28.4 cm²
A_s' = 5- " = 14.2 "
p = 0.00811
p' = 0.00406
d'/d = 0.143

$\frac{M}{N} = \frac{10{,}000 \times 100}{24800} = 40.3$ cm
d-u = 14.2
e = 54.5 cm
e' = e - 30 = 24.5 "
e'/e = 0.449
$\frac{Ne}{bd^2} = \frac{24800 \times 54.5}{100 \times 35^2} = 11.02$
k = 0.49, $\frac{Ne}{bd^2\sigma_c} = 0.243$
$\sigma_c = 11.02 \div 0.243 = 45.3$ kg/cm²
$\sigma_s = 15 \times 45.3 \times \frac{.51}{.49} = 708$ "
$\tau = \frac{13300}{100 \times .837 \times 35} = 4.5$ "
$\tau_0 = \frac{13300}{59.7 \times .837 \times 35} = 7.6$ "

at (A) M_{AB} = -20200 kgm, N = 24800 kg, S = 21500 kg

d/h = 0.919
d'/h = 0.082
p_0 = 0.00466
p_0' = 0.00117

u = 0.515 × 61 = 31.4 cm
d-u = 24.6

b = 100 cm, h = 40 + $\frac{63}{3}$ = 61 cm
d = 56 cm, d' = 5 cm
A_s = 10-19φ = 28.4 cm²
A_s' = 2.5- " = 7.1 "
p = 0.00507
p' = 0.00127
d'/d = 0.089

$\frac{M}{N} = \frac{20200 \times 100}{24800} = 81.5$
d-u = 24.6
e = 106.1 cm
e' = e - 51 = 55.1
e'/e = 0.519
$\frac{Ne}{bd^2} = \frac{24800 \times 106.1}{100 \times 56^2} = 8.38$
k = 0.40, $\frac{Ne}{bd^2\sigma_c} = 0.188$
$\sigma_c = 8.38 \div 0.188 = 44.6$ kg/cm²
$\sigma_s = 15 \times 44.6 \times \frac{.60}{.40} = 1003$ "
$\tau = \frac{21500}{100 \times 0.867 \times 56} = 4.4$ "
$\tau_0 = \frac{21500}{59.7 \times .867 \times 56} = 7.4$ "

K

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CALCULATIONS FOR

at (B) $M_{BA} = -20000$ kgm, $N = 24800$ kg, $S = 17600$ kg — section same as for A

$\frac{M}{N} = \frac{20000 \times 100}{24800} = 80.7$

$d-u = 24.6$

$e = 105.3$ cm

$e' = e - 51 = 54.3$

$e'/e = 0.515$

$\frac{Ne}{bd^2} = \frac{24800 \times 105.3}{100 \times 56^2} = 8.32$

$k = 0.40$, $\frac{Ne}{bd^2 \sigma_c} = 0.188$

$\sigma_c = 8.32 \div 0.188 = 44.2$ kg/cm²

$\sigma_s = 15 \times 44.2 \times \frac{.60}{.40} = 996$ "

$\tau = \frac{17600}{100 \times .867 \times 56} = 3.6$ "

$\tau_0 = \frac{17600}{59.7 \times .867 \times 56} = 6.1$ "

Side wall EF

at (M5) $M_r = 3900$ kgm, $N = 20400$ kg, $S = 0$ — section same as for M_2

$\frac{M}{N} = \frac{3900 \times 100}{20400} = 19.1$ cm

$d-u = 14.0$

$e = 33.1$ cm

$e' = e - 30 = 3.1$ "

$e'/e = 0.094$

$\frac{Ne}{bd^2} = \frac{20400 \times 33.1}{100 \times 35^2} = 5.51$

$k = 0.66$, $\frac{Ne}{bd^2 \sigma_c} = 0.279$

$\sigma_c = 5.51 \div 0.279 = 19.8$ kg/cm²

$\sigma_s = 15 \times 19.8 \times \frac{.34}{.66} = 153$ "

at (H10) $M = -7300$ kgm, $N = 20400$ kg, $S = 13800$ kg — section same as for M_2

$\frac{M}{N} = \frac{7300 \times 100}{20400} = 35.8$

$d-u = 14.0$

$e = 49.8$ cm

$e' = e - 30 = 19.8$

$e'/e = 0.397$

$\frac{Ne}{bd^2} = \frac{20400 \times 49.8}{100 \times 35^2} = 8.29$

$k = 0.510$, $\frac{Ne}{bd^2 \sigma_c} = 0.233$

$\sigma_c = 8.29 \div 0.233 = 35.6$ kg/cm²

$\sigma_s = 15 \times 35.6 \times \frac{.49}{.51} = 513$ "

$\tau = \frac{13800}{100 \times .83 \times 35} = 4.8$ "

$\tau_0 = \frac{13800}{59.7 \times .83 \times 35} = 8.0$ "

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CALCULATIONS FOR

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at (Hq) M = −8200 kgm, N = 20400 kg, S = 11300 kg. — section same as for M_2

$\frac{M}{N} = \frac{8200 \times 100}{20400} = 40.2$ cm

$d - u = 14.0$

$e = 54.2$ cm

$e' = e - 30 = 24.2$

$e'/e = 0.447$

$\frac{Ne}{bd^2} = \frac{20400 \times 54.2}{100 \times 35^2} = 9.03$

$k = .495$, $\frac{Ne}{bd^2 \sigma_c} = 0.227$

$\sigma_c = 9.03 \div 0.227 = 39.8$ kg/cm²

$\sigma_s = 15 \times 39.8 \times \frac{.505}{.495} = 609$ 〃

$\tau = \frac{11300}{100 \times .835 \times 35} = 3.9$ 〃

$\tau_0 = \frac{11300}{59.7 \times .835 \times 35} = 6.5$ 〃

at (E) M_{EF} = −16800 kgm, N = 20400 kg, S = 15100 kg — section same as for A

$\frac{M}{N} = \frac{16800 \times 100}{20400} = 82.4$

$d - u = 24.6$

$e = 107.0$ cm

$e' = e - 51 = 56.0$

$e'/e = 0.523$

$\frac{Ne}{bd^2} = \frac{20400 \times 107.0}{100 \times 56^2} = 6.95$

$k = 0.395$, $\frac{Ne}{bd^2 \sigma_c} = 0.186$

$\sigma_c = 6.95 \div 0.186 = 37.4$ kg/cm²

$\sigma_s = 15 \times 37.4 \times \frac{.605}{.395} = 859$ 〃

$\tau = \frac{15100}{100 \times .868 \times 56} = 3.1$ 〃

$\tau_0 = \frac{15100}{59.7 \times .868 \times 56} = 5.2$ 〃

at (F) M_{FE} = −17500 kgm, N = 20400 kg, S = 19200 kg. — section same as for A

$\frac{M}{N} = \frac{17500 \times 100}{20400} = 85.8$ cm

$d - u = 24.6$

$e = 110.4$ cm

$e' = e - 51 = 59.4$

$e'/e = 0.538$

$\frac{Ne}{bd^2} = \frac{20400 \times 110.4}{100 \times 56^2} = 7.18$

$k = .395$, $\frac{Ne}{bd^2 \sigma_c} = .186$

$\sigma_c = 7.18 \div .186 = 38.6$ kg/cm²

$\sigma_s = 15 \times 38.6 \times \frac{.605}{.395} = 887$

$\tau = \frac{19200}{100 \times .868 \times 56} = 4.0$

$\tau_0 = \frac{19200}{59.7 \times .868 \times 56} = 6.6$

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CALCULATIONS FOR

Center wall. DC

at Ⓓ M_{DC} = 28,100 kgm, N = 25400 kg, S = 15100 kg

b = 100 cm, $h = 60 + \frac{63}{3} = 81$ cm
d = 76 cm, d' = 5 cm
A_s = 10 - 22φ = 38.0 cm²
A_s' = 5 - 19φ = 14.2 cm²
p = 0.00500
p' = 0.00187
d'/d = 0.066

d/h = 0.939
d'/h = 0.062
p_0 = 0.00469
p_0' = 0.00175

u = 0.516 × 81 = 41.8 cm
d - u = 34.2

$\frac{M}{N} = \frac{28100 \times 100}{25400} = 110.6$ cm
d - u = 34.2
e = 144.8 cm
e' = e - 71 = 73.8
e'/e = 0.510
$\frac{Ne}{bd^2} = \frac{25400 \times 144.8}{100 \times 76^2} = 6.37$

k = 0.39, $\frac{Ne}{bd^2 \sigma_c}$ = .194

σ_c = 6.37 ÷ 0.194 = 33.0 kg/cm²
$\sigma_s = 15 \times 33.0 \times \frac{.61}{.39} = 775$ 〃
$\tau = \frac{15100}{100 \times .870 \times 76} = 2.3$ 〃
$\tau_0 = \frac{15100}{69.1 \times .87 \times 76} = 3.3$ 〃

at Ⓒ M_{CD} = 15,500 kgm, N = 25400 kg, S = 10000 kg

b = 100 cm, $h = 60 + \frac{73}{3} = 84$ cm
d = 79 cm, d' = 5 cm
A_s = 10 - 19φ = 28.40 cm²
A_s' = 5 - 19φ = 14.20 〃
p = 0.00360
p' = 0.00180
d'/d = 0.063

d/h = 0.941
d'/h = 0.06
p_0 = 0.00338
p_0' = 0.00169

u = 0.511 × 84 = 42.9 cm
d - u = 38.1

$\frac{M}{N} = \frac{15500 \times 100}{25400} = 61.0$ cm
d - u = 38.1
e = 99.1 cm
e' = e - 74 = 25.1 〃
e'/e = 0.253
$\frac{Ne}{bd^2} = \frac{25400 \times 99.1}{100 \times 79^2} = 4.03$

k = .430, $\frac{Ne}{bd^2 \sigma_c}$ = .207

σ_c = 4.03 ÷ 0.207 = 19.5 kg/cm²
$\sigma_s = 15 \times 19.5 \times \frac{.57}{.43} = 388$ 〃
$\tau = \frac{10000}{100 \times .857 \times 79} = 1.5$ 〃
$\tau_0 = \frac{10000}{69.1 \times .857 \times 79} = 2.1$ 〃

Center wall CG.

at Ⓒ M_{CG} = 16400 kgm, N = 55400 kg, S = 7600 kg

b = 100 cm, $h = 60 + \frac{63}{3} = 81$ cm
d = 76 cm, d' = 5 cm
A_s = 5 - 19φ = 14.2 cm²
A_s' = 2.5 - 19φ = 7.1 〃
p = 0.00187
p' = 0.00094
d'/d = 0.066

d/h = 0.939
d'/h = 0.062
p_0 = 0.00175
p_0' = 0.00088

u = 0.505 × 81 = 40.9 cm
d - u = 35.1

$\frac{M}{N} = \frac{16400 \times 100}{55400} = 29.6$ cm
d - u = 35.1
e = 64.7 cm
e' = 71 - e = 6.3 〃
e'/e = 0.097
$\frac{Ne}{bd^2} = \frac{55400 \times 64.7}{100 \times 76^2} = 6.21$

k = 0.61, $\frac{Ne}{bd^2 \sigma_c}$ = 0.260

σ_c = 6.21 ÷ 0.260 = 23.9 kg/cm²
$\sigma_s = 15 \times 23.9 \times \frac{.39}{.61} = 229$ 〃
$\tau = \frac{7600}{100 \times .797 \times 76} = 1.3$ 〃
$\tau_0 = \frac{7600}{5 \times 5.97 \times .797 \times 76} = 4.2$ 〃

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CALCULATIONS FOR

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at (H6) M = 11600 kgm, N = 55400 kg, S = 7600 kg — b = 100 cm, h = 60 cm

d/h = 0.917
d'/h = 0.083
p_0 = 0.00237
p_0' = 0.00317

u = 0.495 × 60 = 29.7
d−u = 25.2

$\frac{M}{N} = \frac{11600 \times 100}{55400} = 20.9$ cm
d−u = 25.2
e = 46.1 cm
e' = 50 − e = 3.9
e'/e = 0.085
$\frac{Ne}{bd^2} = \frac{55400 \times 46.1}{100 \times 55^2} = 8.44$
k = .65, $\frac{Ne}{bd^2\sigma_c} = .295$

d = 55, d' = 5
As = 5−19φ = 14.2 cm²
As' = 5−22φ = 19.0 "
p = 0.00258
p' = 0.00345
d'/d = 0.091

$\sigma_c = 8.44 \div .295 = 28.6$ kg/cm²
$\sigma_s = 15 \times 28.6 \times \frac{.35}{.65} = 231$ "
$\tau = \frac{7600}{100 \times .783 \times 55} = 1.8$ "
$\tau_0 = \frac{7600}{5.97 \times 5 \times .783 \times 55} = 5.9$ "

Center wall GH.

at (G) M_{GH} = 15,500 kgm, N = 30000 kg, S = 11,600 kg — Section same as for C in DC

$\frac{M}{N} = \frac{15500 \times 100}{30000} = 51.7$ cm
d−u = 38.1
e = 89.8 cm
e' = e − 74 = 15.8 "
e'/e = 0.176
$\frac{Ne}{bd^2} = \frac{30000 \times 89.8}{100 \times 79^2} = 4.32$
k = 0.47, $\frac{Ne}{bd^2\sigma_c} = 0.220$

$\sigma_c = 4.32 \div 0.220 = 19.6$ kg/cm²
$\sigma_s = 15 \times 19.6 \times \frac{.53}{.47} = 332$ "
$\tau = \frac{11600}{100 \times .843 \times 79} = 1.7$ "
$\tau_0 = \frac{11600}{69.1 \times .843 \times 79} = 2.5$ "

at (H) M_{HG} = − 32000 kgm, N = 30000 kg, S = 21500 kg — b = 100 cm, h = 60 + 63/3 = 81 cm

d/h = 0.939
d'/h = 0.062
p_0 = 0.00469
p_0' = 0.00351

u = 0.507 × 81 = 41.0
d−u = 35.0

$\frac{M}{N} = \frac{32000 \times 100}{30000} = 106.7$ cm
d−u = 35.0
e = 141.7 cm
e' = e − 71 = 70.7 "
e'/e = 0.499
$\frac{Ne}{bd^2} = \frac{30000 \times 141.7}{100 \times 76^2} = 7.35$
k = .38, $\frac{Ne}{bd^2\sigma_c} = .212$

d = 76 ", d' = 5 "
As = 10−22φ = 38.00 cm²
As' = 10−19φ = 28.40 "
p = 0.00500
p' = 0.00374
d'/d = 0.066

$\sigma_c = 7.35 \div .212 = 34.7$ kg/cm²
$\sigma_s = 15 \times 34.7 \times \frac{.62}{.38} = 849$ "
$\tau = \frac{21500}{100 \times .873 \times 76} = 3.2$ "
$\tau_0 = \frac{21500}{69.1 \times .873 \times 76} = 4.7$ "

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CALCULATIONS FOR

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不用

赤坂見附
停車場

上下二段式函型隧道設計々算書

断面A5號

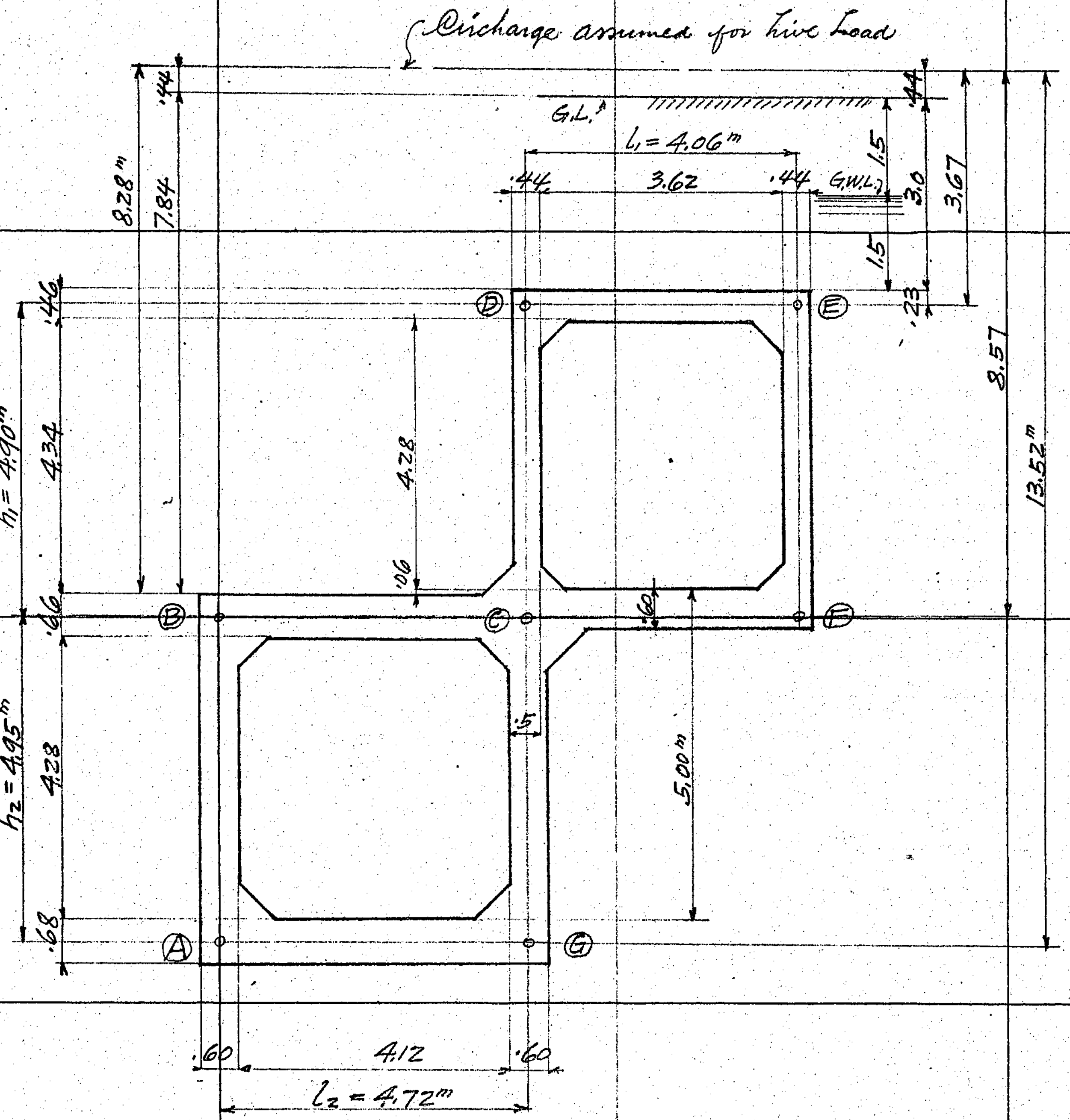
土被 三.〇米

自 百十七頁
至 百四十二頁

二十八葉

断面A5號 土被3,0米

Assumed Cross section of the tonnel, as shown below.



Scale 1:100

Load on Top slab. DE

Earth filling above ground water level	1.50^m @	1600 =	2400	
〃 〃 below 〃 〃 〃	1.50 @	2000 =	3000	
				5400
Weight of slab	0.46 @	2400 =		1100
				6500
Live load on roadway assumed as				700
			w_1 =	7200 kg/m²

Load on Middle floor slab. BC.

Earth filling above ground W.L.	1.50 @	1600 =	2400	
〃 〃 below 〃	6.34 @	2000 =	12680	
				15080
weight of slab	0.66 @	2400 =		1580
				16660
Live Load on roadway assumed as				700
			w_2 =	17360 kg/m²

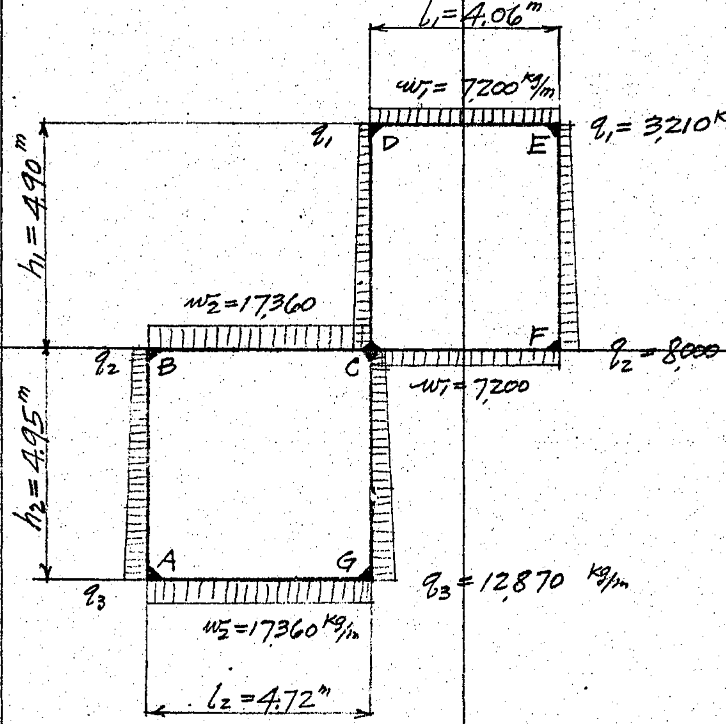
Load on Bottom slab.

for slab CF $w_1 = 7200$ kg/m²

for 〃 AG $w_2 = 17360$ 〃

上下二段式走型隧道 断面A5號 土被3.0米

Loading Condition.



Earth pressure intensity.
pressure coef. = 0.490 for $\phi = 20°$, see on page 83.

at D

1.94^m	@ 1600	=	3,100	
1.73	@ 2000	=	3460	
			6,560	× 0.490 = 3,210 kg/m² = q_1

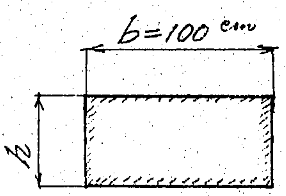
at B

1.94	@ 1600	=	3,100	
6.63	@ 2000	=	13260	
			16360	× 0.490 = 8,000 kg/m² = q_2

at A.

1.94	@ 1600	=	3100	
11.58	@ 2000	=	23,160	
			26,260	× 0.490 = 12,870 kg/m² = q_3

Assumed cross section and moment of inertia of each member.



		width b	depth h	h^3	$J=\frac{bh^3}{12}$		J
Top slab	DE	100 cm	46 cm	97,336	81,000 cm⁴	or	0.00811 m⁴
middle "	BC	"	66	287,496	2398,000 "	"	0.02398 "
" "	CF	"	60	216000	1,800,000 "	"	0.01800 "
bottom "	AG	"	68.	314,432	2,620,000 "	"	0.02620 "
side wall	DC+EF	"	44	85,184	710,000 "	"	0.00710 "
" "	BA+CG	"	60	216,000	1,800,000 "	"	0.01800 "

Values of $K = \frac{J}{l}$

		Moment of inertia J		length of member l or h.		K		
Top slab	DE	0.00811	÷	4.06	=	0.00200	=	K_{DE}
middle "	BC	0.02398	÷	4.72	=	0.00508	=	K_{BC}
" "	CF	0.01800	÷	4.06	=	0.00443	=	K_{CF}
bottom "	AG	0.02620	÷	4.72	=	0.00555	=	K_{AG}
Side wall	DC+EF	0.00710	÷	4.90	=	0.00145	=	$K_{DC}=K_{EF}$
" "	BA+CG	0.01800	÷	4.95	=	0.00364	=	$K_{BA}=K_{CG}$

Values of moment C.

$$\left.\begin{matrix} C_{DE}=C_{ED} \\ C_{CF}=C_{FC} \end{matrix}\right\} = \frac{w_1 l_1^2}{12} = \frac{7.200 \times 4.06^2}{12} = 9.900 \text{ ton meter}$$

$$\left.\begin{matrix} C_{BC}=C_{CB} \\ C_{AG}=C_{GA} \end{matrix}\right\} = \frac{w_2 l_2^2}{12} = \frac{17.360 \times 4.72^2}{12} = 32.220 \text{ "}$$

$q' = q_2 - q_1 = 4.790$ tons/m

$$\left.\begin{matrix} C_{DC} \\ C_{EF} \end{matrix}\right\} = \frac{h_1^2}{60}(5q_1+2q') = \frac{4.90^2}{60}(5\times3.21+2\times4.79) = 10.255 \text{ "}$$

$$\left.\begin{matrix} C_{CD} \\ C_{FE} \end{matrix}\right\} = \frac{h_1^2}{60}(5q_1+3q') = \frac{4.90^2}{60}(5\times3.21+3\times4.79) = 12.275 \text{ "}$$

上下二段式函型隧道 断面A5 端 土被3.0米

$q'' = q_3 - q_2 = 4.870$ ton

$\left.\begin{matrix} C_{BA} \\ C_{CG} \end{matrix}\right\} = \frac{h_2^2}{60}(5q_2 + 2q'') = \frac{4.95^2}{60}(5\times8.00 + 2\times4.87) =$ 20.310 ton.m

$\left.\begin{matrix} C_{AB} \\ C_{GC} \end{matrix}\right\} = \frac{h_2^2}{60}(5q_2 + 3q'') = \frac{4.95^2}{60}(5\times8.00 + 3\times4.87) =$ 22.320 〃

Values of $\rho = 2\Sigma k = 2\Sigma \frac{I}{l}$ for each panel point.

$\rho_A = \rho_G = 2(0.00555 + 0.00364) = 0.01838$

$\rho_B = 2(0.00364 + 0.00508) = 0.01744$

$\rho_C = 2\left\{\begin{matrix} 0.00508 + 0.00364 \\ +0.00443 + 0.00145 \end{matrix}\right\} = 0.02920$

$\rho_D = \rho_E = 2(0.00200 + 0.00145) = 0.00690$

$\rho_F = 2(0.00443 + 0.00145) = 0.01176$

Values of $P = \Sigma C$ for each panel point $-C\curvearrowright$, $\curvearrowleft +C$

$P_A = -32.220 + 22.320 = -9.900$ $P_G = +9.900$

$P_B = -20.310 + 32.220 = 11.910$

$P_C = \left\{\begin{matrix} -32.220 + 20.310 \\ -9.900 + 12.275 \end{matrix}\right\} = -9.535$

$P_D = -10.255 + 9.900 = -0.355$ $P_E = 0.355$

$P_F = -12.275 + 9.900 = -2.375$

Values of $\varphi^{(0)} = \frac{P}{\rho}$ for each panel point.

$\varphi_A^{(0)} = \frac{P_A}{\rho_A} = \frac{-9.900}{0.01838} = -539$ $\varphi_G^{(0)} = 539$

$\varphi_B^{(0)} = \frac{P_B}{\rho_B} = \frac{11.910}{0.01744} = 683$

$\varphi_C^{(0)} = \frac{P_C}{\rho_C} = \frac{-9.535}{0.02920} = -327$

$\varphi_D^{(0)} = \frac{P_D}{\rho_D} = \frac{-0.355}{0.00690} = -52$ $\varphi_E^{(0)} = 52$

$\varphi_F^{(0)} = \frac{P_F}{\rho_F} = \frac{-2.375}{0.01176} = -202$

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MADE BY K. I. DATE 10-11-9 FILE NO 6

CHECKED BY ______ DATE ______ PAGE NO 120

CALCULATIONS FOR

上下二段式函型隧道 断面 A5 部 土被 3.0米

Values of $\gamma = \frac{K}{\rho}$ for each member.

A: $\gamma_{AG} = \frac{K_{AG}}{\rho_A} = \frac{0.00555}{0.01838} = 0.302$

A: $\gamma_{AB} = \frac{K_{AB}}{\rho_A} = \frac{0.00364}{0.01838} = 0.198$

B: $\gamma_{BA} = \frac{K_{BA}}{\rho_B} = \frac{0.00364}{0.01744} = 0.209$

B: $\gamma_{BC} = \frac{K_{BC}}{\rho_B} = \frac{0.00508}{0.01744} = 0.291$

C: $\gamma_{CB} = \frac{K_{CB}}{\rho_C} = \frac{0.00508}{0.02920} = 0.174$

C: $\gamma_{CD} = \frac{K_{CD}}{\rho_C} = \frac{0.00145}{0.02920} = 0.050$

C: $\gamma_{CF} = \frac{K_{CF}}{\rho_C} = \frac{0.00443}{0.02920} = 0.152$

C: $\gamma_{CG} = \frac{K_{CG}}{\rho_C} = \frac{0.00364}{0.02920} = 0.125$

D: $\gamma_{DC} = \frac{K_{DC}}{\rho_D} = \frac{0.00145}{0.00690} = 0.210 = \gamma_{EF}$ (E)

D: $\gamma_{DE} = \frac{K_{DE}}{\rho_D} = \frac{0.00200}{0.00690} = 0.290 = \gamma_{ED}$ (E)

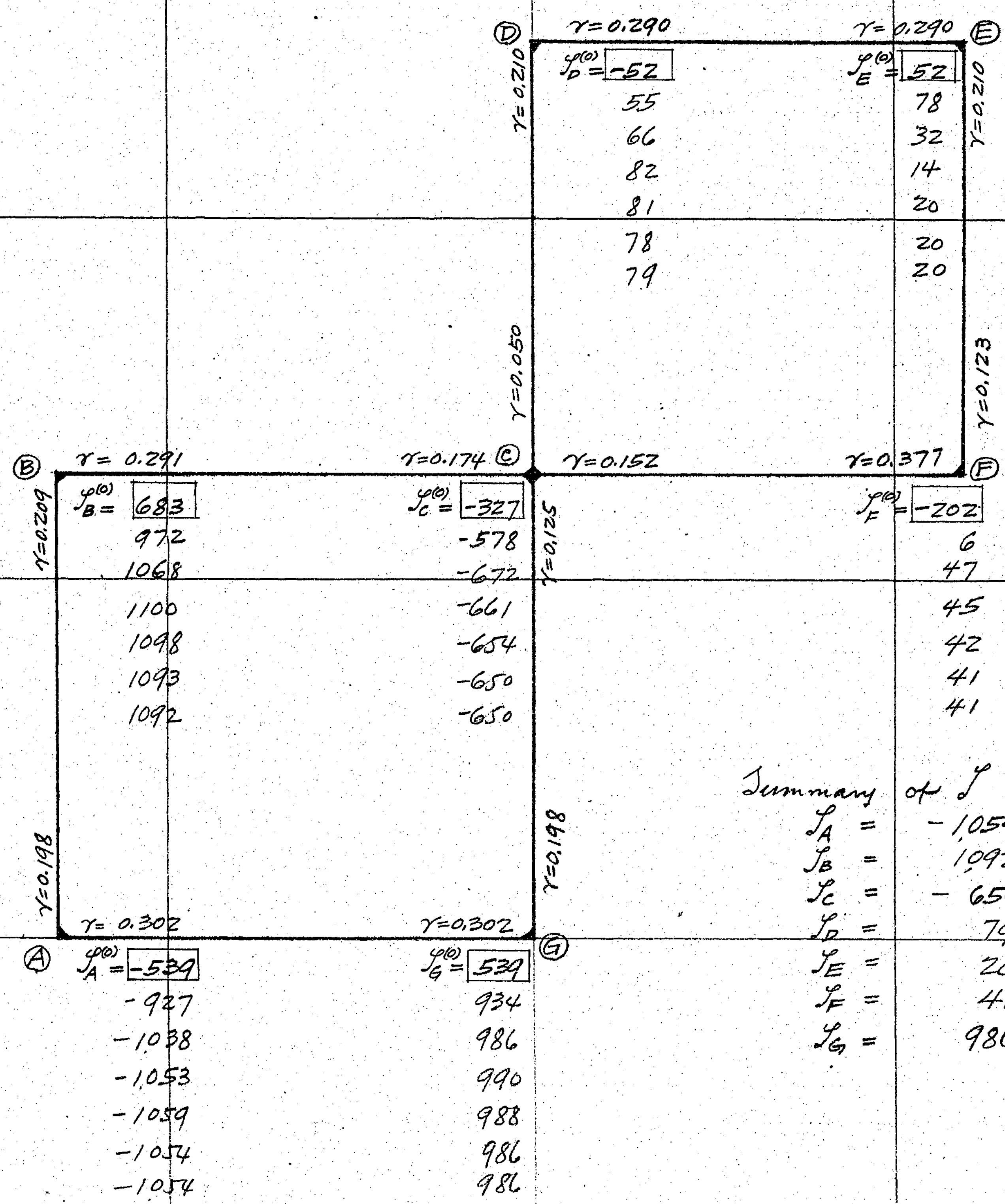
F: $\gamma_{FE} = \frac{K_{FE}}{\rho_F} = \frac{0.00145}{0.01176} = 0.123$

F: $\gamma_{FC} = \frac{K_{FC}}{\rho_F} = \frac{0.00443}{0.01176} = 0.377$

G: $\gamma_{GC} = \frac{K_{GC}}{\rho_G} = \frac{0.00364}{0.01838} = 0.198$

G: $\gamma_{GA} = \frac{K_{GA}}{\rho_G} = \frac{0.00555}{0.01838} = 0.302$

Values of φ.



Summary of φ

$\varphi_A = -1{,}054$

$\varphi_B = 1{,}092$

$\varphi_C = -650$

$\varphi_D = 79$

$\varphi_E = 20$

$\varphi_F = 41$

$\varphi_G = 986$

上下二段式函型隧道 断面A5端 土被3.0米

Moment at each panel point.

$M_{AG} = K_{AG}(2\theta_A + \theta_G) + C_{AG} = 0.00555(-2108 + 986) + 32.220 = -6.220 + 32.220 = 26.00$ ton.m.

$M_{AB} = K_{AB}(2\theta_A + \theta_B) - C_{AB} = 0.00364(-2108 + 1092) - 22.320 = -3.700 - 22.320 = -26.02$

$M_{BA} = K_{AB}(2\theta_B + \theta_A) + C_{BA} = 0.00364(2184 - 1054) + 20.310 = 4.120 + 20.310 = 24.43$

$M_{BC} = K_{BC}(2\theta_B + \theta_C) - C_{BC} = 0.00508(2184 - 650) - 32.220 = 7.770 - 32.220 = -24.45$

$M_{CB} = K_{BC}(2\theta_C + \theta_B) + C_{CB} = 0.00508(-1300 + 1092) + 32.220 = -1.060 + 32.220 = 31.16$

$M_{CG} = K_{CG}(2\theta_C + \theta_G) - C_{CG} = 0.00364(-1300 + 986) - 20.310 = -1.140 - 20.310 = -21.45$

$M_{CF} = K_{CF}(2\theta_C + \theta_F) + C_{CF} = 0.00443(-1300 + 41) + 9.900 = -5.580 + 9.900 = 4.32$

$M_{CD} = K_{CD}(2\theta_C + \theta_D) - C_{CD} = 0.00145(-1300 + 79) - 12.275 = -1.770 - 12.275 = -14.05$

$M_{DC} = K_{CD}(2\theta_D + \theta_C) + C_{DC} = 0.00145(158 - 650) + 10.255 = -0.710 + 10.255 = 9.55$

$M_{DE} = K_{DE}(2\theta_D + \theta_E) - C_{DE} = 0.00200(158 + 20) - 9.900 = 0.360 - 9.900 = -9.54$

$M_{ED} = K_{DE}(2\theta_E + \theta_D) + C_{ED} = 0.00200(40 + 79) + 9.900 = 0.240 + 9.900 = 10.14$

$M_{EF} = K_{EF}(2\theta_E + \theta_F) - C_{EF} = 0.00145(40 + 41) - 10.255 = 0.120 - 10.255 = -10.14$

$M_{FE} = K_{EF}(2\theta_F + \theta_E) + C_{FE} = 0.00145(82 + 20) + 12.275 = 0.150 + 12.275 = 12.43$

$M_{FC} = K_{CF}(2\theta_F + \theta_C) - C_{FC} = 0.00443(82 - 650) - 9.900 = -2.520 - 9.900 = -12.42$

$M_{GC} = K_{CG}(2\theta_G + \theta_C) + C_{GC} = 0.00364(1972 - 650) + 22.320 = 4.810 + 22.320 = 27.13$

$M_{GA} = K_{AG}(2\theta_G + \theta_A) - C_{GA} = 0.00555(1972 - 1054) - 32.220 = 5.090 - 32.220 = -27.13$

Now, we have moment at each panel point as follows.

$M_{AG} = M_{AB} = -\ 26.02$ ton.m.

$M_{BA} = M_{BC} = -\ 24.45$ 〃

$M_{CB} = -\ 31.160$ 〃

$M_{CG} = -\ 21.45$ 〃

$M_{CF} = -\ 4.32$ 〃

$M_{CD} = -\ 14.05$ 〃

$M_{DC} = M_{DE} = -\ 9.55$ 〃

$M_{ED} = M_{EF} = -\ 10.14$ 〃

$M_{FE} = M_{FC} = -\ 12.43$ 〃

$M_{GC} = M_{GA} = -\ 27.13$ 〃

Shear in slabs.

$S_{AG} = -\frac{w_2 l_2}{2} - \frac{M_{GA} - M_{AG}}{l_2} = -\frac{17360 \times 4.72}{2} - \frac{-1.110}{4.72} = -40980 + 240 = -40740$ kg

$S_{GA} = 40980 + 240 = 41220$ 〃

$S_{H_1} = -40740 \times \frac{1.55}{2.35} = -\ 26880$ kg

$S_{H_{16}} = 41220 \times \frac{1.57}{2.37} = 27300$ 〃

Point of zero shear $x = 4.72 \times \frac{40740}{81960} = 2.35^m$ from A

上下二段式函型隧道 断面A5号 土被3.0米

$S_{BC} = \frac{w_2 l_2}{2} + \frac{M_{CB}-M_{BC}}{l_2} = \frac{17360\times4.72}{2} + \frac{-6710}{4.72} = 40980 - 1420 = 39560$ kg

S_{CB} $= -40980 - 1420 = -42400$ 〃

$S_{H4} = 39560\times\frac{1.58}{2.28} = 27400$ kg

$S_{H5} = -42400\times\frac{1.74}{2.44} = -30200$ 〃 point of zero shear $x = 4.72\times\frac{39560}{81960} = 2.28^m$ from B.

$S_{CF} = -\frac{w_1 l_1}{2} - \frac{M_{FC}-M_{CF}}{l_1} = -\frac{7200\times4.06}{2} - \frac{-8110}{4.06} = -14620 + 2000 = -12620$ kg

S_{FC} $= 14620 + 2000 = 16620$ 〃

$S_{H13} = -12620\times\frac{0.93}{1.75} = -6710$ kg

$S_{H12} = 16620\times\frac{1.59}{2.31} = 11430$ 〃 Point of zero shear $x = 4.06\times\frac{12620}{29240} = 1.75^m$ from C

$S_{DE} = \frac{w_1 l_1}{2} + \frac{M_{ED}-M_{DE}}{l_1} = \frac{7200\times4.06}{2} + \frac{-590}{4.06} = 14620 - 150 = 14470$ kg

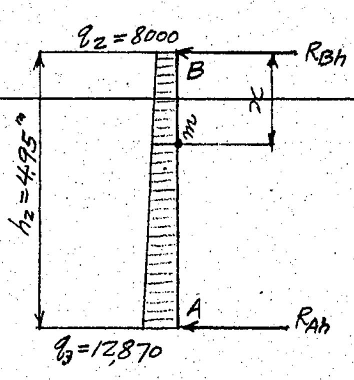
S_{ED} $= -14620 - 150 = -14770$ 〃

$S_{H8} = 14470\times\frac{1.39}{2.01} = 10000$ kg

$S_{H9} = -14770\times\frac{1.43}{2.05} = -10090$ 〃 point of zero shear $x = 4.06\times\frac{14470}{29240} = 2.01^m$ from D.

Shear in walls.

wall AB.



$R_{Ah} = \frac{h_2}{6}(2q_3+q_2) = \frac{4.95}{6}(25740+8000) = 27820$ kg

$R_{Bh} = \frac{h_2}{6}(q_3+2q_2) = \frac{4.95}{6}(12870+16000) = 23820$ 〃

$S_{AB} = R_{Ah} + \frac{M_{BA}-M_{AB}}{h_2} = 27820 + \frac{1570}{4.95} = 28140$ 〃

$S_{BA} = -R_{Bh} - \frac{M_{AB}-M_{BA}}{h_2} = -23820 + 320 = -23500$ 〃

Shear at any point m.

$S_m = S_{BA} + q_2 x + \frac{q_3-q_2}{2h_2}x^2 = -23500 + 8000x + 492x^2$

Point of zero shear.

$492x^2 + 8000x - 23500 = 0$

$x = \frac{-8000}{984} \pm \frac{\sqrt{8000^2+4\times492\times23500}}{984} = 2.54^m$ from B

Shear at end of haunch.

	x	x^2	S_{BA}		$8000x$		$492x^2$		S_m
H2	4.11^m	16.892	−23500	+	32880	+	8310	=	17690 kg
H3	0.73	0.533	−23500	+	5840	+	260	=	−17400 〃

wall CG.

$R_{Gh} = 27820$ kg , $R_{Ch} = 23820$ kg.

$S_{GC} = -R_{Gh} - \frac{M_{CG}-M_{GC}}{h_2} = -27820 - \frac{5680}{4.95} = -28970$ kg

S_{CG} $= 23820 - 1150 = 22670$ 〃

Shear at any point m.

$S_m = S_{CG} - q_2 x - \frac{q_3 - q_2}{2h_2} x^2 = 22670 - 8000x - 492x^2$

x for point of zero shear.

$492x^2 + 8000x - 22670 = 0$

$x = \frac{-8000}{984} \pm \frac{\sqrt{8000^2 + 4 \times 492 \times 22670}}{984} = 2.46^m$ from C

Shear at end of haunch.

	x	x^2	S_{CG}	$-8000x$	$-492x^2$		S_m	
H_{14}	0.73^m	0.533	22670	− 5840	− 260	=	16570	kg
H_{15}	4.11	16.892	22670	− 32880	− 8310	=	−18520	"

Wall CD.

$R_{Ch} = \frac{h_1}{6}(2q_2 + q_1) = \frac{4.90}{6}(16000 + 3210) = 15680$ kg

$R_{Dh} = \frac{h_1}{6}(2q_1 + q_2) = \frac{4.90}{6}(6420 + 8000) = 11770$ "

$S_{CD} = R_{Ch} + \frac{M_{DC} - M_{CD}}{h_1} = 15680 + \frac{4500}{4.90} = 16600$ "

$S_{DC} = -11770 + 920 = -10850$ "

Shear at any point m.

$S_m = S_{DC} + q_1 x + \frac{q_2 - q_1}{2h_1} x^2 = -10850 + 3210x + 489x^2$

x for point of zero shear.

$x = \frac{-3210}{978} \pm \frac{\sqrt{3210^2 + 4 \times 489 \times 10850}}{978} = 2.46^m$ from D.

Shear at end of haunch.

	x	x^2	S_{DC}	$3210x$	$489x^2$		S_m	
H_6	4.11^m	16.892	−10850	+ 13200	+ 8260	=	10610	kg
H_7	0.63	0.397	−10850	+ 2020	+ 190	=	−8640	"

Wall EF

$R_{Fh} = 15680$ kg, $R_{Eh} = 11770$ kg

$S_{FE} = -R_{Fh} - \frac{M_{EF} - M_{FE}}{h_1} = -15680 - \frac{2290}{4.90} = -16150$ kg

$S_{EF} = R_{Eh} + \frac{M_{FE} - M_{EF}}{h_1} = 11770 - 470 = 11300$ "

Shear at any point m.

$S_m = S_{EF} - q_1 x - \frac{q_2 - q_1}{2h_1} x^2 = 11300 - 3210x - 489x^2$

x for point of zero shear.

$x = \frac{-3210}{978} \pm \frac{\sqrt{3210^2 + 4 \times 489 \times 11300}}{978} = 2.54^m$ from E.

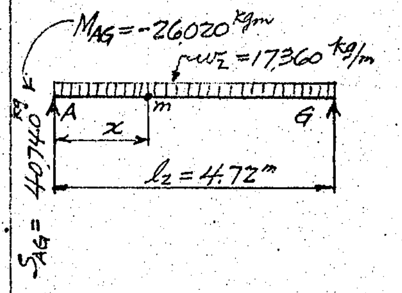
Shear at end of haunch.

	x	x^2	S_{EF}	$3210x$	$489x^2$		S_m	
H_{10}	0.63^m	0.397	11300	− 2020	− 190	=	9090	kg
H_{11}	4.11	16.892	11300	− 13200	− 8260	=	−10160	"

上下二段式函型隧道 断面A5號 土被3.0米

Moment at end of haunch and maximum positive moment for each member.

Slab AG.



$$M_m = M_{AG} - S_{AG}x - \frac{w_2 x^2}{2} = -26020 + 40740x - 8680x^2$$

	x	x^2					
H_1	0.80^m	0.640	−26,020	+ 32600 −	5550	=	1,030 kgm
M_1	2.35	5.523	〃	+ 95,700 −	47,950	=	21,730 〃
H_{16}	3.92	15.366	〃	+ 159,700 −	133,400	=	280 〃

Slab BC.

$$M_m = M_{BC} + S_{BC}x - \frac{w_2 x^2}{2} = -24450 + 39560x - 8680x^2$$

	x	x^2					
H_4	0.70^m	0.490	−24450	+ 27700 −	4250	=	−1000 kgm
M_3	2.28	5.198	〃	+ 90,200 −	45,100	=	20,650 〃
H_5	4.02	16.160	〃	+ 159,050 −	140,300	=	−5,700 〃

Slab CF

$$M_m = M_{CF} - S_{CF}x - \frac{w_1 x^2}{2} = -4320 + 12620x - 3600x^2$$

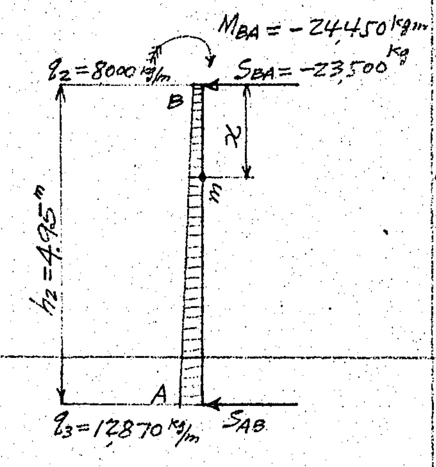
	x	x^2					
H_{12}	3.44^m	11.834	−4,320	+ 43,400 −	42,600	=	−3,520 kgm
M_7	1.75	3.063	〃	+ 22,100 −	11,030	=	6750 〃
H_{13}	0.82	0.672	〃	+ 10,340 −	2,420	=	3600 〃

Slab DE.

$$M_m = M_{DE} + S_{DE}x - \frac{w_1 x^2}{2} = -9550 + 14470x - 3600x^2$$

	x	x^2					
H_8	0.62^m	0.384	−9,550	+ 8970 −	1,380	=	−1,960 kgm
M_5	2.01	4.041	〃	+ 29070 −	14,560	=	4,960 〃
H_9	3.44	11.834	〃	+ 49,750 −	42,650	=	−2,450 〃

wall AB.



$$M_m = M_{BA} - S_{BA}x - \frac{q_2 x^2}{2} - \frac{q_3-q_2}{6h_2}x^3 = -24450 + 23500x - 4000x^2 - 164x^3$$

	x	x^2	x^3					
H_2	4.11^m	16.892	69.427	−24,450 +	96,600 −	67,580 −	11,380 =	−6,810 kgm
M_2	2.54	6.452	16.387	〃 +	59,650 −	25,800 −	2690 =	6,710 〃
H_3	0.73	0.533	0.389	〃 +	17,150 −	2,130 −	60 =	−9490 〃

wall CG.

$$M_m = M_{CG} + S_{CG}x - \frac{q_2 x^2}{2} - \frac{q_3-q_2}{6h_2}x^3 = -21450 + 22670x - 4000x^2 - 164x^3$$

	x	x^2	x^3					
H_{14}	0.73	0.533	0.389	−21,450 +	16,550 −	2130 −	60 =	−7,090 kgm
M_8	2.46	6.052	14.887	− 〃 +	55,790 −	24,200 −	2,440 =	7,700 〃
H_{15}	4.11	16.892	69.427	− 〃 +	93,200 −	67,550 −	11,380 =	−7,180 〃

上下二段式函型隧道 断面 A5 号 土被 3.0米

wall CD. $M_m = M_{DC} - S_{DC}x - \frac{q_1 x^2}{2} - \frac{q_2 - q_1}{6h_1}x^3 = -9550 + 10850x - 1605x^2 - 163x^3$

	x	x^2	x^3					
H_6	4.110 m	16.892	69.427	−9550 + 44600 −	27100	− 11320 =	−3370 kgm
M_4	2.46	6.052	14.887	〃 + 26700 −	9710	− 2430 =	5010 〃
H_7	0.630	0.397	0.250	〃 + 6830 −	640	− 40 =	−3400 〃

wall EF $M_m = M_{EF} + S_{EF}x - \frac{q_1 x^2}{2} - \frac{q_2 - q_1}{6h_1}x^3 = -10140 + 11300x - 1605x^2 - 163x^3$

	x						
H_{10}	0.630 m	0.397	0.250	−10140 + 7120 −	640	− 40 =	−3700 kgm
M_6	2.54	6.452	16.387	〃 + 28700 −	10350	− 2670 =	5540 〃
H_{11}	4.110	16.892	69.427	〃 + 46450 −	27100	− 11320 =	−2110 〃

Axial Thrust in each member.

Slab	AG	Thrust	N_{AG} =	28,560 kg	mean value.
〃	BC	〃	N_{BC} =	23,500 〃	
〃	CF	〃	N_{CF} =	16,150 〃	
〃	DE	〃	N_{DE} =	11,080 〃	mean value
wall	AB	〃	N_{AB} =	39,560 〃	
〃	CG	〃	N_{CG} =	41,220 〃	
〃	CD	〃	N_{CD} =	14,470 〃	
〃	EF	〃	N_{EF} =	14,770 〃	

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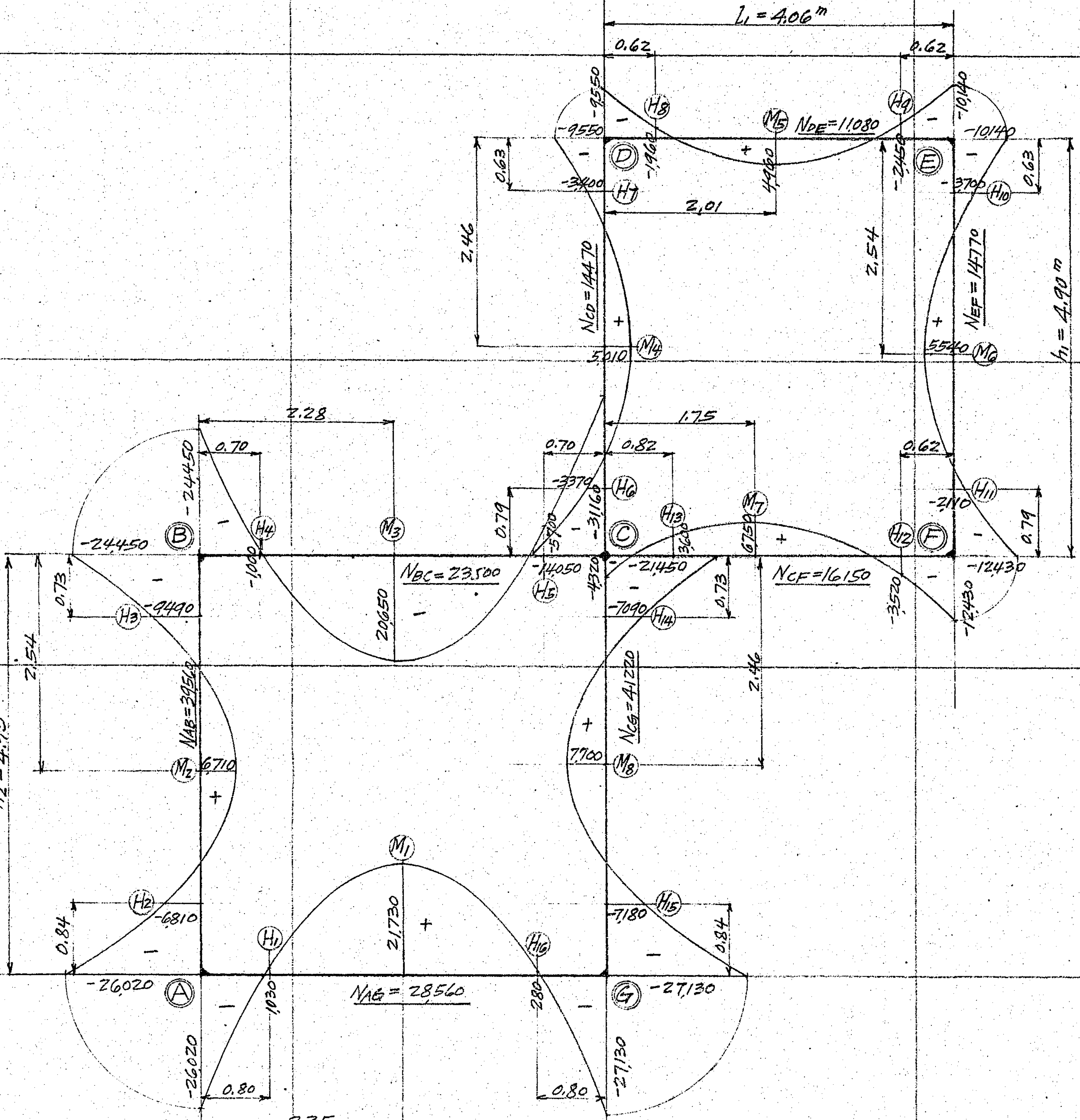
CALCULATIONS FOR

上下二段式函型隧道 断面A5 地土被3.0米

Bending moment diagram.



Scale of space 1:60

〃 〃 moment $\frac{1}{100}^m$ = 10,000 kgm.

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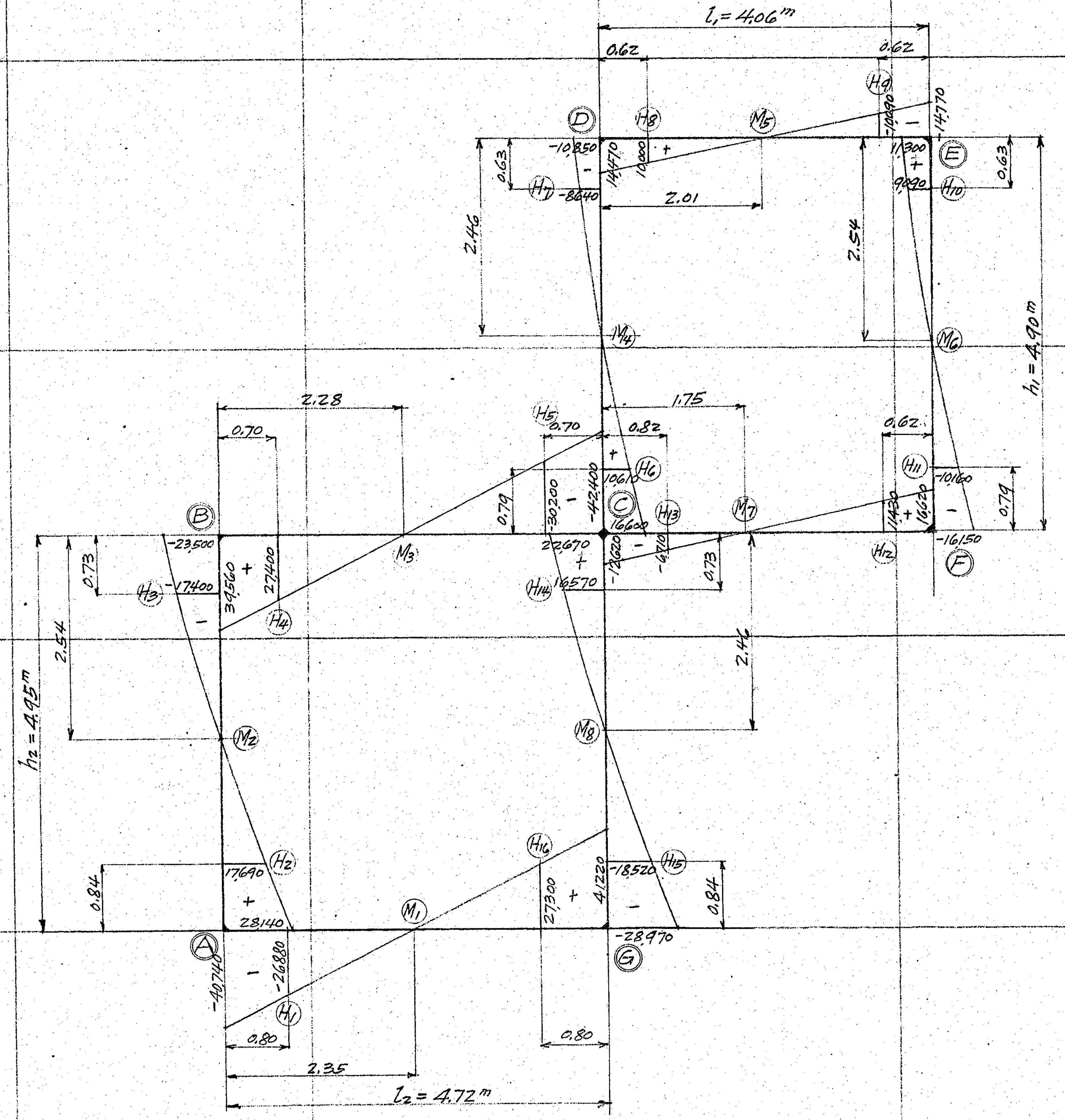
CALCULATIONS FOR

上下二段式函型隧道 断面A5號 土被3.0米

Shear diagram.



Scale of space 1 : 60
" " Shear $\frac{1}{200}^m = 10,000$ kg

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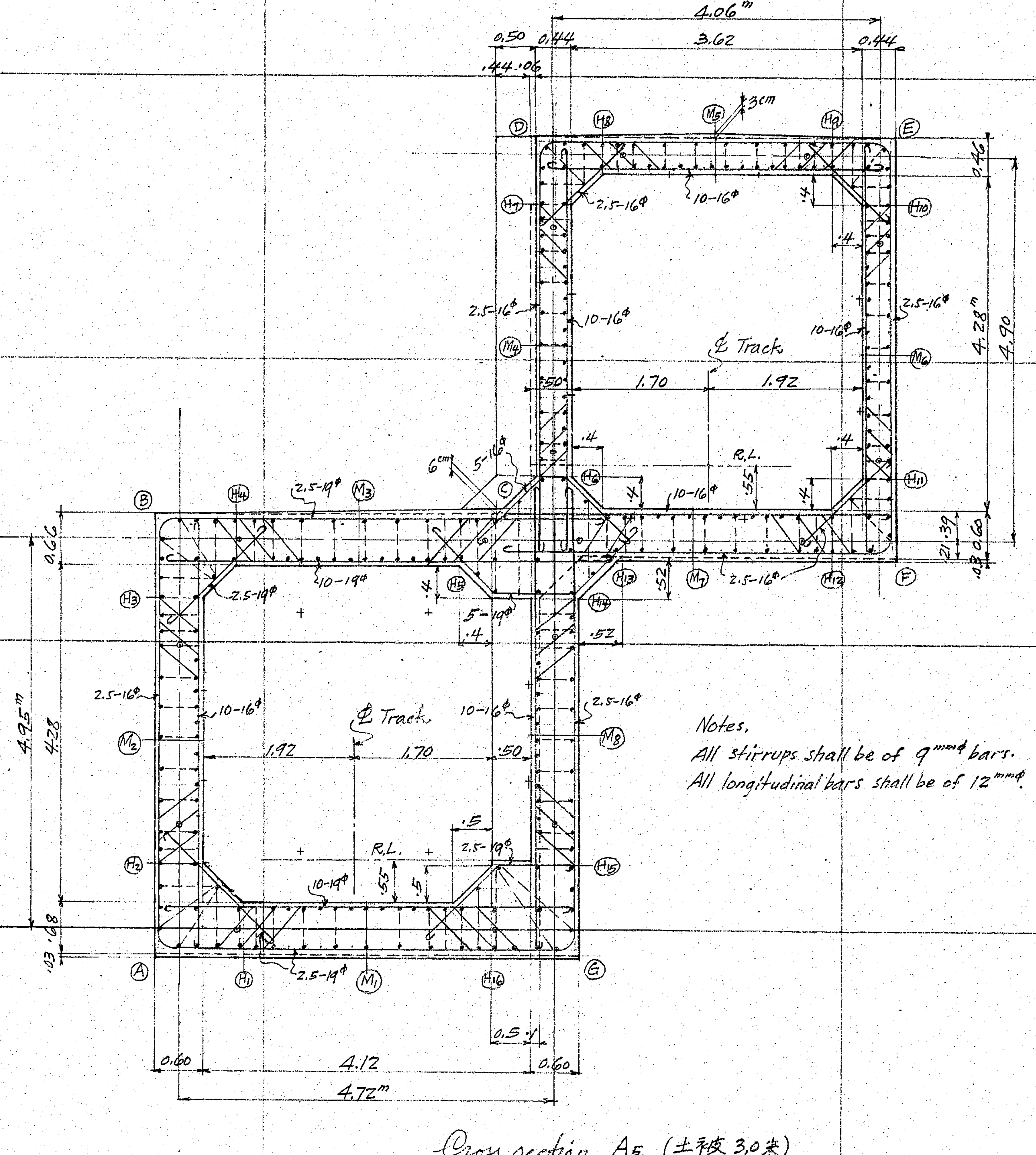
上下二段式函型隧道 断面A5號 土被3.0米

Assumed Cross section and Reinforcements for each member.



Notes.
All stirrups shall be of $9^{mm\phi}$ bars.
All longitudinal bars shall be of $12^{mm\phi}$.

Cross section A5. (土被 3,0米)
Scale 1:60.

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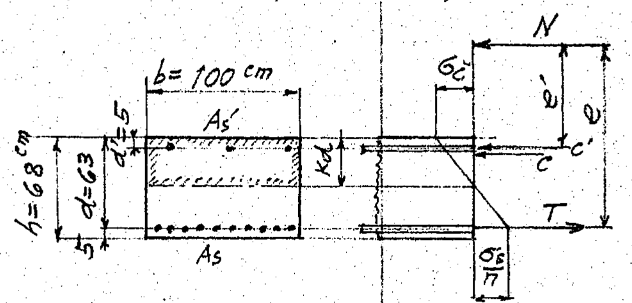
CALCULATIONS FOR

上下二段式函型隧道 断面A5號 土被3.0米

Unit stress calculations.

Bottom slab. AG.

at (M1) $M_1 = 21{,}730$ kgm , $N = 28{,}560$ kg , $S = 0$.



$\frac{M}{N} = \frac{21730 \times 100}{28560} = 76.1$ cm

$d - u = 27.5$

$e = 103.6$ cm

$e' = e - 58 = 45.6$ "

$e'/e = 45.6/103.6 = 0.440$

$\frac{Ne}{bd^2} = \frac{28560 \times 103.6}{100 \times 63^2} = 7.480$

$b = 100$ cm, $h = 68$ cm

$d = 63$ ", $d' = 5$ "

$A_s = 10\text{-}19^\phi = 28.4$ cm²

$A_s' = 2.5\text{-}19^\phi = 7.1$ "

$p = \frac{28.4}{6300} = 0.00451$

$p' = \frac{7.1}{6300} = 0.00113$

$d'/d = 5/63 = 0.079$

$d/h = 63/68 = 0.927$ $u/h = 0.522$

$d'/h = 5/68 = 0.074$ $u = 0.522 \times 68 = 35.5$ cm

$p_0 = 28.4/6800 = 0.00417$ $d - u = 27.5$ "

$p_0' = 7.1/6800 = 0.00104$

$k = 0.405$, $\frac{Ne}{bd^2\sigma_c} = 0.190$

$\sigma_c = \frac{7.480}{0.190} = 39.4$ kg/cm²

$\sigma_s = 15 \times 39.4 \times \frac{1 - .405}{.405} = 870$ "

at (H1) $M = 1{,}030$ kgm, $N = 28{,}560$ kg , $S = 26{,}880$ kg

$e = \frac{M}{N} = \frac{1030 \times 100}{28560} = 3.6$ cm

$b = 100$ cm , $h = 68$ cm

$d = 63$ " , $d' = 5$ cm

$d/h = 63/68 = 0.927$

$d'/h = 5/68 = 0.074$

Whole section under compression

$A_s = 7.5\text{-}19^\phi = 21.3$ cm²

$A_s' = 2.5\text{-}19^\phi = 7.1$ "

$p_0 = \frac{21.3}{6800} = 0.00314$

$p_0' = \frac{7.1}{6800} = 0.00104$

$u/h = 0.513$

$u = 0.513 \times 68 = 34.9$ cm

$A_i = bh + n(A_s + A_s') = 100 \times 68 + 15 \times 28.4 = 7{,}226$ cm²

$I_i = \frac{b}{3}\left[u^3 + (h-u)^3\right] + nA_s(d-u)^2 + nA_s'(u-d')^2 = \frac{100}{3}(34.9^3 + 33.1^3) + 15 \times 21.3 \times 28.1^2 + 15 \times 7.1 \times 29.9^2$

$= 2{,}626{,}000 + 252{,}000 + 95300 = 2{,}973{,}300$ cm⁴

$\sigma_c = \frac{N}{A_i} + \frac{Ne}{I_i}u = \frac{28560}{7226} + \frac{28560 \times 3.6}{2973300} \times 34.9 = 4.0 + 1.2 = 5.2$ kg/cm² c

$\sigma_c' = \frac{N}{A_i} - \frac{Ne}{I_i}(h-u) = \frac{28560}{7226} - \frac{28560 \times 3.6}{2973300} \times 33.1 = 4.0 - 1.1 = 2.9$ "

$\sigma_s = 15\left(\frac{2.3 \times 63}{68} + 2.9\right) = 75$ kg/cm² c

$\tau \fallingdotseq 26880 \div 6800 = 4.0$ kg/cm²

at (H16) $M = 280$ kgm, $N = 28560$ kg, $S = 27{,}300$ kg

$e = \frac{M}{N} = \frac{280 \times 100}{28560} = 1.0$ cm

Section same as for H1 assumed.

$\sigma_c = \frac{28560}{72260} + \frac{28560 \times 1.0}{2973300} \times 34.9 = 4.0 + 0.3 = 4.3$ kg/cm² c

$\sigma_c' = \frac{28560}{72260} - \frac{28560 \times 1.0}{2973300} \times 33.1 = 4.0 - 0.3 = 3.7$ "

$\sigma_s = 15\left(\frac{0.6 \times 63}{68} + 3.7\right) = 65$ kg/cm² c

$\tau \fallingdotseq 27300 \div 6800 = 4.0$ kg/cm²

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CALCULATIONS FOR

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上下二段式函型隧道 断面A5端 土被3.0米

at Ⓐ $M_{AG} = -26{,}020$ kgm, $N = 28560$ kg, $S = 40740$ kg

$d/h = 89/94 = 0.947$
$d'/h = 5/94 = 0.053$ $u/h = 0.506$
$p_0 = 20.1/9400 = 0.00214$ $u = 0.506 \times 94 = 47.5$ cm
$p'_0 = 7.1/9400 = 0.00076$ $d-u = 41.5$ "

$\frac{M}{N} = \frac{26020 \times 100}{28560} = 91.1$ cm
$d-u = 41.5$
$e = 132.6$ cm
$e' = e - 84 = 48.6$ "
$e'/e = 48.6/132.6 = 0.367$
$\frac{Ne}{bd^2} = \frac{28560 \times 132.6}{100 \times 89^2} = 4.785$
$k = 0.330$, $\frac{Ne}{bd^2\sigma_c} = 0.158$

$b = 100$ cm, $h = 68 + \frac{80}{3} = 94$ cm
$d = 89$ ", $d' = 5$ cm
$A_s = 10-16^\phi = 20.1$ cm²
$A'_s = 2.5-19^\phi = 7.1$ "
$p = 20.1/8900 = 0.00226$
$p' = 7.1/8900 = 0.00080$
$d'/d = 5/89 = 0.056$

$\sigma_c = 4.785 \div 0.158 = 30.3$ kg/cm²
$\sigma_s = 15 \times 30.3 \times \frac{1-.33}{.33} = 923$ "
$\tau = \frac{40740}{100 \times 0.89 \times 89} = 5.1$ " use 3 sets of bent up bars each 2-19$^\phi$ bars. 30cm ctoc.
$\tau_0 = \frac{40740}{5.03 \times 10 \times .89 \times 89} = 10.2$ "

at Ⓖ $M_{GA} = -27130$ kgm, $N = 28560$ kg, $S = 41220$ kg

$\frac{M}{N} = \frac{27130 \times 100}{28560} = 95.0$ cm
$d-u = 41.5$
$e = 136.5$ cm
$e' = e - 84 = 52.5$ "
$e'/e = 52.5/136.5 = 0.385$
$\frac{Ne}{bd^2} = \frac{28560 \times 136.5}{100 \times 89^2} = 4.920$
$k = 0.325$, $\frac{Ne}{bd^2\sigma_c} = 0.156$

Section same as for A assumed.

$\sigma_c = 4.920 \div 0.156 = 31.5$ kg/cm²
$\sigma_s = 15 \times 31.5 \times \frac{1-.325}{.325} = 982$ "
$\tau = \frac{41220}{100 \times .892 \times 89} = 5.2$ kg/cm² use bent up bars. 3 sets @ 2-19$^\phi$
$\tau_0 = \frac{41220}{50.3 \times .892 \times 89} = 10.3$ "

Top slab BC

at (M_3) $M_3 = 20650$ kgm, $N = 23500$ kg, $S = 0$

$d/h = 61/66 = 0.924$
$d'/h = 5/66 = 0.076$ $u/h = 0.517$
$p_0 = 28.4/6600 = 0.00430$ $u = 0.517 \times 66 = 34.1$ cm
$p'_0 = 7.1/6600 = 0.00108$ $d-u = 26.9$ "

$\frac{M}{N} = \frac{20650 \times 100}{23500} = 87.9$ cm
$d-u = 26.9$
$e = 114.8$ cm
$e' = e - 56 = 58.8$ "
$e'/e = 58.8/114.8 = 0.512$
$\frac{Ne}{bd^2} = \frac{23500 \times 114.8}{100 \times 61^2} = 7.250$
$k = 0.390$, $\frac{Ne}{bd^2\sigma_c} = 0.183$

$b = 100$ cm, $h = 66$ cm
$d = 61$ ", $d' = 5$ "
$A_s = 10-19^\phi = 28.4$ cm²
$A'_s = 2.5-$ " $= 7.1$ "
$p = 28.4/6100 = 0.00466$
$p' = 7.1/6100 = 0.00116$
$d'/d = 5/61 = 0.082$

$\sigma_c = 7.250 \div 0.183 = 39.6$ kg/cm²
$\sigma_s = 15 \times 39.6 \times \frac{1-.390}{.390} = 929$ "

上下二段式函型隧道 断面 A5 點 土被 3.0米

at (H4) $M = -1000$ kgm, $N = 23500$ kg, $S = 27400$ kg

$e = \frac{M}{N} = \frac{1000 \times 100}{23500} = 43$ cm

$b = 100$ cm, $h = 66$ cm
$d = 61$ cm, $d' = 5$ cm
$A_s = 7.5 - 19^\phi = 21.3$ cm²
$A_s' = 2.5 - 〃 = 7.1$ 〃
$p_0 = 21.3/6600 = 0.00323$
$p_0' = 7.1/6600 = 0.00108$

$d/h = 61/66 = 0.924$ $u/h = 0.512$
$d'/h = 5/66 = 0.076$ $u = 0.512 \times 66 = 33.8$ cm whole section under compression.

$A_i = 100 \times 66 + 15 \times 28.4 = 7026$ cm²

$I_i = \frac{100}{3}(33.8^3 + 32.2^3) + 15 \times 21.3 \times 27.2^2 + 15 \times 7.1 \times 28.8^2$

$= 2{,}400{,}000 + 236500 + 88300 = 2{,}724{,}800$ cm⁴

$\sigma_c = \frac{23500}{7026} + \frac{23500 \times 43}{2724800} \times 33.8 = 3.4 + 1.3 = 4.7$ kg/cm² c

$\sigma_c' = \frac{23500}{7026} - \frac{23500 \times 43}{2724800} \times 32.2 = 3.4 - 1.2 = 2.2$ 〃

$\sigma_s = 15\left(\frac{2.5 \times 61}{66} + 2.2\right) = 68$ kg/cm² c

$\tau \doteqdot 27400 \div 6600 = 4.2$ kg/cm²

at (H5) $M = -5700$ kgm, $N = 23500$ kg, $S = 30200$ kg

$b = 100$ cm, $h = 66 + \frac{40}{3} = 79$ cm
$d = 74$ 〃, $d' = 5$ cm
$A_s = 7.5 - 19^\phi = 21.3$ cm²
$A_s' = 2.5 - 〃 = 7.1$ 〃
$p = 21.3/7400 = 0.00288$
$p' = 7.1/7400 = 0.00096$
$d'/d = 5/74 = 0.068$

$d/h = 74/79 = 0.937$
$d'/h = 5/79 = 0.063$ $u/h = 0.510$
$p_0 = 21.3/7900 = 0.00270$ $u = 0.510 \times 79 = 40.3$ cm
$p_0' = 7.1/7900 = 0.00090$ $d-u = 33.7$ 〃

$\frac{M}{N} = \frac{5700 \times 100}{23500} = 243$ cm
$d-u = 33.7$
$e = 58.0$ cm
$e' = 69 - 58 = 11.0$ 〃
$e'/e = 11/58 = 0.190$
$\frac{Ne}{bd^2} = \frac{23500 \times 58.0}{100 \times 74^2} = 2.490$
$k = 0.740$, $\frac{Ne}{bd^2\sigma_c} = 0.293$

$\sigma_c = 2.49 \div 0.293 = 8.5$ kg/cm²

$\sigma_s = 15 \times 8.5 \times \frac{1 - .74}{.74} = 45$ 〃

$\tau = \frac{30200}{100 \times .753 \times 74} = 5.4$ 〃 Use 3 sets of bentup bars @ 2-19φ

$\tau_0 = \frac{30200}{5.97 \times 7.5 \times .753 \times 74} = 12.1$

注意.
附着応力ハ抗張鉄筋ノ直径20mm未満ナルヲ以テ 11.0 kg/cm² ヲ多少超過スルモ差支ナキモノトス.
土木学会発表 鉄筋混凝土標準示方書第十九章第三節第八十八條(3)項参照. 以下全様.

at (B) $M_{BC} = -24450$ kgm, $N = 23500$ kg, $S = 39560$ kg

$b = 100$ cm, $h = 66 + \frac{70}{3} = 89$ cm
$d = 84$ cm, $d' = 5$ cm
$A_s = 10 - 16^\phi = 20.1$ cm²
$A_s' = 2.5 - 19^\phi = 7.1$ 〃
$p = 20.1/8400 = 0.00239$
$p' = 7.1/8400 = 0.00085$
$d'/d = 5/84 = 0.060$

$d/h = 84/89 = 0.944$
$d'/h = 5/89 = 0.056$ $u/h = 0.507$
$p_0 = 20.1/8900 = 0.00226$ $u = 0.507 \times 89 = 45.1$ cm
$p_0' = 7.1/8900 = 0.00080$ $d-u = 38.9$ 〃

$\frac{M}{N} = \frac{24450 \times 100}{23500} = 1040$ cm
$d-u = 38.9$
$e = 142.9$ cm
$e' = e - 79 = 63.9$
$e'/e = 63.9/142.9 = 0.447$
$\frac{Ne}{bd^2} = \frac{23500 \times 142.9}{100 \times 84^2} = 4.760$
$k = 0.320$, $\frac{Ne}{bd^2\sigma_c} = 0.155$

$\sigma_c = 4.760 \div 0.155 = 30.7$ kg/cm²

$\sigma_s = 15 \times 30.7 \times \frac{1 - .320}{.320} = 979$ 〃

$\tau = \frac{39560}{100 \times 0.893 \times 84} = 5.3$ 〃

$\tau_0 = \frac{39560}{5.03 \times 10 \times .893 \times 84} = 10.5$ 〃

上下二段式函型隧道 断面 A5 號 土被 3.0米

at Ⓒ $M_{CB} = -31160$ kgm, $N = 23500$ kg, $S = 42400$ kg

$b = 100$ cm, $h = 66 + \frac{120}{3} = 106$ cm
$d = 101$ cm, $d' = 5$ cm
$A_s = 10-19^\phi = 28.4$ cm²
$A_s' = 2.5-$ " $= 7.1$ "
$p = 28.4/10100 = 0.00281$
$p' = 7.1/10100 = 0.00070$
$d'/d = 5/101 = 0.050$

$d/h = 101/106 = 0.954$
$d'/h = 5/106 = 0.047$ $u/h = 0.511$
$p_0 = 28.4/10600 = 0.00268$ $u = 0.511 \times 106 = 54.2$ cm
$p_0' = 7.1/10600 = 0.00067$ $d - u = 46.8$

$\frac{M}{N} = \frac{31160 \times 100}{23500} = 132.7$ cm
$d - u = 46.8$
$e = 179.5$ cm
$e' = e - 96 = 83.5$
$e'/e = 83.5/179.5 = 0.465$
$\frac{Ne}{bd^2} = \frac{23500 \times 179.5}{100 \times 101^2} = 4.135$
$k = 0.330$, $\frac{Ne}{bd^2 \sigma_c} = 0.157$

$\sigma_c = 4.135 \div 0.157 = 26.3$ kg/cm²
$\sigma_s = 15 \times 26.3 \times \frac{1-.33}{.33} = 801$ "
$\tau = \frac{42400}{100 \times 0.890 \times 101} = 4.7$ " use bent up bars 3 sets @ 2-19ϕ.
$\tau_0 = \frac{42400}{59.7 \times .890 \times 101} = 7.9$ "

Side wall AB.

at Ⓜ₂ $M_2 = 6710$ kgm, $N = 39560$ kg, $S = 0$

$b = 100$ cm, $h = 60$ cm
$d = 55$ ", $d' = 5$ "
$A_s = 10-16^\phi = 20.1$ cm²
$A_s' = 2.5-$ " $= 5.0$ "
$p = 20.1/5500 = 0.00365$
$p' = 5.0/5500 = 0.00091$
$d'/d = 5/55 = 0.091$

$d/h = 55/60 = 0.917$
$d'/h = 5/60 = 0.083$ $u/h = 0.512$
$p_0 = 20.1/6000 = 0.00335$ $u = 0.512 \times 60 = 30.7$ cm
$p_0' = 5.0/6000 = 0.00083$ $d - u = 24.3$ "

$\frac{M}{N} = \frac{6710 \times 100}{39560} = 17.0$ cm
$d - u = 24.3$
$e = 41.3$ cm
$e' = 50 - e = 8.7$ "
$e'/e = 8.7/41.3 = 0.211$
$\frac{Ne}{bd^2} = \frac{39560 \times 41.3}{100 \times 55^2} = 5.400$
$k = 0.820$, $\frac{Ne}{bd^2 \sigma_c} = 0.310$

$\sigma_c = 5.400 \div 0.310 = 17.4$ kg/cm²
$\sigma_s = 15 \times 17.4 \times \frac{1-.82}{.82} = 57$ "

at Ⓗ₂ $M = -6810$ kgm, $N = 39560$ kg, $S = 17690$ kg

Section same as for M_2

$\frac{M}{N} = \frac{6810 \times 100}{39560} = 17.2$ cm
$d - u = 24.3$
$e = 41.5$ cm
$e' = 50 - 41.5 = 8.5$ "
$e'/e = 8.5/41.5 = 0.205$
$\frac{Ne}{bd^2} = \frac{39560 \times 41.5}{100 \times 55^2} = 5.430$
$k = 0.820$, $\frac{Ne}{bd^2 \sigma_c} = 0.310$

$\sigma_c = 5.430 \div 0.310 = 17.5$ kg/cm²
$\sigma_s = 15 \times 17.5 \times \frac{1-.82}{.82} = 58$ "
$\tau = \frac{17690}{100 \times .727 \times 55} = 4.4$ "
$\tau_0 = \frac{17690}{5.03 \times 10 \times .727 \times 55} = 8.8$ "

上下二段式函型隧道 断面A5號 土被3.0米

at (H3) $M = -9490$ kgm, $N = 39560$ kg, $S = 17400$ kg — section same as for M_2

$\frac{M}{N} = \frac{9490 \times 100}{39560} = 24.0$ cm

$d-u = 24.3$

$e = 48.3$ cm

$e' = 50 - e = 1.7$ cm

$e'/e = 1.7/48.3 = 0.035$

$\frac{Ne}{bd^2} = \frac{39560 \times 48.3}{100 \times 55^2} = 6.320$

$k = 0.64$, $\frac{Ne}{bd^2\sigma_c} = 0.265$

$\sigma_c = 6.320 \div 0.265 = 23.8$ kg/cm²

$\sigma_s = 15 \times 23.8 \times \frac{1-.64}{.64} = 201$ 〃

$\tau = \frac{17400}{100 \times .787 \times 55} = 4.0$ 〃

$\tau_0 = \frac{17400}{5.03 \times 10 \times .787 \times 55} = 8.0$ 〃

at (A) $M_{AB} = -26020$ kgm, $N = 39560$ kg, $S = 28140$ kg. — $b = 100$ cm, $h = 60 + \frac{84}{3} = 88$ cm

$d/h = 83/88 = 0.943$

$d'/h = 5/88 = 0.057$ $u/h = 0.506$

$p_0 = 20.1/8800 = 0.00228$ $u = 0.506 \times 88 = 44.5$ cm

$p_0' = 7.1/8800 = 0.00081$ $d-u = 38.5$ 〃

$\frac{M}{N} = \frac{26020 \times 100}{39560} = 65.8$ cm

$d-u = 38.5$

$e = 104.3$ cm

$e' = e - 78 = 26.3$ 〃

$e'/e = 26.3/104.3 = 0.252$

$\frac{Ne}{bd^2} = \frac{39560 \times 104.3}{100 \times 83^2} = 5.990$

$k = 0.385$, $\frac{Ne}{bd^2\sigma_c} = 0.180$

$d = 83$ 〃, $d' = 5$ cm

$A_s = 10-16^\phi = 20.1$ cm²

$A_s' = 2.5-19^\phi = 7.1$ 〃

$p = 20.1/8300 = 0.00242$

$p' = 7.1/8300 = 0.00086$

$d'/d = 5/83 = 0.060$

$\sigma_c = 5.99 \div 0.180 = 33.3$ kg/cm²

$\sigma_s = 15 \times 33.3 \times \frac{1-.385}{.385} = 800.$ 〃

$\tau = \frac{28140}{100 \times .872 \times 83} = 3.9$ 〃

$\tau_0 = \frac{28140}{5.03 \times 10 \times .872 \times 83} = 7.7$ 〃

at (B) $M_{BA} = -24450$ kgm, $N = 39560$ kg, $S = 23500$ kg — $b = 100$ cm, $h = 60 + \frac{73}{3} = 84$ cm

$d/h = 79/84 = 0.941$

$d'/h = 5/84 = 0.060$ $u/h = 0.509$

$p_0 = 20.1/8400 = 0.00239$ $u = 0.509 \times 84 = 42.8$ cm

$p_0' = 7.1/8400 = 0.00085$ $d-u = 36.2$ 〃

$\frac{M}{N} = \frac{24450 \times 100}{39560} = 61.8$ cm

$d-u = 36.2$

$e = 98.0$ cm

$e' = e - 74 = 24.0$ 〃

$e'/e = 24/98 = 0.245$

$\frac{Ne}{bd^2} = \frac{39560 \times 98}{100 \times 79^2} = 6.210$

$k = 0.395$, $\frac{Ne}{bd^2\sigma_c} = 0.182$

$d = 79$ cm, $d' = 5$ cm

$A_s = 10-16^\phi = 20.1$ cm²

$A_s' = 2.5-19^\phi = 7.1$ 〃

$p = 20.1/7900 = 0.00254$

$p' = 7.1/7900 = 0.00090$

$d'/d = 5/79 = 0.063$

$\sigma_c = 6.210 \div 0.182 = 34.2$ kg/cm²

$\sigma_s = 15 \times 34.2 \frac{1-.395}{.395} = 786$ 〃

$\tau = \frac{23500}{100 \times .868 \times 79} = 3.4$ 〃

$\tau_0 = \frac{23500}{5.03 \times 10 \times .868 \times 79} = 6.8$ 〃

上下二段式函型隧道 断面A5號 土被3.0米

wall CG.

at (M8) $M_8 = 7700$ kgm, $N = 41220$ kg, $S = 0$. — section same as for M_2, See page 132

$\frac{M}{N} = \frac{7700 \times 100}{41220} = 18.7$ cm

$d - u = 24.3$

$e = 43.0$ cm

$e' = 50 - e = 7.0$ 〃

$e'/e = 7.0/43.0 = 0.163$

$\frac{Ne}{bd^2} = \frac{41220 \times 43.0}{100 \times 55^2} = 5.860$

$k = 0.77$, $\frac{Ne}{bd^2\sigma_c} = 0.298$

$\sigma_c = 5.860 \div 0.298 = 19.7$ kg/cm²

$\sigma_s = 15 \times 19.7 \times \frac{1-.77}{.77} = 88$ 〃

at (H14) $M = -7090$ kgm, $N = 41220$ kg, $S = 16570$ kg — section same as for M_2

$\frac{M}{N} = \frac{7090 \times 100}{41220} = 17.2$ cm

$d - u = 24.3$

$e = 41.5$ cm

$e' = 50 - e = 8.5$ 〃

$e'/e = 8.5/41.5 = 0.205$

$\frac{Ne}{bd^2} = \frac{41220 \times 41.5}{100 \times 55^2} = 5.660$

$k = 0.82$, $\frac{Ne}{bd^2\sigma_c} = 0.310$

$\sigma_c = 5.660 \div 0.310 = 18.3$ kg/cm²

$\sigma_s = 15 \times 18.3 \times \frac{.18}{.82} = 60$ 〃

$\tau = \frac{16570}{100 \times .727 \times 55} = 4.1$ 〃

$\tau_0 = \frac{16570}{50.3 \times .727 \times 55} = 8.2$ 〃

at (H15) $M = -7180$ kgm, $N = 41220$ kg, $S = 18520$ kg — section same as for M_2

$\frac{M}{N} = \frac{7180 \times 100}{41220} = 17.4$ cm

$d - u = 24.3$

$e = 41.7$ cm

$e' = 50 - e = 8.3$ 〃

$e'/e = 8.3/41.7 = 0.199$

$\frac{Ne}{bd^2} = \frac{41220 \times 41.7}{100 \times 55^2} = 5.690$

$k = 0.810$, $\frac{Ne}{bd^2\sigma_c} = 0.308$

$\sigma_c = 5.690 \div 0.308 = 18.5$ kg/cm²

$\sigma_s = 15 \times 18.5 \times \frac{1-.81}{.81} = 65$ 〃

$\tau = \frac{18520}{100 \times .73 \times 55} = 4.6$ 〃

$\tau_0 = \frac{18520}{50.3 \times .73 \times 55} = 9.2$ 〃

上下二段式函型隧道 断面 As 強 土被 3.0 米

at Ⓖ $M_{GC} = -27130$ kgm, $N = 41220$ kg, $S = 28970$ kg

section same as for M_{AB}. Page 133.

$\frac{M}{N} = \frac{27130 \times 100}{41220} = 65.8$ cm

$d-u = 38.5$

$e = 104.3$ cm

$e' = e - 78 = 26.3$

$e'/e = 26.3/104.3 = 0.252$

$\frac{Ne}{bd^2} = \frac{41220 \times 104.3}{100 \times 83^2} = 6.250$

$k = 0.385$, $\frac{Ne}{bd^2\sigma_c} = 0.180$

$\sigma_c = 6.250 \div 0.180 = 34.7$ kg/cm²

$\sigma_s = 15 \times 34.7 \times \frac{1-.385}{.385} = 832$ 〃

$\tau = \frac{28970}{100 \times .872 \times 83} = 4.0$ 〃

$\tau_0 = \frac{28970}{50.3 \times .872 \times 83} = 8.0$ 〃

at Ⓒ $M_{CG} = -21450$ kgm, $N = 41220$ kg, $S = 22670$ kg

$b = 100$ cm, $h = 60 + \frac{73}{3} = 84$ cm
$d = 79$ cm, $d' = 5$ cm
$A_s = 10-16^\phi = 20.1$ cm²
$A_s' = 2.5-19^\phi = 7.1$
$p = 20.1/7900 = 0.00254$
$p' = 7.1/$ 〃 $= 0.00090$
$d'/d = 5/79 = 0.063$

$d/h = 79/84 = 0.940$
$d'/h = 5/84 = 0.060$ $u/h = 0.509$
$p_0 = 20.1/8400 = 0.00239$ $u = 0.509 \times 84 = 42.8$ cm
$p_0' = 7.1/8400 = 0.00083$ $d-u = 36.2$

$\frac{M}{N} = \frac{21450 \times 100}{41220} = 52.0$ cm

$d-u = 36.2$

$e = 88.2$ cm

$e' = e - 74 = 14.2$

$e'/e = 14.2/88.2 = 0.161$

$\frac{Ne}{bd^2} = \frac{41220 \times 88.2}{100 \times 79^2} = 5.825$

$k = 0.430$, $\frac{Ne}{bd^2\sigma_c} = 0.197$

$\sigma_c = 5.825 \div 0.197 = 29.6$ kg/cm²

$\sigma_s = 15 \times 29.6 \times \frac{.57}{.43} = 589$ 〃

$\tau = \frac{22670}{100 \times .857 \times 79} = 3.3$ 〃

$\tau_0 = \frac{22670}{50.3 \times .857 \times 79} = 6.7$ 〃

Bottom slab. CF

at Ⓜ7 $M_7 = 6750$ kgm, $N = 16150$ kg, $S = 0$

$b = 100$ cm, $h = 60$ cm
$d = 55$ cm, $d' = 5$ cm
section same as for M_2 see page 132.

$\frac{M}{N} = \frac{6750 \times 100}{16150} = 41.8$ cm

$d-u = 24.3$

$e = 66.1$ cm

$e' = e - 50 = 16.1$

$e'/e = 16.1/66.1 = 0.244$

$\frac{Ne}{bd^2} = \frac{16150 \times 66.1}{100 \times 55^2} = 3.530$

$k = 0.450$, $\frac{Ne}{bd^2\sigma_c} = 0.204$

$\sigma_c = 3.530 \div 0.204 = 17.3$ kg/cm²

$\sigma_s = 15 \times 17.3 \times \frac{.55}{.45} = 317$ 〃

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CALCULATIONS FOR

上下二段式函型隧道 断面A5 鉄土被3.0米

at (H12) M= −3520 kgm, N= 16150 kg, S= 11430 kg

$b=100$ cm, $h=60$ cm
$d=55$ ", $d'=5$ "
$A_s = 7.5-16^\phi = 15.1$ cm²
$A_s' = 2.5-16^\phi = 5.0$ "
$p = 15.1/5500 = 0.00274$
$p' = 5/5500 = 0.00091$
$d'/d = 5/55 = 0.091$

$d/h = 55/60 = 0.917$
$d'/h = 5/60 = 0.083$ $u/h = 0.507$
$p_0 = 15.1/6000 = 0.00252$ $u = 0.507 \times 60 = 30.4$ cm
$p_0' = 5/6000 = 0.00083$ $d-u = 24.6$ "

$\frac{M}{N} = \frac{3520 \times 100}{16150} = 21.8$ cm
$d-u = 24.6$
$e = 46.4$ cm
$e' = 50-e = 3.6$ "
$e'/e = 3.6/46.4 = 0.078$
$\frac{Ne}{bd^2} = \frac{16150 \times 46.4}{100 \times 55^2} = 2.48$
$k = 0.650$, $\frac{Ne}{bd^2\sigma_c} = 0.266$

$\sigma_c = 2.48 \div 0.266 = 9.3$ kg/cm²
$\sigma_s = 15 \times 9.3 \times \frac{.35}{.65} = 75$ "
$\tau = \frac{11430}{100 \times .783 \times 55} = 2.7$ "
$\tau_0 = \frac{11430}{5.03 \times 7.5 \times .783 \times 55} = 7.0$ "

at (H13) M= +3600 kgm, N= 16150 kg, S= 6710 kg

section same as for H12

$\frac{M}{N} = \frac{3600 \times 100}{16150} = 22.3$ cm
$d-u = 24.6$
$e = 46.9$ cm
$e' = 50-e = 3.1$ "
$e'/e = 3.1/46.9 = 0.066$
$\frac{Ne}{bd^2} = \frac{16150 \times 46.9}{100 \times 55^2} = 2.505$
$k = 0.640$, $\frac{Ne}{bd^2\sigma_c} = 0.264$

$\sigma_c = 2.505 \div 0.264 = 9.5$ kg/cm²
$\sigma_s = 15 \times 9.5 \times \frac{.36}{.64} = 80$ "
$\tau = \frac{6710}{100 \times .787 \times 55} = 1.6$ "
$\tau_0 = \frac{6710}{5.03 \times 7.5 \times .787 \times 55} = 4.1$ "

at (C) M_{CF} = −4320 kgm, N= 16150 kg, S= 12620 kg

$b=100$ cm, $h = 60 + \frac{62}{3} = 80$ cm
$d=75$ ", $d'=5$ cm
$A_s = 7.5-16^\phi = 15.1$ cm²
$A_s' = 2.5-16^\phi = 5.0$ "
$p = 15.1/7500 = 0.00201$
$p' = 5.0/7500 = 0.00067$
$d'/d = 5/75 = 0.067$

$d/h = 75/80 = 0.938$
$d'/h = 5/80 = 0.063$ $u/h = 0.505$
$p_0 = 15.1/8000 = 0.00189$ $u = 0.505 \times 80 = 40.4$ cm
$p_0' = 5.0/8000 = 0.00063$ $d-u = 34.6$ "

$\frac{M}{N} = \frac{4320 \times 100}{16150} = 26.8$ cm
$d-u = 34.6$
$e = 61.4$ cm
$e' = 70-e = 8.6$ "
$e'/e = 8.6/61.4 = 0.140$
$\frac{Ne}{bd^2} = \frac{16150 \times 61.4}{100 \times 75^2} = 1.762$
$k = 0.410$, $\frac{Ne}{bd^2\sigma_c} = 0.187$

$\sigma_c = 1.762 \div 0.187 = 9.4$ kg/cm²
$\sigma_s = 15 \times 9.4 \times \frac{.59}{.41} = 203$ "
$\tau = \frac{12620}{100 \times .863 \times 75} = 2.0$ "
$\tau_0 = \frac{12620}{50.3 \times .863 \times 75} = 3.9$ "

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CALCULATIONS FOR

上下二段式函型隧道 断面A5 跡土被3.0米

at Ⓕ $M_{FC} = -12430$ kgm, N = 16150 kg, S = 16620 kg

$b = 100$ cm, $h = 60 + \frac{62}{3} = 80$ cm
$d = 75$ cm, $d' = 5$ cm
$A_s = 10-16^\phi = 20.1$ cm
$A_s' = 2.5-16^\phi = 5.0$ "
$p = 20.1/7500 = 0.00268$
$p' = 5.0/7500 = 0.00067$
$d'/d = 5/75 = 0.067$

$d/h = 75/80 = 0.938$
$d'/h = 5/80 = 0.063$ $u/h = 0.507$
$p_0 = 20.1/8000 = 0.00251$ $u = 0.507 \times 80 = 40.6$ cm
$p_0' = 5/8000 = 0.00063$ $d-u = 34.4$ "

$\frac{M}{N} = \frac{12430 \times 100}{16150} = 77.0$ cm
$d-u = 34.4$
$e = 111.4$ cm
$e' = e - 70 = 41.4$
$e'/e = 41.4/111.4 = 0.372$
$\frac{Ne}{bd^2} = \frac{16150 \times 111.4}{100 \times 75^2} = 3,200$
$k = 0.350$, $\frac{Ne}{bd^2\sigma_c} = 0.164$

$\sigma_c = 3,200 \div 0.164 = 19.5$ kg/cm²
$\sigma_s = 15 \times 19.5 \times \frac{.65}{.35} = 543$ "
$\tau = \frac{16620}{100 \times .883 \times 75} = 2.5$ "
$\tau_0 = \frac{16620}{50.3 \times .883 \times 75} = 5.0$ "

Top slab DE
at Ⓜ5 $M_5 = 4960$ kgm, N = 11080 kg, S = 0

$b = 100$ cm, $h = 46$ cm
$d = 41$ ", $d' = 5$ "
$A_s = 10-16^\phi = 20.1$ cm²
$A_s' = 2.5-$ " $= 5.0$ "
$p = 20.1/4100 = 0.00491$
$p' = 5.0/4100 = 0.00122$
$d'/d = 5/41 = 0.122$

$d/h = 41/46 = 0.892$
$d'/h = 5/46 = 0.109$ $u/h = 0.515$
$p_0 = 20.1/4600 = 0.00437$ $u = 0.515 \times 46 = 23.7$ cm
$p_0' = 5.0/4600 = 0.00109$ $d-u = 17.3$ "

$\frac{M}{N} = \frac{4960 \times 100}{11080} = 44.8$ cm
$d-u = 17.3$
$e = 62.1$ cm
$e' = e - 36 = 26.1$ "
$e'/e = 26.1/62.1 = 0.420$
$\frac{Ne}{bd^2} = \frac{11080 \times 62.1}{100 \times 41^2} = 4,095$
$k = 0.430$, $\frac{Ne}{bd^2\sigma_c} = 0.198$

$\sigma_c = 4,095 \div 0.198 = 20.7$ kg/cm²
$\sigma_s = 15 \times 20.7 \times \frac{.57}{.43} = 412$ "

at Ⓗ8 M = −1960 kgm, N = 11080 kg, S = 10,000 kg

$b = 100$ cm, $h = 46$ cm
$d = 41$ ", $d' = 5$ "
$A_s = 7.5-16^\phi = 15.1$ cm²
$A_s' = 2.5-$ " $= 5.0$ "
$p = 15.1/4100 = 0.00368$
$p' = 5.0/4100 = 0.00122$
$d'/d = 5/41 = 0.122$

$d/h = 41/46 = 0.892$
$d'/h = 5/46 = 0.109$ $u/h = 0.510$
$p_0 = 15.1/4600 = 0.00328$ $u = 0.510 \times 46 = 23.5$ cm
$p_0' = 5.0/4600 = 0.00109$ $d-u = 17.5$ "

$\frac{M}{N} = \frac{1960 \times 100}{11080} = 17.7$ cm
$d-u = 17.5$
$e = 35.2$ cm
$e' = 36 - e = 0.8$ "
$e'/e = 0.8/35.2 = 0.023$
$\frac{Ne}{bd^2} = \frac{11080 \times 35.2}{100 \times 41^2} = 2,320$
$k = 0.650$, $\frac{Ne}{bd^2\sigma_c} = 0.268$

$\sigma_c = 2,320 \div 0.268 = 8.7$ kg/cm²
$\sigma_s = 15 \times 8.7 \times \frac{.35}{.65} = 70$ "
$\tau = \frac{10000}{100 \times .783 \times 41} = 3.1$ "
$\tau_0 = \frac{10000}{5.03 \times 7.5 \times .783 \times 41} = 8.3$ "

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CALCULATIONS FOR

上下二段式函型隧道 断面 A5 號 土被 3.0米

at (H9) M = -2450 kgm, N = 11080 kg, S = 10090 kg. — Section same as for H8

$\frac{M}{N} = \frac{2450 \times 100}{11080} = 22.1$ cm

d-u = 17.5

e = 39.6 cm

e' = e - 36 = 3.6 "

e'/e = 3.6/39.6 = 0.091

$\frac{Ne}{bd^2} = \frac{11080 \times 39.6}{100 \times 41^2} = 2.610$

k = 0.550 , $\frac{Ne}{bd^2\sigma_c} = 0.240$

σ_c = 2.610 ÷ 0.240 = 10.9 kg/cm²

$\sigma_s = 15 \times 10.9 \times \frac{.45}{.55} = 134$ "

$\tau = \frac{10090}{100 \times .817 \times 41} = 3.0$ "

$\tau_0 = \frac{10090}{5.03 \times 7.5 \times .817 \times 41} = 8.0$ "

at (D) M_{DE} = -9550 kgm, N = 11080 kg, S = 14470 kg

b = 100 cm, h = 46 + 62/3 = 66 cm
d = 61 ", d' = 5 "
A_s = 10-16φ = 20.1 cm²
A_s' = 2.5- " = 5.0 "
p = 20.1/6100 = 0.00330
p' = 5.0/6100 = 0.00082
d'/d = 5/61 = 0.082

$\frac{M}{N} = \frac{9550 \times 100}{11080} = 86.2$ cm

d/h = 61/66 = 0.925
d'/h = 5/66 = 0.076 u/h = 0.514
p_0 = 20.1/6600 = 0.00305 u = 0.514 × 66 = 33.9 cm
p_0' = 5.0/6600 = 0.00076 d-u = 27.1 "

d-u = 27.1

e = 113.3 cm

e' = e - 56 = 57.3 "

e'/e = 57.3/113.3 = 0.505

$\frac{Ne}{bd^2} = \frac{11080 \times 113.3}{100 \times 61^2} = 3.375$

k = 0.345 , $\frac{Ne}{bd^2\sigma_c} = 0.164$

σ_c = 3.375 ÷ 0.164 = 20.6 kg/cm²

~~$\sigma_s = 15 \times 20.6 \times \frac{.655}{.345} = 587$~~ "

$\tau = \frac{14470}{100 \times .885 \times 61} = 2.7$ "

$\tau_0 = \frac{14470}{50.3 \times .885 \times 61} = 5.3$ "

at (E) M_{ED} = -10140 kgm, N = 11080 kg, S = 14770 kg — Section same as for D.

$\frac{M}{N} = \frac{10140 \times 100}{11080} = 91.5$ cm

d-u = 27.1

e = 118.6 cm

e' = e - 56 = 62.6 "

e'/e = 62.6/118.6 = 0.528

$\frac{Ne}{bd^2} = \frac{11080 \times 118.6}{100 \times 61^2} = 3.535$

k = 0.340 , $\frac{Ne}{bd^2\sigma_c} = 0.161$

σ_c = 3.535 ÷ .161 = 22.0 kg/cm²

$\sigma_s = 15 \times 22 \times \frac{.66}{.34} = 641$ "

$\tau = \frac{14770}{100 \times .887 \times 61} = 2.7$

$\tau_0 = \frac{14770}{50.3 \times .887 \times 61} = 5.4$ "

上下二段式函型隧道 断面 A5 號 土被 3.0米

wall CD.

at (M4) $M_4 = 5010$ kgm, $N = 14470$ kg, $S = 0$

$d/h = 39/44 = 0.886$
$d'/h = 5/44 = 0.114$ $\quad u/h = 0.516$
$p_t = 20.1/4400 = 0.00457$ $\quad u = 0.516 \times 44 = 22.7$ cm
$p_t' = 5.0/4400 = 0.00114$ $\quad d-u = 16.3$ "

$\frac{M}{N} = \frac{5010 \times 100}{14470} = 34.7$ cm
$d-u = 16.3$
$e = 51.0$ cm
$e' = e - 34 = 17.0$ "
$e'/e = 17.0/51.0 = 0.333$
$\frac{Ne}{bd^2} = \frac{14470 \times 51.0}{100 \times 39^2} = 4.850$

$b = 100$ cm, $h = 44$ cm
$d = 39$ cm, $d' = 5$ cm
$A_s = 10-16^\phi = 20.1$ cm²
$A_s' = 2.5-$ " $= 5.0$ "
$p = 20.1/3900 = 0.00515$
$p' = 5.0/$ " $= 0.00128$
$d'/d = 5/39 = 0.128$

$k = 0.470$, $\frac{Ne}{bd^2\sigma_c} = 0.211$

$\sigma_c = 4.850 \div 0.211 = 23.0$ kg/cm²

$\sigma_s = 15 \times 23.0 \times \frac{.53}{.47} = 389$ "

at (H6) $M = -3370$ kgm, $N = 14470$ kg, $S = 10610$ kg

$\frac{M}{N} = \frac{3370 \times 100}{14470} = 23.3$ cm
$d-u = 16.3$
$e = 39.6$ cm
$e' = e - 34 = 5.6$ "
$e'/e = 5.6/39.6 = 0.141$
$\frac{Ne}{bd^2} = \frac{14470 \times 39.6}{100 \times 39^2} = 3.765$
$k = 0.570$, $\frac{Ne}{bd^2\sigma_c} = 0.245$
$\sigma_c = 3.765 \div 0.245 = 15.4$ kg/cm²
$\sigma_s = 15 \times 15.4 \times \frac{.43}{.57} = 174$ "

$b = 100$ cm, $h = 44$ cm
$d = 39$ ", $d' = 5$ "
section same as for M4.

$\tau = \frac{10610}{100 \times .810 \times 39} = 3.4$ "

$\tau_0 = \frac{10610}{50.3 \times .810 \times 39} = 6.7$ "

at (H7) $M = -3400$ kgm, $N = 14470$ kg, $S = 8640$ kg

$\frac{M}{N} = \frac{3400 \times 100}{14470} = 23.5$ cm
$d-u = 16.3$
$e = 39.8$ cm
$e' = e - 34 = 5.8$ "
$e'/e = 5.8/39.8 = 0.146$
$\frac{Ne}{bd^2} = \frac{14470 \times 39.8}{100 \times 39^2} = 3.785$
$k = 0.560$, $\frac{Ne}{bd^2\sigma_c} = 0.243$
$\sigma_c = 3.785 \div 0.243 = 15.6$ kg/cm²
$\sigma_s = 15 \times 15.6 \times \frac{.44}{.56} = 184$ "
$\tau = \frac{8640}{100 \times .813 \times 39} = 2.7$ "
$\tau_0 = \frac{8640}{10 \times 5.03 \times .813 \times 39} = 5.4$ "

section same as for M4

上下二段式函型隧道 断面A5部 土被3.0米

at Ⓒ $M_{CD} = -14050$ kgm, $N = 14470$ kg, $S = 16600$ kg

$b = 100^{cm}$, $h = 44 + \frac{79}{3} = 70^{cm}$
$d = 65$", $d' = 5^{cm}$
$A_s = 10-16^{\phi} = 20.1^{cm}$
$A_s' = 2.5-$ " $= 5.0$"
$p = 20.1/6500 = 0.00309$
$p' = 5.0/6500 = 0.00077$
$d'/d = 5/65 = 0.077$

$d/h = 65/70 = 0.929$
$d'/h = 5/70 = 0.071$
$p_0 = 20.1/7000 = 0.00287$
$p_0' = 5.0/7000 = 0.00071$

$u/h = 0.511$
$u = 0.511 \times 70 = 35.8^{cm}$
$d - u = 29.2$"

$\frac{M}{N} = \frac{14050 \times 100}{14470} = 97.1^{cm}$
$d - u = 29.2$
$e = 126.3^{cm}$
$e' = e - 60 = 66.3$"
$e'/e = 66.3/126.3 = 0.525$
$\frac{Ne}{bd^2} = \frac{14470 \times 126.3}{100 \times 65^2} = 4.320$
$k = 0.330$, $\frac{Ne}{bd^2\sigma_c} = 0.156$

$\sigma_c = 4.320 \div 0.156 = 27.7$ kg/cm²
$\sigma_s = 15 \times 27.7 \times \frac{.670}{.330} = 844$ "
$\tau = \frac{16600}{100 \times .890 \times 65} = 2.9$ "
$\tau_0 = \frac{16600}{50.3 \times .890 \times 65} = 5.7$ "

at Ⓓ $M_{DC} = -9550$ kgm, $N = 14470$ kg, $S = 10850$ kg

$b = 100^{cm}$, $h = 44 + \frac{63}{3} = 65^{cm}$
$d = 60$", $d' = 5^{cm}$
$A_s = 10-16^{\phi} = 20.1$ cm²
$A_s' = 2.5-$ " $= 5.0$"
$p = 20.1/6000 = 0.00335$
$p' = 5.0/6000 = 0.00083$
$d'/d = 5/60 = 0.083$

$d/h = 60/65 = 0.923$
$d'/h = 5/65 = 0.077$
$p_0 = 20.1/6500 = 0.00309$
$p_0' = 5.0/6500 = 0.00077$

$u/h = 0.514$
$u = 0.514 \times 65 = 33.4^{cm}$
$d - u = 26.6$"

$\frac{M}{N} = \frac{9550 \times 100}{14470} = 66.0$ cm
$d - u = 26.6$
$e = 92.6^{cm}$
$e' = e - 55 = 37.6$"
$e'/e = 37.6/92.6 = 0.406$
$\frac{Ne}{bd^2} = \frac{14470 \times 92.6}{100 \times 60^2} = 3.723$
$k = 0.375$, $\frac{Ne}{bd^2\sigma_c} = 0.175$

$\sigma_c = 3.723 \div 0.175 = 21.3$ kg/cm²
$\sigma_s = 15 \times 21.3 \times \frac{.625}{.375} = 533$ "
$\tau = \frac{10850}{100 \times .875 \times 60} = 2.1$ "
$\tau_0 = \frac{10850}{50.3 \times .875 \times 60} = 4.1$ "

wall EF
at Ⓜ6 $M_6 = 5540$ kgm, $N = 14770$ kg, $S = 0$

section same as for M_4
see page 139.

$\frac{M}{N} = \frac{5540 \times 100}{14770} = 37.5$ cm
$d - u = 16.3$
$e = 53.8$ cm
$e' = e - 34 = 19.8$"
$e'/e = 19.8/53.8 = 0.368$
$\frac{Ne}{bd^2} = \frac{14770 \times 53.8}{100 \times 39^2} = 5.230$
$k = 0.460$, $\frac{Ne}{bd^2\sigma_c} = 0.208$

$\sigma_c = 5.230 \div 0.208 = 25.2$ kg/cm²
$\sigma_s = 15 \times 25.2 \times \frac{54}{46} = 444$ "

上下二段式函型隧道 断面A5 締土被3.0米

at (H10) M = −3700 kgm, N = 14770 kg, S = 9090 kg — Section same as for M4 page 139.

$\frac{M}{N} = \frac{3700\times100}{14770} = 25.1$ cm
d−u = 16.3
e = 41.4 cm
e′ = e − 34 = 7.4 "
e′/e = 7.4/41.4 = 0.179
$\frac{Ne}{bd^2} = \frac{14770\times41.4}{100\times39^2} = 4.020$
k = 0.540, $\frac{Ne}{bd^2\sigma_c} = 0.235$

$\sigma_c = 4.020 \div 0.235 = 17.1$ kg/cm²
$\sigma_s = 15\times17.1\times\frac{.46}{.54} = 219$ "
$\tau = \frac{9090}{100\times.820\times39} = 2.8$ "
$\tau_0 = \frac{9090}{50.3\times.820\times39} = 5.7$ "

at (H11) M = −2110 kgm, N = 14770 kg, S = 10160 kg — Section same as for M4

$\frac{M}{N} = \frac{2110\times100}{14770} = 14.3$
d−u ÷ 16.3
e = 30.6 cm
e′ = 34 − e = 3.4 "
e′/e = 3.4/30.6 = 0.111
$\frac{Ne}{bd^2} = \frac{14770\times30.6}{100\times39^2} = 2.975$
k = 0.780, $\frac{Ne}{bd^2\sigma_c} = 0.278$

$\sigma_c = 2.975 \div 0.278 = 10.7$ kg/cm²
$\sigma_s = 15\times10.7\times\frac{.22}{.78} = 45$ "
$\tau = \frac{10160}{100\times.74\times39} = 3.5$ "
$\tau_0 = \frac{10160}{50.3\times.74\times39} = 7.0$ "

at (E) M_{EF} = −10,140 kgm, N = 14770 kg, S = 11300 kg — section same as for D. see on page 140

$\frac{M}{N} = \frac{10140\times100}{14770} = 68.7$ cm
d−u = 26.6
e = 95.3 cm
e′ = e − 55 = 40.3 "
e′/e = 40.3/95.3 = 0.423
$\frac{Ne}{bd^2} = \frac{14770\times95.3}{100\times60^2} = 3.910$
k = 0.370, $\frac{Ne}{bd^2\sigma_c} = 0.172$

$\sigma_c = 3.910 \div 0.172 = 22.8$ kg/cm²
$\sigma_s = 15\times22.8\times\frac{.63}{.37} = 582$ "
$\tau = \frac{11300}{100\times.877\times60} = 2.1$ "
$\tau_0 = \frac{11300}{50.3\times.877\times60} = 4.3$ "

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CALCULATIONS FOR

上下二段式函型隧道 断面 A5 弱 土被3.0米

at Ⓕ $M_{FE} = -12430$ kgm, $N = 14770$ kg, $S = 16150$ kg

Section same as for M_{CD}, see on page 140

$\frac{M}{N} = \frac{12430 \times 100}{14770} = 84.3$ cm

$d-u = 29.2$

$e = 113.5$ cm

$e' = e - 60 = 53.5$

$e'/e = 53.5/113.5 = 0.471$

$\frac{Ne}{bd^2} = \frac{14770 \times 113.5}{100 \times 65^2} = 3.965$

$k = 0.330$, $\frac{Ne}{bd^2 \sigma_c} = 0.156$

$\sigma_c = 3.965 \div 0.156 = 25.5$ kg/cm²

$\sigma_s = 15 \times 25.5 \times \frac{.670}{.330} = 777$ 〃

$\tau = \frac{16150}{100 \times .890 \times 65} = 2.8$ 〃

$\tau_0 = \frac{16150}{50.3 \times .890 \times 65} = 5.6$ 〃

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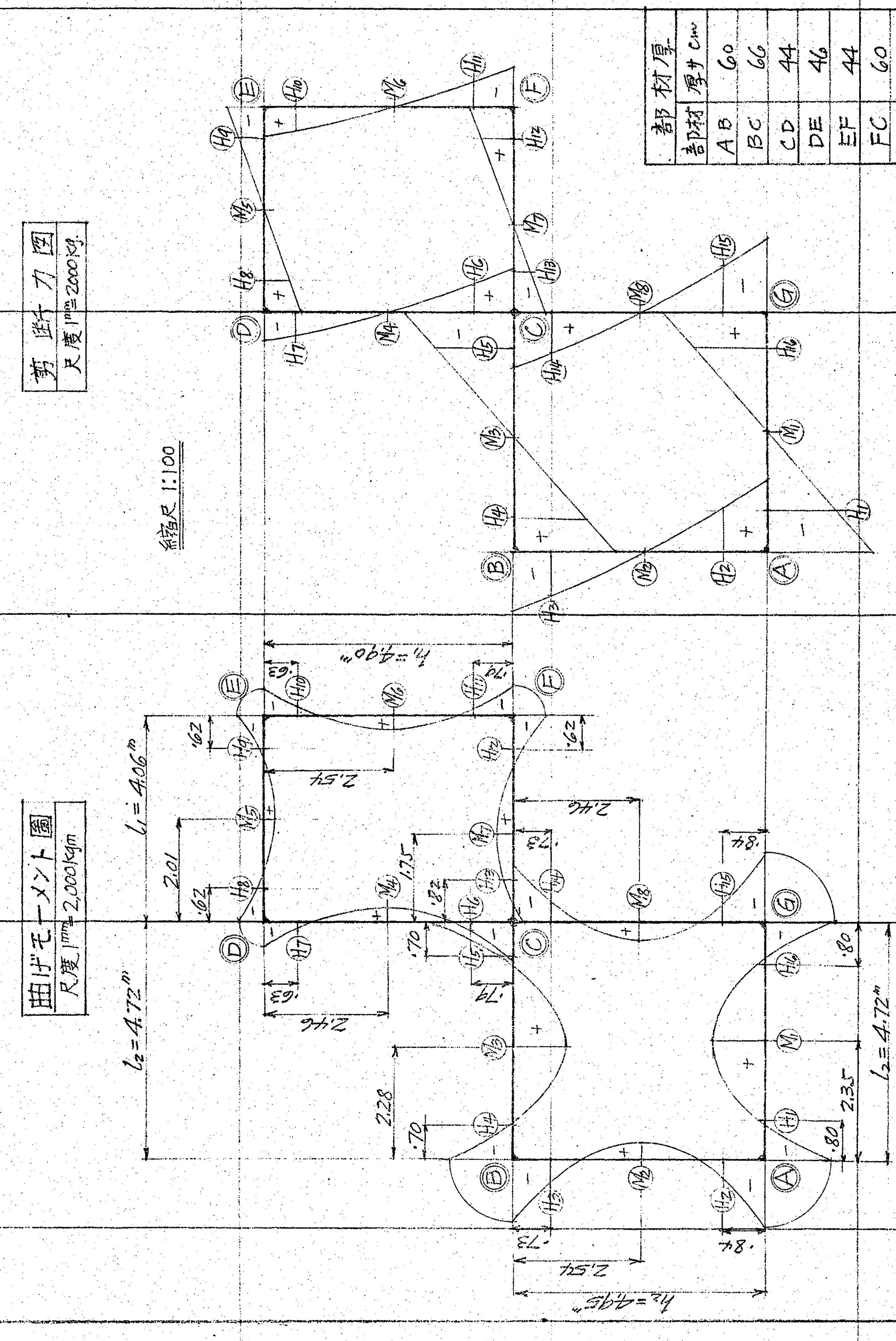
CALCULATIONS FOR

上下二段式函型隧道 断面A5號 土被3.0米

鐵筋混凝土上下二段式函型隧道斷面A5號應力表 土被三.〇米 其一



部材厚

部材	厚サ cm
AB	60
BC	66
CD	44
DE	46
EF	44
FC	60
CG	60
GA	68

土圧 E点 $g_1=3210$ kg/m²
〃 F点 $g_2=8000$ 〃
〃 G点 $g_3=12870$ 〃

荷重状態
土被 3.00m
地下水位 地表面下 1.50m
土ノ安息角 φ = 20°00'
上床荷重 DE w_1 = 7,200 kg/m²
〃 BC w_2 = 17,360 〃
下床 〃 CF w_1 = 7,200 〃
〃 AG w_2 = 17,360 〃

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CALCULATIONS FOR

上下二段式函型隧道 断面A5號 土被3.0米

鐵筋混凝土上下二段式函型隧道断面A5號 土被三・〇米 其二

上下二段式函型隧道應力度表
断面A5號 ― 土被3.0米

寸法 應力 \ 位置		下床 (AG)					上床 (BC)					側壁 (AB)			側壁 (CG)			
		A	H_1	M_1	H_{16}	G	B	H_4	M_3	H_5	C	H_2	M_2	H_3	H_{15}	M_8	H_{14}	C
断面	b (cm)	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
	h (cm)	94	68	68	68	94	89	66	66	79	106	60	60	60	60	60	60	84
	d (cm)	89	63	63	63	89	84	61	61	74	101	55	55	55	55	55	55	79
	d' (cm)	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5
	A_s (cm²)	20.1	21.3	28.4	21.3	20.1	20.1	21.3	28.4	21.3	28.4	20.1	20.1	20.1	20.1	20.1	20.1	20.1
	A_s' (cm²)	7.1	7.1	7.1	7.1	7.1	7.1	7.1	7.1	7.1	7.1	5.0	5.0	5.0	5.0	5.0	5.0	7.1
應力	M (kgm)	26020	1030	21730	280	27130	24450	1000	20650	5700	31160	6810	6710	9440	7180	7700	7090	21450
	N (kg)	28560	28560	28560	28560	28560	23500	23500	23500	23500	23500	39560	39560	39560	41220	41220	41220	41220
	S (kg)	39560	26880	0	27300	41220	39560	27400	0	30200	42400	17690	0	17400	18520	0	16570	22670
應力度	σ_c (kg/cm²)	30.3	5.2	39.4	4.3	31.5	30.7	4.7	39.6	8.5	26.3	17.5	17.4	23.8	18.5	19.7	18.3	29.6
	σ_s (kg/cm²)	923	75	870	65	982	979	68	929	45	801	58	57	201	65	88	60	589
	τ (kg/cm²)	5.1	4.0	—	4.0	5.2	5.3	4.2	—	5.4	4.7	4.4	—	4.0	4.6	—	4.1	3.3
	τ_0 (kg/cm²)	10.2		—		10.3	10.5		—	※12.1	7.9	8.8	—	8.0	9.2	—	8.2	6.7

寸法 應力 \ 位置		下床 (CF)				上床 (DE)					側壁 (CD)				側壁 (EF)			
		C	H_{13}	M_7	H_{12}	D	H_8	M_5	H_9	E	C	H_6	M_4	H_7	H_{10}	M_6	H_{11}	F
断面	b (cm)	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
	h (cm)	80	60	60	60	66	46	46	46	66	70	44	44	44	44	44	44	70
	d (cm)	75	55	55	55	61	41	41	41	61	65	39	39	39	39	39	39	65
	d' (cm)	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5
	A_s (cm²)	15.1	15.1	20.1	15.1	20.1	15.1	20.1	15.1	20.1	20.1	20.1	20.1	20.1	20.1	20.1	20.1	20.1
	A_s' (cm²)	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0
應力	M (kgm)	4320	3600	6750	3520	9550	1960	4960	2450	10140	14050	3370	5010	3400	3700	5540	2110	12430
	N (kg)	16150	16150	16150	16150	11080	11080	11080	11080	11080	14470	14470	14470	14470	14770	14770	14770	14770
	S (kg)	12620	6710	0	11430	14470	10000	0	10090	14770	16600	10610	0	8640	9090	0	10160	16150
應力度	σ_c (kg/cm²)	9.4	9.5	17.3	9.3	20.6	8.7	20.7	10.9	22.0	27.7	15.4	23.0	15.6	17.1	25.2	10.7	25.5
	σ_s (kg/cm²)	203	80	317	75	587	70	412	134	641	844	174	389	184	219	444	45	777
	τ (kg/cm²)	2.0	1.6	—	2.7	2.7	3.1	—	3.0	2.7	2.9	3.4	—	2.7	2.8	—	3.5	2.8
	τ_0 (kg/cm²)	3.9	4.1	—	7.0	5.3	8.3	—	8.0	5.4	5.7	6.7	—	5.4	5.7	—	7.0	5.6

※印ノ箇所ニ於ケル附着応力ハ11.0kg/cm²ヲ超過セルモ抗張鉄筋ノ直径ガ20mm未満ナルヲ以テ之レヲ許容スルモノトス（鐵筋混凝土標準示方書第3節八十八条(3)項参照

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CALCULATIONS FOR

(7)

不用

赤坂見附
停車場

上小三段式立坐隧道

断面A号 土被四〇尺

143頁～147
丗七
参照

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CALCULATIONS FOR

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赤坂見附
停車場
上下二段式函型隧道設計々算書

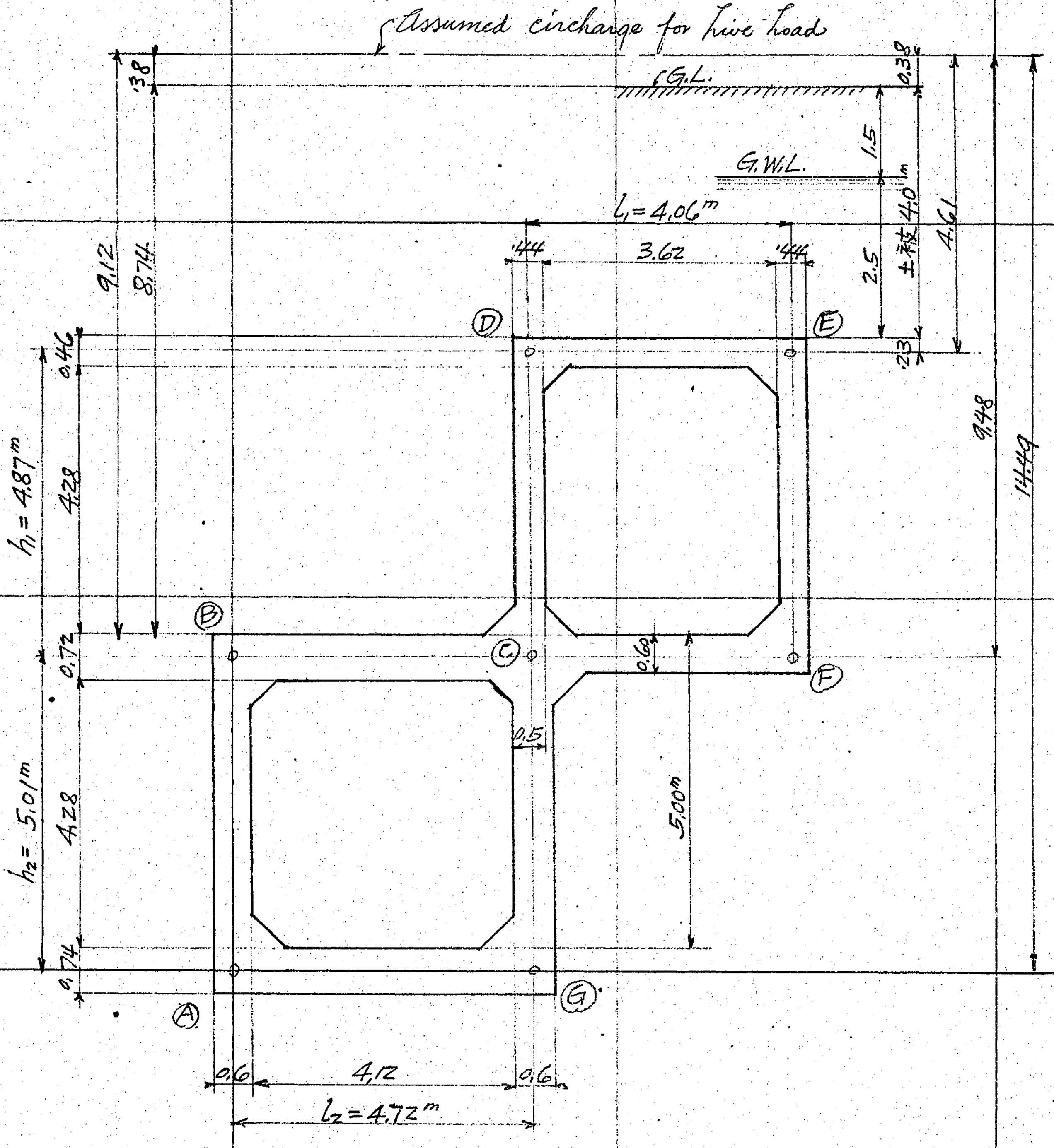
断面A5號
土被四、〇米

自百四十三頁
至百七十一頁

二十九葉

断面A5端 土被4.0米

Assumed Cross section of the tonnel as shown on sketch below.



Scale 1:100.

Load on Top slab. DE

Earth filling above ground water level	1.50m @ 1600	=	2,400
" " below " " "	2.50 @ 2000	=	5,000.
			7,400
weight of concrete slab	0.46 @ 2400	=	1,100
			8,500
Live load on roadway assumed as			600
		w_1 =	9,100 kg/m²

Load on middle floor slab. BC.

Earth filling above ground water level	1.50m @ 1600	=	2400
" " below " " "	7.24 @ 2000	=	14480
			16880
weight of concrete slab	0.72 @ 2400	=	1730
			18,610
Live load on roadway assumed as			600
		w_2 =	19,210 kg/m²

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CALCULATIONS FOR

上下二段式函型隧道 断面A5號 土被4.0米

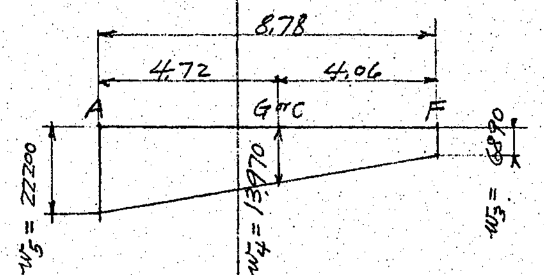
Load on Bottom slabs AG and CF.

Taking moment about Ⓐ, of the loads w_1 and w_2

Load			lever arm	moment
w_1	9100 × 4.06 =	36950	× 6.75 =	249,500
w_2	19210 × 4.72 =	90600	× 2.36 =	214,000
	V =	127,550 kg	× 3.63ᵐ =	463,500 kgm

Eccentricity $e = \frac{4.72+4.06}{2} - 3.62 = 4.39 - 3.62 = 0.77^m$

Toe pressure. $= \frac{V}{d}\left(1 \pm \frac{6e}{d}\right) = \frac{127,550}{8.78}\left(1 \pm \frac{6 \times 0.77}{8.78}\right)$



$= 14530\ (1 \pm 0.526) = 22200$ kg/m² $= w_5$ at Ⓐ

or 6890 " $= w_3$ at Ⓕ

22200 − 6890 = 15,310

$15310 \times \frac{4.06}{8.78} =$ 7080
6890
13970 kg/m² $= w_4$ at Ⓖ or Ⓒ

Side pressure on walls. pressure coefficient = 0.490 for φ = 20°, see on page 83.

pressure intensity

at point D

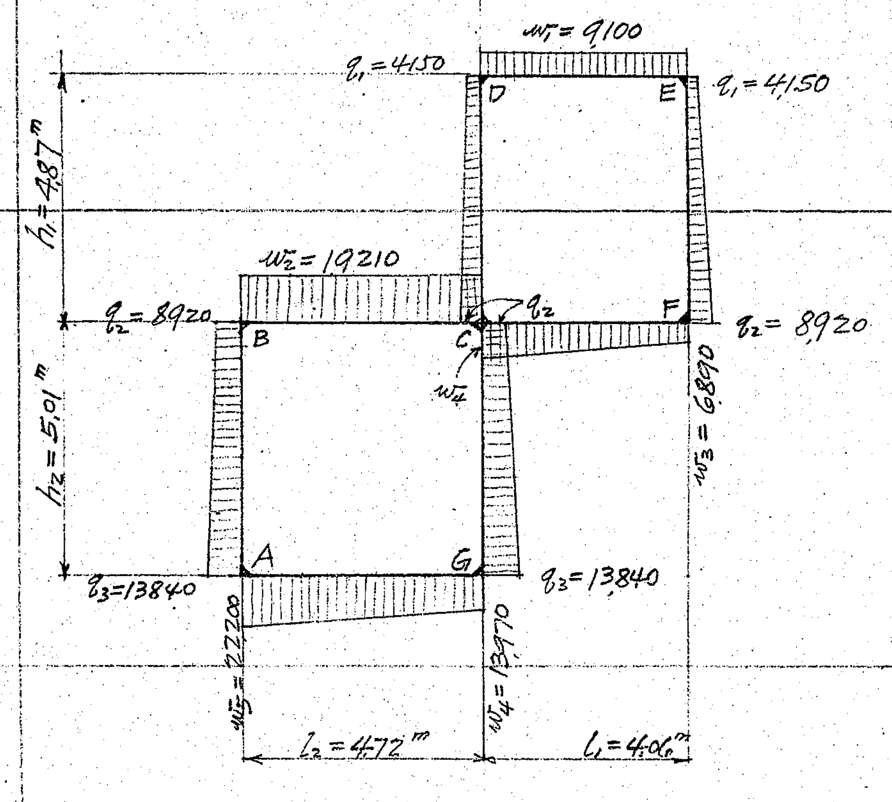
1.88ᵐ @ 1600 = 3,010
2.73 @ 2000 = 5460
8,470 × 0.490 = 4,150 kg/m² $= q_1$

at point B

1.88 @ 1,600 = 3,010
7.60 @ 2000 = 15200
18210 × 0.490 = 8,920 kg/m² $= q_2$

at point A

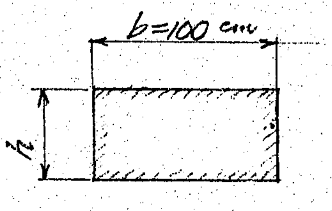
1.88 @ 1600 = 3,010
12.61 @ 2000 = 25220
28230 × 0.490 = 13,840 kg/m² $= q_3$



Loading Condition.

上下二段式函型隧道 断面A5部 土被4.0米

Assumed crosssection and moment of inertia of each member.



	width b	depth h	h^3	$J=\frac{bh^3}{12}$		J
Top slab DE	100 cm	46 cm	97,336	811,000 cm⁴	or	0.00811 m⁴
middle 〃 BC	〃	72	373,248	3,110,000 〃	〃	0.03110 〃
〃 〃 CF	〃	60	216,000	1,800,000 〃	〃	0.01800 〃
bottom 〃 AG	〃	74	405,224	3,380,000 〃	〃	0.03380 〃
side wall DC+EF	〃	44	85,184	710,000 〃	〃	0.00710 〃
〃 〃 BA+CG	〃	60	216,000	1,800,000 〃	〃	0.01800 〃

Values of $K = J/l$

		moment of inertia J		length of member l m		K		
Top slab	DE	0.00811	÷	4.06	=	0.00200	=	K_{DE}
middle 〃	BC	0.03110	÷	4.72	=	0.00659	=	K_{BC}
〃 〃	CF	0.01800	÷	4.06	=	0.00443	=	K_{CF}
bottom 〃	AG	0.03380	÷	4.72	=	0.00716	=	K_{AG}
Side wall	DC+EF	0.00710	÷	4.87	=	0.00146	=	$K_{DC}=K_{EF}$
〃 〃	BA+CG	0.01800	÷	5.01	=	0.00359	=	$K_{BA}=K_{CG}$

Values of moment C.

$C_{DE}=C_{ED} = \frac{w_1 l_1^2}{12} = \frac{9.100\times4.06^2}{12} = 12.500$ ton-meter

$C_{BC}=C_{CB} = \frac{w_2 l_2^2}{12} = \frac{19.210\times4.72^2}{12} = 35.660$ 〃

$w' = w_4 - w_3 = 7.080$ ton/m

$C_{FC} = \frac{l_1^2}{60}(5w_3+2w') = \frac{4.06^2}{60}(5\times6.890+2\times7.080) = 13.360$ 〃

$C_{CF} = \frac{l_1^2}{60}(5w_3+3w') = \frac{4.06^2}{60}(5\times6.890+3\times7.080) = 15.300$ 〃

$w'' = w_5 - w_4 = 8.230$ ton/m

$C_{GA} = \frac{l_2^2}{60}(5w_4+2w'') = \frac{4.72^2}{60}(5\times13.970+2\times8.230) = 32.050$ 〃

$C_{AG} = \frac{l_2^2}{60}(5w_4+3w'') = \frac{4.72^2}{60}(5\times13.970+3\times8.230) = 35.100$ 〃

$q' = q_2 - q_1 = 4.770$ ton/m

$\left.\begin{matrix}C_{DC}\\C_{EF}\end{matrix}\right\} = \frac{h_1^2}{60}(5q_1+2q') = \frac{4.87^2}{60}(5\times4.150+2\times4.770) = 11.980$ 〃

$\left.\begin{matrix}C_{CD}\\C_{FE}\end{matrix}\right\} = \frac{h_1^2}{60}(5q_1+3q') = \frac{4.87^2}{60}(5\times4.150+3\times4.770) = 13.870$ 〃

$q'' = q_3 - q_2 = 4.920$ ton/m

$\left.\begin{matrix}C_{BA}\\C_{CG}\end{matrix}\right\} = \frac{h_2^2}{60}(5q_2+2q'') = \frac{5.01^2}{60}(5\times8.920+2\times4.920) = 22.770$ 〃

$\left.\begin{matrix}C_{AB}\\C_{GC}\end{matrix}\right\} = \frac{h_2^2}{60}(5q_2+3q'') = \frac{5.01^2}{60}(5\times8.920+3\times4.920) = 24.810$ 〃

上下二段式函型隧道 断面A5號 土被4.0米

Value of $\rho = 2\Sigma K = 2\Sigma \frac{I}{l}$ for each panel point.

$\rho_A = \rho_G = 2(0.00716 + 0.00359) = 0.02150$

$\rho_B = 2(0.00359 + 0.00659) = 0.02036$

$\rho_C = 2\begin{Bmatrix} 0.00659 + 0.00146 \\ +0.00443 + 0.00359 \end{Bmatrix} = 0.03214$

$\rho_D = \rho_E = 2(0.00146 + 0.00200) = 0.00692$

$\rho_F = 2(0.00146 + 0.00443) = 0.01178$

Value of $P = \Sigma C$ for each panel point. $-C$), $\downarrow$+C

$P_A = -35.100 + 24.81 = -10.290$

$P_G = 32.050 - 24.81 = 7.240$

$P_B = -22.770 + 35.660 = 12.890$

$P_C = \begin{pmatrix} -35.660 + 13.870 \\ -15.300 + 22.770 \end{pmatrix} = -14.320$

$P_D = -11.980 + 12.500 = 0.520$

$P_E = -12.500 + 11.980 = -0.520$

$P_F = -13.870 + 13.360 = -0.510$

Value of $\varphi^{(0)} = P/\rho$ for each panel point.

$\varphi_A^{(0)} = \frac{P_A}{\rho_A} = \frac{-10.290}{0.02150} = -479$

$\varphi_G^{(0)} = \frac{P_G}{\rho_G} = \frac{7.240}{0.02150} = 337$

$\varphi_B^{(0)} = \frac{P_B}{\rho_B} = \frac{12.890}{0.02036} = 633$

$\varphi_C^{(0)} = \frac{P_C}{\rho_C} = \frac{-14.320}{0.03214} = -446$

$\varphi_D^{(0)} = \frac{P_D}{\rho_D} = \frac{0.520}{0.00692} = 75$

$\varphi_E^{(0)} = \frac{P_E}{\rho_E} = \frac{-0.520}{0.00692} = -75$

$\varphi_F^{(0)} = \frac{P_F}{\rho_F} = \frac{-0.510}{0.01178} = -43$

上下二段式函型隧道 断面A5踏土被40米

Value of $\gamma = \frac{K}{\rho}$ for each member.

A:
$\gamma_{AG} = \frac{K_{AG}}{\rho_A} = \frac{0.00716}{0.02150} = 0.333$

$\gamma_{AB} = \frac{K_{AB}}{\rho_A} = \frac{0.00359}{0.02150} = 0.167$

B:
$\gamma_{BA} = \frac{K_{BA}}{\rho_B} = \frac{0.00359}{0.02036} = 0.176$

$\gamma_{BC} = \frac{K_{BC}}{\rho_B} = \frac{0.00659}{0.02036} = 0.324$

C:
$\gamma_{CB} = \frac{K_{CB}}{\rho_C} = \frac{0.00659}{0.03214} = 0.205$

$\gamma_{CD} = \frac{K_{CD}}{\rho_C} = \frac{0.00146}{0.03214} = 0.045$

$\gamma_{CF} = \frac{K_{CF}}{\rho_C} = \frac{0.00443}{0.03214} = 0.138$

$\gamma_{CG} = \frac{K_{CG}}{\rho_C} = \frac{0.00359}{0.03214} = 0.112$

D (= E):
$\gamma_{DC} = \frac{K_{DC}}{\rho_D} = \frac{0.00146}{0.00692} = 0.211 = \gamma_{EF}$

$\gamma_{DE} = \frac{K_{DE}}{\rho_D} = \frac{0.00200}{0.00692} = 0.289 = \gamma_{ED}$

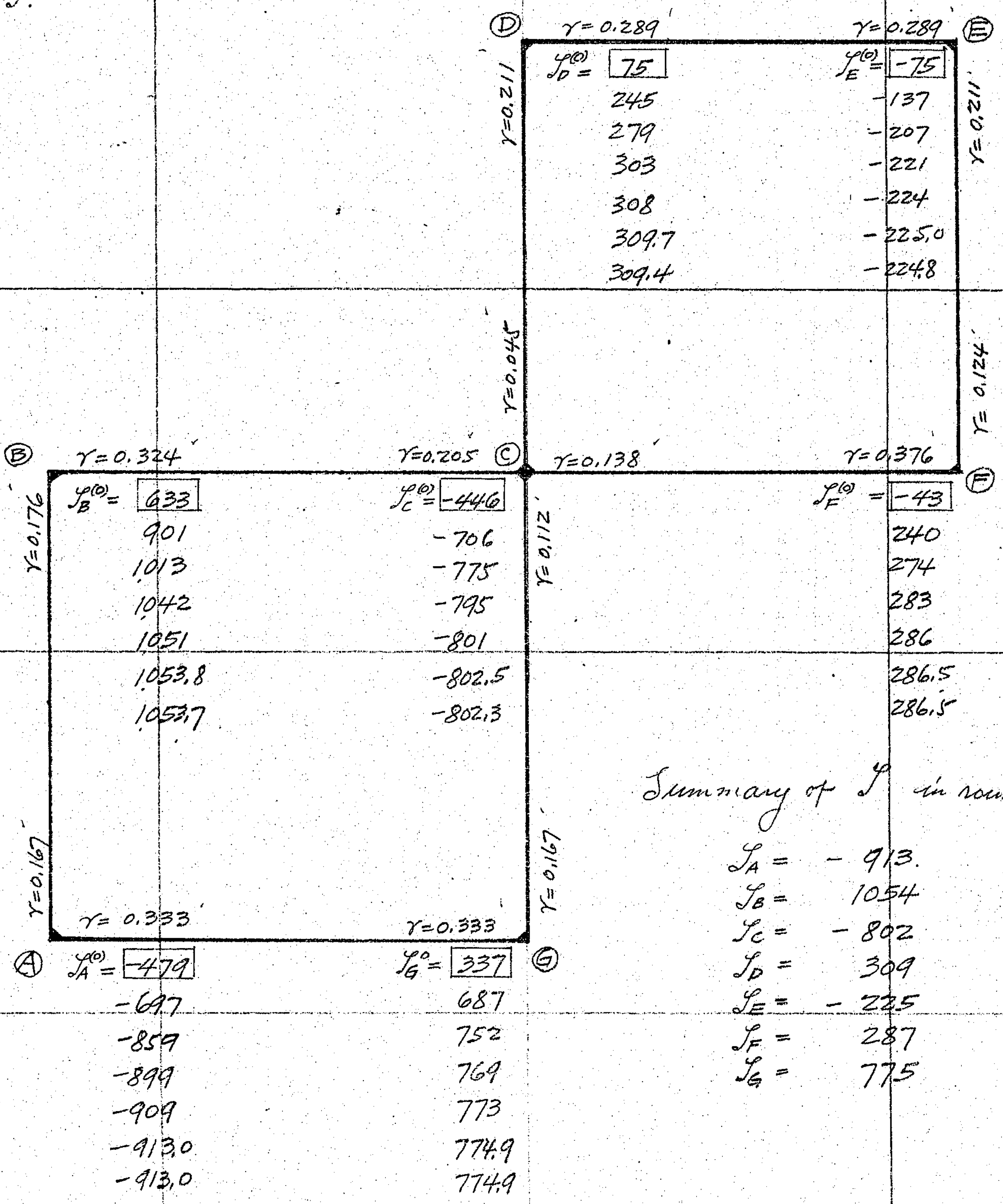
F:
$\gamma_{FE} = \frac{K_{FE}}{\rho_F} = \frac{0.00146}{0.01178} = 0.124$

$\gamma_{FC} = \frac{K_{FC}}{\rho_F} = \frac{0.00443}{0.01178} = 0.376$

G:
$\gamma_{GC} = \frac{K_{GC}}{\rho_G} = \frac{0.00359}{0.02150} = 0.167$

$\gamma_{GA} = \frac{K_{GA}}{\rho_G} = \frac{0.00716}{0.02150} = 0.333$

Values of $\mathcal{S}$.



Summary of $\mathcal{S}$ in round numbers.

$\mathcal{S}_A = -913.$
$\mathcal{S}_B = 1054$
$\mathcal{S}_C = -802$
$\mathcal{S}_D = 309$
$\mathcal{S}_E = -225$
$\mathcal{S}_F = 287$
$\mathcal{S}_G = 775$

上下二段式函型隧道 断面A5號 土被4.0米

Moment at each panel point.

$M_{AG} = K_{AG}(2\varphi_A+\varphi_G) + C_{AG} = 0.00716(-1826 + 775) + 35.100 = -7.530 + 35.100 = 27.570$ ton.m.
$M_{AB} = K_{AB}(2\varphi_A+\varphi_B) - C_{AB} = 0.00359(-1826 + 1054) - 24.810 = -2.770 - 24.810 = -27.580$

$M_{BA} = K_{AB}(2\varphi_B+\varphi_A) + C_{BA} = 0.00359(2108 - 913) + 22.770 = 4.290 + 22.770 = 27.060$
$M_{BC} = K_{BC}(2\varphi_B+\varphi_C) - C_{BC} = 0.00659(2108 - 802) - 35.660 = 8.610 - 35.660 = -27.050$

$M_{CB} = K_{BC}(2\varphi_C+\varphi_B) + C_{CB} = 0.00659(-1604 + 1054) + 35.660 = -3.630 + 35.660 = 32.030$
$M_{CG} = K_{CG}(2\varphi_C+\varphi_G) - C_{CG} = 0.00359(-1604 + 775) - 22.770 = -2.980 - 22.770 = -25.750$
$M_{CF} = K_{CF}(2\varphi_C+\varphi_F) + C_{CF} = 0.00443(-1604 + 287) + 15.300 = -5.830 + 15.300 = 9.470$
$M_{CD} = K_{CD}(2\varphi_C+\varphi_D) - C_{CD} = 0.00146(-1604 + 309) - 13.870 = -1.890 - 13.870 = -15.760$

$M_{DC} = K_{CD}(2\varphi_D+\varphi_C) + C_{DC} = 0.00146(618 - 802) + 11.980 = -0.269 + 11.980 = 11.711$
$M_{DE} = K_{DE}(2\varphi_D+\varphi_E) - C_{DE} = 0.00200(618 - 225) - 12.500 = 0.786 - 12.500 = -11.714$

$M_{ED} = K_{DE}(2\varphi_E+\varphi_D) + C_{ED} = 0.00200(-450 + 309) + 12.500 = -0.282 + 12.500 = 12.218$
$M_{EF} = K_{EF}(2\varphi_E+\varphi_F) - C_{EF} = 0.00146(-450 + 287) - 11.980 = -0.238 - 11.980 = -12.218$

$M_{FE} = K_{EF}(2\varphi_F+\varphi_E) + C_{FE} = 0.00146(574 - 225) + 13.870 = 0.509 + 13.870 = 14.379$
$M_{FC} = K_{CF}(2\varphi_F+\varphi_C) - C_{FC} = 0.00443(574 - 802) - 13.360 = -1.010 - 13.360 = -14.370$

$M_{GC} = K_{CG}(2\varphi_G+\varphi_C) + C_{GC} = 0.00359(1550 - 802) + 24.810 = 2.685 + 24.810 = 27.495$
$M_{GA} = K_{AG}(2\varphi_G+\varphi_A) - C_{GA} = 0.00716(1550 - 913) - 32.050 = 4.560 - 32.050 = -27.490$

Now we have moment at each panel point as follows.

$M_{AG} = M_{AB}$	$= -27.58$ ton.m.	$M_{DC} = M_{DE}$	$= -11.71$ ton.m.
$M_{BA} = M_{BC}$	$= -27.06$ 〃	$M_{ED} = M_{EF}$	$= -12.22$ 〃
M_{CB}	$= -32.03$ 〃	$M_{FE} = M_{FC}$	$= -14.37$ 〃
M_{CG}	$= -25.75$ 〃		
M_{CF}	$= -9.47$ 〃	$M_{GC} = M_{GA}$	$= -27.49$ 〃
M_{CD}	$= -15.76$ 〃		

Shear in slab BC

$S_{BC} = \frac{w_2 l_2}{2} + \frac{M_{CB}-M_{BC}}{l_2} = \frac{19210\times4.72}{2} + \frac{-4.970}{4.72} = 45340 - 1050 = 44290$ kg

$S_{CB} = -45340 - 1050 = -46390$ 〃

$S_{H4} = 44290 \times \frac{1.61}{2.31} = 30850$ kg

$S_{H5} = -46390 \times \frac{1.61}{2.41} = -31000$ 〃

Shear in slab DE

$S_{DE} = \frac{w_1 l_1}{2} + \frac{M_{ED}-M_{DE}}{l_1} = \frac{9100\times4.06}{2} + \frac{-510}{4.06} = 18480 - 130 = 18350$ kg.

$S_{ED} = -18480 - 130 = -18610$ 〃

$S_{H8} = 18350 \times \frac{1.40}{2.02} = 12710$ kg

$S_{H9} = -18610 \times \frac{1.42}{2.04} = -12950$ 〃

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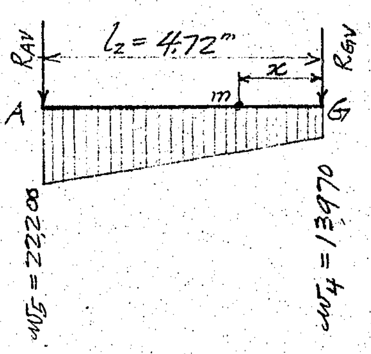
CALCULATIONS FOR

上下二段式函型隧道 断面 A5端 土被 4.0米

Shear in slab AG.



$R_{AV} = \frac{l_2}{6}(2w_5 + w_4) = \frac{4.72}{6}(44400 + 13970) = 45900$ kg

$R_{GV} = \frac{l_2}{6}(w_5 + 2w_4) = \frac{4.72}{6}(22200 + 27940) = 39420$ 〃

$S_{AG} = -45900 + \frac{-90}{4.72} = -45900 - 20 = -45920$ 〃

$S_{GA} = 39420 - 20 = 39400$ 〃

Shear at any point m

$S_m = S_{GA} - w_4 x - \frac{w_5 - w_4}{2 l_2} x^2 = 39400 - 13970x - 872x^2$

point of zero shear

$872x^2 + 13970x - 39400 = 0$

$x = \frac{-13970}{1744} \pm \frac{\sqrt{13970^2 + 4 \times 872 \times 39400}}{1744} = 2.444^m$ from G

Shear at end of haunch

	x	x^2	S_{GA}		$13970x$		$872x^2$		S_m	
H_1	3.92^m	15.366	39400	−	54700	−	13400	=	−28,700	kg
H_{16}	0.80	0.640	〃	−	11,170	−	560	=	27,670	〃

Shear in slab CF.

$R_{CV} = \frac{l_1}{6}(2w_4 + w_3) = \frac{4.06}{6}(27940 + 6890) = 23570$ kg

$R_{FV} = \frac{l_1}{6}(w_4 + 2w_3) = \frac{4.06}{6}(13970 + 13780) = 18780$ 〃

$S_{CF} = -23570 - \frac{-4900}{4.06} = -23570 + 1210 = -22360$ 〃

$S_{FC} = 18780 + 1210 = 19990$ 〃

Shear at any point m.

$S_m = S_{FC} - w_3 x - \frac{w_4 - w_3}{2 l_1} x^2 = 19990 - 6890x - 872x^2$

point of zero shear

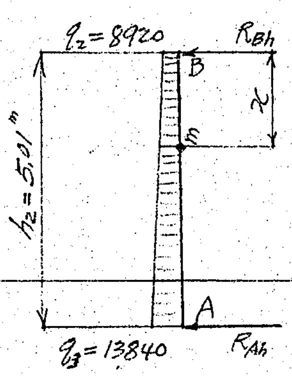
$872x^2 + 6890x - 19990 = 0$

$x = \frac{-6890}{1744} \pm \frac{\sqrt{6890^2 + 4 \times 872 \times 19990}}{1744} = 2.258^m$ from F.

Shear at end of haunch.

	x	x^2	S_{FC}		$6890x$		$872x^2$		S_m	
H_{12}	0.62^m	0.384	19990	−	4270	−	340	=	15380	kg
H_{13}	3.24	10.498	〃	−	22330	−	9160	=	−11,500	〃

Shear in wall AB.



$R_{Ah} = \frac{h_2}{6}(2q_3 + q_2) = \frac{5.01}{6}(27680 + 8920) = 30550$ kg

$R_{Bh} = \frac{h_2}{6}(q_3 + 2q_2) = \frac{5.01}{6}(13840 + 17840) = 26450$ 〃

$S_{AB} = 30550 + \frac{520}{5.01} = 30550 + 100 = 30650$ 〃

$S_{BA} = -26450 + 100 = -26350$ 〃

Shear at any point m.

$S_m = S_{BA} + q_2 x + \frac{q_3 - q_2}{2 h_2} x^2 = -26350 + 8920x + 491x^2$

Point of zero shear.

$x = \frac{-8920}{982} \pm \frac{\sqrt{8920^2 + 4 \times 491 \times 26350}}{982} = 2.590^m$ from B.

上下二段式函型隧道 断面 A5 踌土被 40米

Shear at end of haunch

	x	x^2	S_{BA}	$8920x$	$491x^2$		S_m
H_2	4.14ᵐ	17.140	−26350	+ 36920	+ 8420	=	18990 kg
H_3	0.76	0.578	〃	+ 6780	+ 280	=	−19290 〃

Shear in wall CG.

$R_{Gh} = 30550$ kg , $R_{Ch} = 26450$ kg

$S_{GC} = -30550 - \frac{1740}{5.01} = -30550 - 350 = -30900$ kg

$S_{CG} = 26450 - 350 = 26100$ 〃

Shear at any point m.

$S_m = S_{CG} - q_2 x - \frac{q_3 - q_2}{2h_2} x^2 = 26100 - 8920x - 491x^2$

point of zero shear.

$x = \frac{-8920}{982} \pm \frac{\sqrt{8920^2 + 4 \times 491 \times 26100}}{982} = 2.565$ m from C

Shear at end of haunch.

	x	x^2	S_{CG}	$8920x$	$491x^2$		S_m
H_{14}	0.76ᵐ	0.578	26100	− 6780	− 280	=	19040
H_{15}	4.14	17.140	〃	− 36920	− 8420	=	− 19240

Shear in wall CD.

$R_{Ch} = \frac{h_1}{6}(2q_2 + q_1) = \frac{4.87}{6}(17840 + 4150) = 17850$ kg

$R_{Dh} = \frac{h_1}{6}(2q_1 + q_2) = \frac{4.87}{6}(8300 + 8920) = 13980$ 〃

$S_{CD} = 17850 + \frac{4050}{4.87} = 17850 + 830 = 18680$ kg

$S_{DC} = -13980 + 830 = -13150$ 〃

Shear at any point m.

$S_m = S_{DC} + q_1 x + \frac{q_2 - q_1}{2h_1} x^2 = -13150 + 4150x + 490x^2$

point of zero shear.

$x = \frac{-4150}{980} \pm \frac{\sqrt{4150^2 + 4 \times 490 \times 13150}}{980} = 2.460$ m from D.

Shear at end of haunch.

	x	x^2	S_{DC}	$4150x$	$490x^2$		S_m
H_6	4.11ᵐ	16.892	−13150	+ 17070	+ 8280	=	12200 kg
H_7	0.63	0.397	〃	+ 2620	+ 190	=	−10340 〃

Shear in wall EF.

$R_{Fh} = 17850$ kg, $R_{Eh} = 13980$ kg.

$S_{FE} = -17850 - \frac{2150}{4.87} = -17850 - 440 = -18290$ kg

$S_{EF} = 13980 - 440 = 13540$ 〃

Shear at any point m.

$S_m = S_{EF} - q_1 x - \frac{q_2 - q_1}{2h_1} x^2 = 13540 - 4150x - 490x^2$

Point of Zero shear.

$x = \frac{-4150}{980} \pm \frac{\sqrt{4150^2 + 4 \times 490 \times 13540}}{980} = 2.515$ m from E

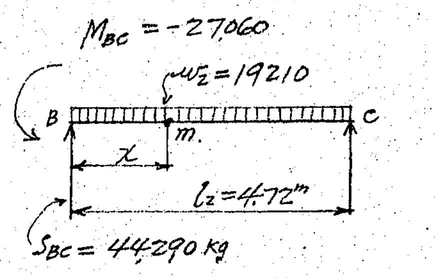
Shear at end of haunch.

	x	x^2	S_{EF}	$4150x$	$490x^2$		S_m
H_{10}	0.63ᵐ	0.397	13540	− 2620	− 190	=	10730 kg
H_{11}	4.11	16.892	〃	− 17070	− 8280	=	− 11810 〃

上下二段式函型隧道 断面A5 土被4.0m

Moment at end of haunch and max. positive moment for each member.

moment in slab BC.



$M_m = M_{BC} + S_{BC}x - \frac{w_2 x^2}{2} = -27060 + 44290x - 9605x^2$

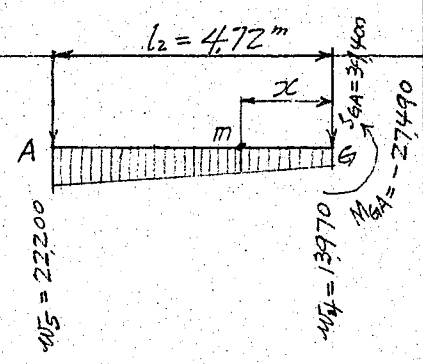
	x	x^2	M_{BC}	$44290x$	$9605x^2$	M_m
H_4	0.70^m	0.490	−27060	+ 31000	− 4710	= −770 kgm
M_3	2.31	5.336	〃	+ 102300	− 51250	= 23990 〃
H_5	3.92	15.366	〃	+ 173550	− 147550	= −1060 〃

moment in slab DE.

$M_m = M_{DE} + S_{DE}x - \frac{w_1 x^2}{2} = -11710 + 18350x - 4550x^2$

	x	x^2	M_{DE}	$18350x$	$4550x^2$	M_m
H_8	0.62^m	0.384	−11710	+ 11370	− 1750	= −2090 kgm
M_5	2.02	4.080	〃	+ 37050	− 18570	= 6770 〃
H_9	3.44	11.834	〃	+ 63100	− 53850	= −2460 〃

moment in slab AG.



$M_m = M_{GA} + S_{GA}x - \frac{w_4 x^2}{2} - \frac{w_5 - w_4}{6l_2}x^3 = -27490 + 39400x - 6985x^2 - 291x^3$

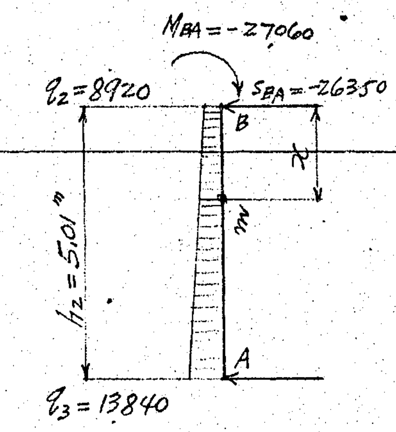
	x	x^2	x^3	M_{GA}	$39400x$	$6985x^2$	$291x^3$	M_m
H_1	3.92^m	15.366	60.236	−27490	+ 154500	− 107300	− 17530	= 2180 kgm
M_1	2.444	5.973	14.598	〃	+ 96300	− 41700	− 4250	= 22860 〃
H_{16}	0.80	0.640	0.512	〃	+ 31520	− 4470	− 150	= −590 〃

moment in slab CF

$M_m = M_{FC} + S_{FC}x - \frac{w_3 x^2}{2} - \frac{w_4 - w_3}{6l_1}x^3 = -14370 + 19990x - 3445x^2 - 291x^3$.

	x	x^2	x^3	M_{FC}	$19990x$	$3445x^2$	$291x^3$	M_m
H_{12}	0.620^m	0.384	0.238	−14370	+ 12390	− 1320	− 70	= −3370 kgm
M_7	2.258	5.099	11.513	〃	+ 45130	− 17580	− 3350	= 9830 〃
H_{13}	3.240	10.498	34.012	〃	+ 62750	− 36150	− 9900	= 2330 〃

Moment in wall AB.



$M_m = M_{BA} - S_{BA}x - \frac{q_2 x^2}{2} - \frac{q_3 - q_2}{6h_2}x^3 = -27060 + 26350x - 4460x^2 - 164x^3$

	x	x^2	x^3	M_{BA}	$26350x$	$4460x^2$	$164x^3$	M_m
H_2	4.140^m	17.140	70.958	−27060	+ 109100	− 76400	− 11640	= −6000 kgm
M_2	2.590	6.708	17.374	〃	+ 68300	− 29930	− 2850	= 8460 〃
H_3	0.760	0.578	0.439	〃	+ 20040	− 2580	− 70	= −9670 〃

moment in wall CG.

$M_m = M_{CG} + S_{CG}x - \frac{q_2}{2}x - \frac{q_3 - q_2}{6h_2}x^3 = -25750 + 26100x - 4460x^2 - 164x^3$

	x	x^2	x^3	M_{CG}	$26100x$	$4460x^2$	$164x^3$	M_m
H_{14}	0.760^m	0.578	0.439	−25750	+ 19850	− 2580	− 70	= −8550 kgm
M_8	2.565	6.579	16.876	〃	+ 66920	− 29350	− 2770	= 9050 〃
H_{15}	4.140	17.140	70.958	〃	+ 108100	− 76400	− 11640	= −5690 〃

上下二段式函型隧道 断面A5端 土被4.0米

Moment in wall CD. $M_m = M_{DC} - S_{DC}x - \frac{q_1 x^2}{2} - \frac{q_2 - q_1}{6h_1}x^3 = -11,710 + 13150x - 2075x^2 - 163.3x^3$

	x	x^2	x^3	M_{DC}	$13150x$	$2075x^2$	$163.3x^3$	M_m
H_6	4.110m	16.892	69.427	−11,710 +	54030 −	35,040	− 11,340	= −4060 tgm
M_4	2.460	6.052	14.887	〃 +	32,350 −	12,550	− 2,430	= 5,660 〃
H_7	0.630	0.397	0.250	〃 +	8,290 −	820	− 40	= −4,280 〃

moment in wall EF $M_m = M_{EF} + S_{EF}x - \frac{q_1 x^2}{2} - \frac{q_2 - q_1}{6h_1}x^3 = -12,220 + 13540x - 2075x^2 - 163.3x^3$

	x	x^2	x^3	M_{EF}	$13540x$	$2075x^2$	$163.3x^3$	M_m
H_{10}	0.630	0.397	0.250	−12,220 +	8,540 −	820	− 40	= −4,540 kgm
M_6	2.515	6.325	15.908	〃 +	34,050 −	13,120	− 2600	= 6,110 〃
H_{11}	4.110	16.892	69.427	〃 +	55,650 −	35,040	− 11340	= −2,950 〃

Axial Thrust in each member.

Slab	AG	Thrust	N_{AG} =	30,780 kg	mean value.
〃	BC	〃	N_{BC} =	26,350 〃	
〃	CF	〃	N_{CF} =	18,290 〃	
〃	DE	〃	N_{DE} =	13,350 〃	mean value
wall	AB	〃	N_{AB} =	44,290 〃	
〃	CG	〃	N_{CG} =	39,400 〃	
〃	CD	〃	N_{CD} =	18,350 〃	
〃	EF	〃	N_{EF} =	18,610 〃	

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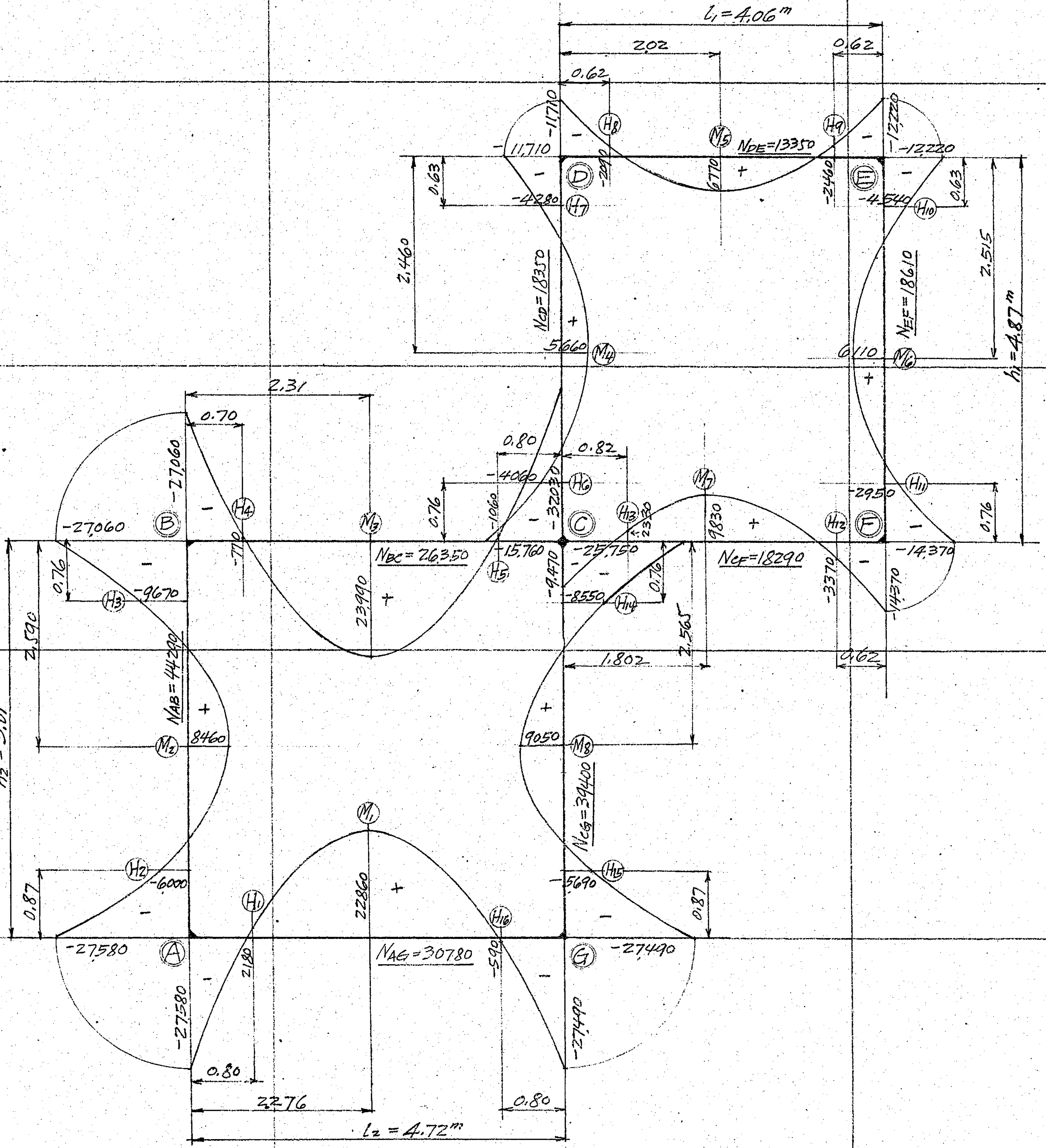
CALCULATIONS FOR

上下二段式函型隧道 断面A5號 土被4.0米

Bending moment diagram.



Scale of space 1:60

" " moment $\frac{1}{100}^m$ = 10,000 Kgm.

増田淳氏関係資料 (独立行政法人 土木研究所蔵)

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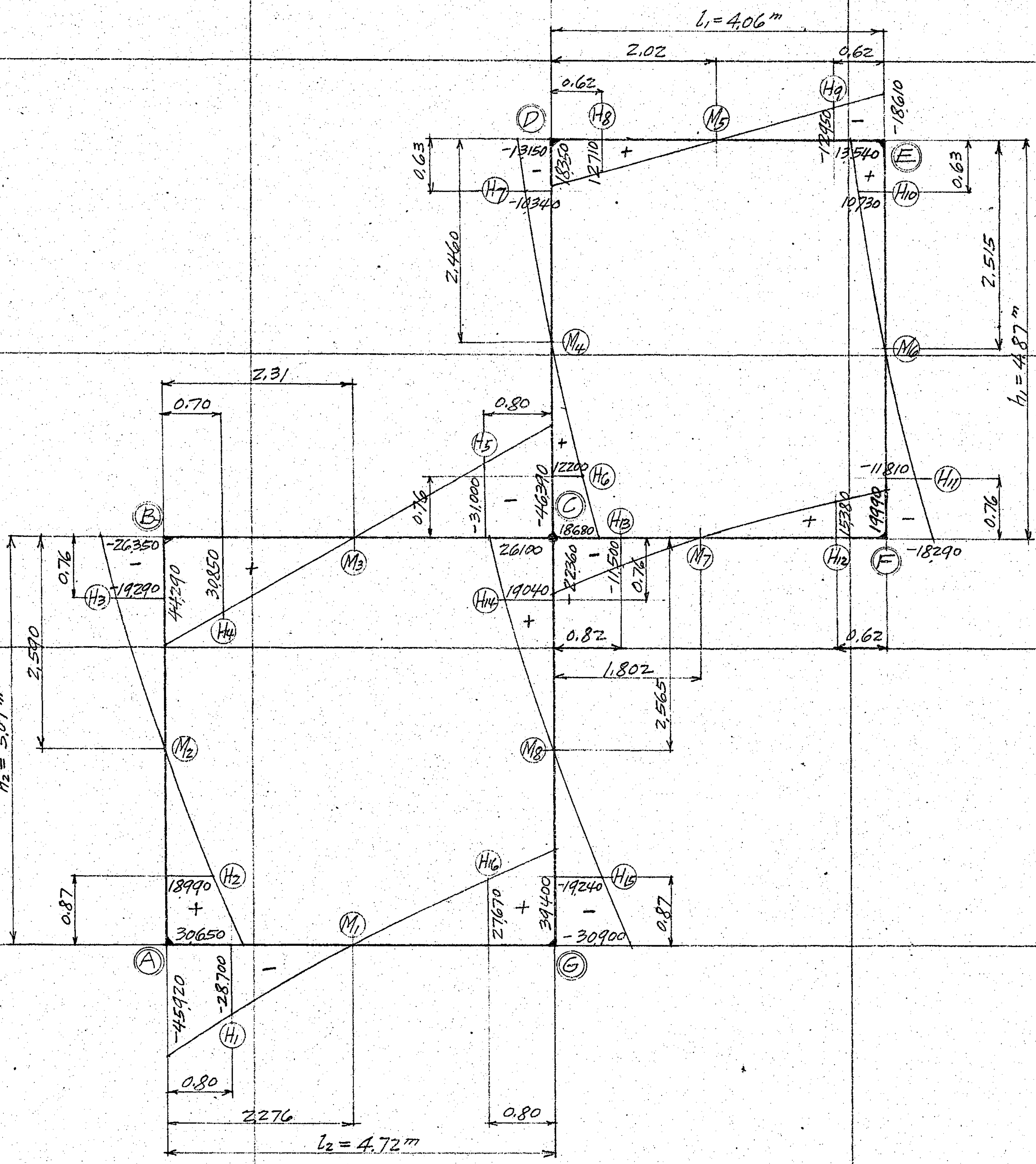
CALCULATIONS FOR

上下二段式函型隧道 断面A5號土被4.0米

Shearing stress diagram.



Scale of space 1:60
" " Shear $\frac{1}{200}$ m = 10000 kg

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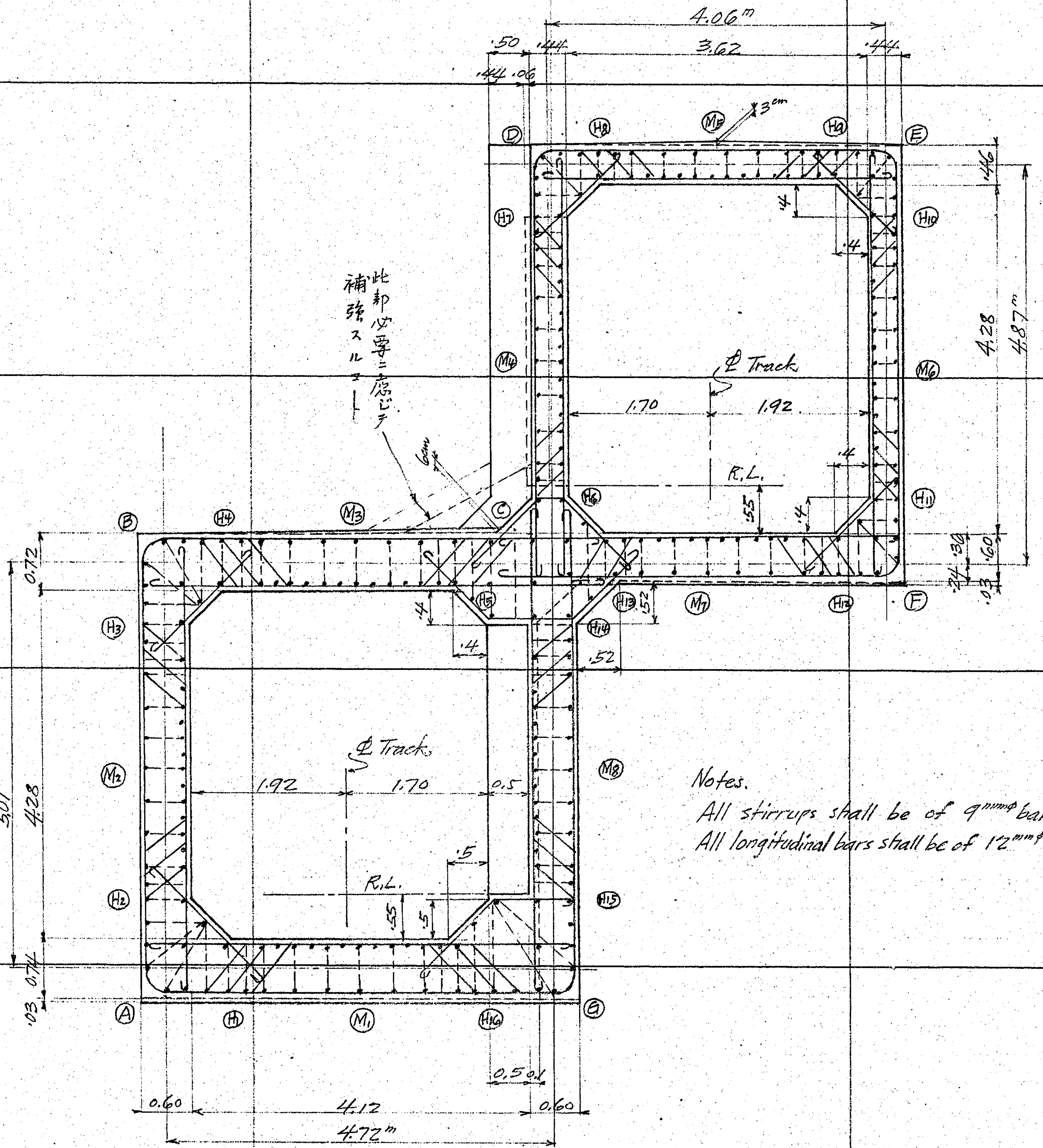
CALCULATIONS FOR

上下二段式函型隧道 断面A5號 土被4.0米

Assumed Cross section and Reinforcements for each member.



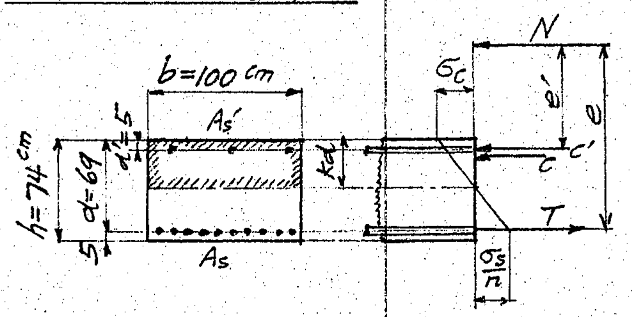
Notes.
All stirrups shall be of 9mmϕ bars.
All longitudinal bars shall be of 12mmϕ.

Cross section A5 (土被 4.0米)
Scale 1:60

上下二段式函型隧道 断面 A5準 土被4.0米

Unit stress calculations.

Bottom slab AG



at (M) 22860 kgm , N= 30780 kg, S=0

$\frac{M}{N} = \frac{22860 \times 100}{30780} = 743$ cm

$d-u = 30.9$

$e = 105.2$ cm

$e' = e - 64 = 41.2$ "

$e'/e = 41.2/105.2 = 0.392$

$\frac{Ne}{bd^2} = \frac{30780 \times 105.2}{100 \times 69^2} = 6.805$

$k = 0.405$, $\frac{Ne}{bd^2\sigma_c} = 0.189$

$\sigma_c = 6.805/0.189 = 36.1$ kg/cm²

$\sigma_s = 15 \times 36.1 \times \frac{.595}{.405} = 796$

b=100 cm, h= 74 cm
d= 69 cm, d'= 5 cm
A_s = 10-19φ = 28.4 cm²
A_s' = 2.5- " = 7.1 "
p = 28.4/6900 = 0.00412
p' = 7.1/6900 = 0.00103
d'/d = 5/69 = 0.073

$d/h = 69/74 = 0.932$

$d'/h = 5/74 = 0.068$ $u/h = 0.515$

$p_o = 28.4/7400 = 0.00384$ $u = 0.515 \times 74 = 38.1$ cm

$p_o' = 7.1/7400 = 0.00096$ $d-u = 30.9$ "

at (H1) M= 2180 kgm, N= 30780 kg, S= 28700 kg

$e = \frac{M}{N} = \frac{2180 \times 100}{30780} = 7.1$ cm

whole section under compression.

b=100 cm, h= 74 cm
d= 69 " , d'= 5 "
A_s = 7.5-19φ = 21.3 cm²
A_s' = 2.5- " = 7.1 "
p_o = 21.3/7400 = 0.00288
p_o' = 7.1/ " = 0.00096

$d/h = 69/74 = 0.932$

$d'/h = 5/74 = 0.068$

$u/h = 0.510$

$u = 0.510 \times 74 = 37.7$ cm.

$A_i = bh + n(A_s + A_s') = 100 \times 74 + 15 \times 28.4 = 7826$ cm²

$I_i = \frac{b}{3}[u^3 + (h-u)^3] + nA_s(d-u)^2 + nA_s'(u-d')^2 = \frac{100}{3}(37.7^3 + 36.3^3) + 15 \times 21.3 \times 31.3^2 + 15 \times 7.1 \times 32.7^2$

$= 3377000 + 313000 + 114000 = 3804000$ cm⁴

$\sigma_c = \frac{N}{A_i} + \frac{Ne}{I_i}u = \frac{30780}{7826} + \frac{30780 \times 7.1}{3804000} \times 37.7 = 3.9 + 2.2 = 6.1$ kg/cm² C

$\sigma_c' = \frac{N}{A_i} - \frac{Ne}{I_i}(h-u) =$ " $-$ " $\times 36.3 = 3.9 - 2.1 = 1.8$ "

$\sigma_s = 15\left(\frac{4.3 \times 69}{74} + 1.8\right) = 87$ kg/cm²

$\tau \fallingdotseq \frac{28700}{7400} = 3.9$ "

at (H16) M= -590 kgm , N= 30780 kg; S= 27670 kg

$e = \frac{M}{N} = \frac{590 \times 100}{27670} = 2.1$ cm Section same as for H1 assumed.

$\sigma_c = 3.9 + \frac{30780 \times 2.1}{3804000} \times 37.7 = 3.9 + 0.6 = 4.5$ kg/cm²

$\sigma_c' = 3.9 -$ " $\times 36.3 = 3.9 - 0.6 = 3.3$ "

$\sigma_s = 15\left(\frac{1.2 \times 69}{74} + 3.3\right) = 66$ kg/cm²

$\tau \fallingdotseq \frac{27670}{7400} = 3.7$ "

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CALCULATIONS FOR

上下二段式函型隧道 断面A5號 土被4.0米

at Ⓐ $M_{AG} = -27{,}580$ kgm, $N = 30{,}780$ kg, $S = 45920$ kg

$d/h = 95/100 = 0.950$
$d'/h = 5/100 = 0.050$ $u/h = 0.507$
$p_0 = 20.1/10000 = 0.00201$ $u = 0.507 \times 100 = 50.7$
$p_0' = 7.1/10000 = 0.00071$ $d-u = 44.3$ cm

$\frac{M}{N} = \frac{27580 \times 100}{30780} = 89.7$ cm
$d-u = 44.3$
$e = 134.0$ cm
$e' = e - 90 = 44.0$ "
$e'/e = 44/134 = 0.329$
$\frac{Ne}{bd^2} = \frac{30780 \times 134.0}{100 \times 95^2} = 4.573$

$b = 100$ cm, $h = 74 + \frac{80}{3} = 100$ cm
$d = 95$ ", $d' = 5$ "
$A_s = 10\text{-}16^\phi = 20.1$ cm²
$A_s' = 2.5\text{-}19^\phi = 7.1$ "
$p = 20.1/9500 = 0.00212$
$p' = 7.1/9500 = 0.00075$
$d'/d = 5/95 = 0.053$

$k = 0.340$, $\frac{Ne}{bd^2\sigma_c} = 0.160$
$\sigma_c = 4.573 \div 0.160 = 28.6$ kg/cm²
$\sigma_s = 15 \times 28.6 \times \frac{.66}{.34} = 835$ "
$\tau = \frac{45920}{100 \times .887 \times 95} = 5.5$ " use 3-sets of bent up bars @ 2-19φ bars. 30 cm c/c of sets, att.
$\tau_0 = \frac{45920}{50.3 \times .887 \times 95} = 10.8$ "

at Ⓖ $M_{GA} = -27{,}490$ kgm, $N = 30780$ kg, $S = 39400$ kg

$\frac{M}{N} = \frac{27490 \times 100}{30780} = 89.4$ cm
$d-u = 44.3$
$e = 133.7$ cm
$e' = e - 90 = 43.7$ "
$e'/e = 43.7/133.7 = 0.327$
$\frac{Ne}{bd^2} = \frac{30780 \times 133.7}{100 \times 95^2} = 4.560$

Section same as for A assumed.

$k = 0.34$, $\frac{Ne}{bd^2\sigma_c} = 0.160$
$\sigma_c = 4.560 \div 0.160 = 28.5$ kg/cm²
$\sigma_s = 15 \times 28.5 \times \frac{.66}{.34} = 830$ "
$\tau = \frac{39400}{100 \times .887 \times 95} = 4.7$
$\tau_0 = \frac{39400}{50.3 \times .887 \times 95} = 9.3$ "

Top slab BC

at Ⓜ3 $M_3 = 23{,}990$ kgm, $N = 26350$ kg, $S = 0$

$d/h = 67/72 = 0.931$
$d'/h = 5/72 = 0.07$ $u/h = 0.516$
$p_0 = 28.4/7200 = 0.00394$ $u = .516 \times 72 = 37.2$
$p_0' = 0.00099$ $d-u = 29.8$ cm

$\frac{M}{N} = \frac{23990 \times 100}{26350} = 91.0$ cm
$d-u = 29.8$
$e = 120.8$ cm
$e' = e - 62 = 58.8$ "
$e'/e = 58.8/120.8 = 0.487$
$\frac{Ne}{bd^2} = \frac{26350 \times 120.8}{100 \times 67^2} = 7.100$

$b = 100$ cm, $h = 72$ cm
$d = 67$ cm, $d' = 5$ "
$A_s = 10\text{-}19^\phi = 28.4$ cm²
$A_s' = 2.5\text{-}$ " $= 7.1$ "
$p = 28.4/6700 = 0.00424$
$p' = 0.00106$
$d'/d = 5/67 = 0.075$

$k = 0.380$, $\frac{Ne}{bd^2\sigma_c} = 0.180$
$\sigma_c = 7.100 \div 0.180 = 39.5$ kg/cm²
$\sigma_s = 15 \times 39.5 \times \frac{.62}{.38} = 967$ "

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CALCULATIONS FOR

上下二段式函型隧道 断面 A5 踏土被 40米

at (H4) $M = -770$ kgm, $N = 26350$ kg, $S = 30850$ kg.

$b = 100$ cm, $h = 72$ cm, $d = 67$ ", $d' = 5$ "

$As = 7.5 - 19\phi = 21.3$ cm²

$As' = 2.5 -$ " $= 7.1$ "

$p_0 = 21.3/7200 = 0.00296$

$p_0' = 0.00099$

$e = \frac{M}{N} = \frac{770 \times 100}{26350} = 2.9$ cm

whole section under compression.

$d/h = 67/72 = 0.931$

$d'/h = 5/72 = 0.070$

$u/h = 0.511$

$u = 0.511 \times 72 = 36.8$ cm

$A_i = 100 \times 72 + 28.4 \times 15 = 7626$ cm²

$I_i = \frac{100}{3}(36.8^3 + 35.2^3) + 15 \times 21.3 \times 30.2^2 + 15 \times 7.1 \times 31.8^2$

$= 3115000 + 291000 + 108000 = 3514000$ cm⁴

$\sigma_c = \frac{26350}{7626} + \frac{26350 \times 2.9}{3514000} \times 36.8 = 3.5 + 0.8 = 4.3$ kg/cm² c

$\sigma_c' =$ " $-$ " $\times 35.2 = 3.5 - 0.8 = 2.7$ " c

$\sigma_s = 15\left(\frac{1.6 \times 67}{72} + 2.7\right) = 63$ kg/cm²

$\tau \doteqdot 30850 / 72000 = 4.3$ kg/cm²

at (H5) $M = -1060$ kgm, $N = 26350$ kg, $S = 31000$ kg.

$b = 100$, $h = 72 + \frac{40}{3} = 85$ cm, $d = 80$, $d' = 5$

$As = 7.5 - 19\phi = 21.3$ cm²

$As' = 2.5 -$ " $= 7.1$ "

$p_0 = 21.3/8500 = 0.00251$

$p_0' = 0.00084$

$e = \frac{M}{N} = \frac{1060 \times 100}{26350} = 4.0$ cm

whole section under compression.

$d/h = 80/85 = 0.941$

$d'/h = 5/85 = 0.059$

$u/h = 0.508$

$u = 0.508 \times 85 = 43.2$ cm

$A_i = 100 \times 85 + 28.4 \times 15 = 8926$ cm²

$I_i = \frac{100}{3}(43.2^3 + 41.8^3) + 15 \times 21.3 \times 36.8^2 + 15 \times 7.1 \times 38.2^2$

$= 5122000 + 433000 + 155000 = 5710000$ cm⁴

$\sigma_c = \frac{26350}{8926} + \frac{26350 \times 4.0}{5710000} \times 43.2 = 3.0 + 0.8 = 3.8$ kg/cm² c

$\sigma_c' =$ " $-$ " $\times 41.8 = 3.0 - 0.8 = 2.2$ "

$\sigma_s' = 15\left(\frac{1.6 \times 80}{85} + 2.2\right) = 55$ kg/cm² c

$\tau \doteqdot 31000 / 8500 = 3.7$ kg/cm².

at (B) $M_{BC} = -27060$ kgm, $N = 26350$ kg, $S = 44290$ kg

$b = 100$ cm, $h = 72 + \frac{70}{3} = 95$ cm, $d = 90$ ", $d' = 5$ "

$As = 10 - 16\phi = 20.1$ cm²

$As' = 2.5 - 19\phi = 7.1$

$\frac{M}{N} = \frac{27060 \times 100}{26350} = 102.7$ cm

$d - u = 41.9$

$e = 144.6$ cm

$e' = e - 85 = 59.6$ "

$e'/e = 59.6/144.6 = 0.412$

$\frac{Ne}{bd^2} = \frac{26350 \times 144.6}{100 \times 90^2} = 4.703$

$d/h = 90/95 = 0.948$

$d'/h = 5/95 = 0.053$ $u/h = 0.506$

$p_0 = 20.1/9500 = 0.00212$ $u = 0.506 \times 95 = 48.1$

$p_0' = 7.1/9500 = 0.00075$ $d - u = 41.9$ cm

$p = 20.1/9000 = 0.00223$

$p' = 7.1/9000 = 0.00079$

$d'/d = 5/90 = 0.056$

$k = 0.320$, $\frac{Ne}{bd^2\sigma_c} = 0.152$

$\sigma_c = 4.703 \div 0.152 = 31.0$ kg/cm²

$\sigma_s = 15 \times 31.0 \times \frac{.68}{.32} = 988$ "

$\tau = \frac{44290}{100 \times .893 \times 90} = 5.5$ "

$\tau_0 = \frac{44290}{50.3 \times .893 \times 90} = 10.9$ "

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CALCULATIONS FOR

上下二段式函型隧 断面A5 殆土被40米

at © $M_{CB} = -32030$ kgm, $N = 26350$ kg, $S = 46390$ kg

$b = 100$ cm, $h = 72 + \frac{120}{3} = 112$ cm
$d = 107$ cm, $d' = 5$ cm
$A_s = 10-19\phi = 28.4$ cm²
$A_s' = 2.5-$ 〃 $= 7.1$ 〃
$p = 28.4/10700 = 0.00266$
$p' = 7.1/$ 〃 $= 0.00066$
$d'/d = 5/107 = 0.047$

$d/h = 107/112 = 0.960$
$d'/h = 5/112 = 0.045$ $u/h = 0.509$
$p_0 = 28.4/11200 = 0.00254$ $u = 0.509 \times 112 = 57.0$
$p_0' = 7.1/$ 〃 $= 0.00063$ $d-u = 50.0$ cm

$\frac{M}{N} = \frac{32030 \times 100}{26350} = 121.6$ cm
$d-u = 50.0$
$e = 171.6$ cm
$e' = e - 102 = 69.6$ 〃
$e'/e = 69.6/171.6 = 0.406$
$\frac{Ne}{bd^2} = \frac{26350 \times 171.6}{100 \times 107^2} = 3.950$
$k = 0.340$, $\frac{Ne}{bd^2\sigma_c} = 0.162$

$\sigma_c = 3.950 \div .162 = 24.4$ kg/cm²
$\sigma_s = 15 \times 24.4 \times \frac{.66}{.34} = 711$ 〃
$\tau = \frac{46390}{100 \times .887 \times 107} = 4.9$ 〃
$\tau_0 = \frac{46390}{59.7 \times .887 \times 107} = 8.2$ 〃

Side wall AB.

at (M_2) $M_2 = 8460$ kgm, $N = 44290$ kg, $S = 0$

$b = 100$ cm, $h = 60$ cm
$d = 55$ cm, $d' = 5$ 〃
$A_s = 10-16\phi = 20.1$ cm²
$A_s' = 2.5-$ 〃 $= 5.0$ 〃
$p = 20.1/5500 = 0.00365$
$p' = 5.0/5500 = 0.00091$
$d'/d = 5/55 = 0.091$

$d/h = 55/60 = 0.917$
$d'/h = 5/60 = 0.083$ $u/h = 0.512$
$p_0 = 20.1/6000 = 0.00335$ $u = 0.512 \times 60 = 30.7$ cm
$p_0' = 5.0/6000 = 0.00083$ $d-u = 24.3$ 〃

$\frac{M}{N} = \frac{8460 \times 100}{44290} = 19.1$ cm
$d-u = 24.3$ 〃
$e = 43.4$ 〃
$e' = 50 - e = 6.6$
$e'/e = 6.6/43.4 = 0.152$
$\frac{Ne}{bd^2} = \frac{44290 \times 43.4}{100 \times 55^2} = 6.355$
$k = 0.750$, $\frac{Ne}{bd^2\sigma_c} = 0.293$

$\sigma_c = 6.355 \div 0.293 = 21.7$ kg/cm²
$\sigma_s = 15 \times 21.7 \times \frac{.25}{.75} = 109$ 〃

at (H_2) $M = -6000$ kgm, $N = 44290$ kg, $S = 18990$ kg

Section same as for M_2

$\frac{M}{N} = \frac{6000 \times 100}{44290} = 13.6$ cm
$d-u = 24.3$
$e = 37.9$ cm
$e' = 50 - e = 12.1$ 〃
$e'/e = 12.1/37.9 = 0.320$
$\frac{Ne}{bd^2} = \frac{44290 \times 37.9}{100 \times 55^2} = 5.550$
$k = 0.940$, $\frac{Ne}{bd^2\sigma_c} = 0.335$

$\sigma_c = 5.550 \div 0.335 = 16.6$ kg/cm²
$\sigma_s = 15 \times 16.6 \times \frac{.06}{.94} = 16$ 〃
$\tau = \frac{18990}{100 \times .687 \times 55} = 5.0$ 〃
$\tau_0 = \frac{18990}{50.3 \times .687 \times 55} = 10.0$ 〃

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CALCULATIONS FOR

上下二段式函型隧道 断面As錐 土被40米

at (H3) $M = -9670$ kgm, $N = 44290$ kg, $S = 19290$ kg

$\frac{M}{N} = \frac{9670 \times 100}{44290} = 21.9$ cm

Same section as for M_2

$d-u = 24.3$

$e = 46.2$ cm

$e' = 50 - e = 3.8$ 〃

$e'/e = 3.8/46.2 = 0.082$

$\frac{Ne}{bd^2} = \frac{44290 \times 46.2}{100 \times 55^2} = 6.765$

$k = 0.680$, $\frac{Ne}{bd^2\sigma_c} = 0.274$

$\sigma_c = 6.765 \div 0.274 = 24.7$ kg/cm²

$\sigma_s = 15 \times 24.7 \times \frac{.32}{.68} = 175$ 〃

$\tau = \frac{19290}{100 \times .773 \times 55} = 4.5$ 〃

$\tau_0 = \frac{19290}{50.3 \times .773 \times 55} = 9.0$ 〃

at (A) $M_{AB} = -27580$ kgm, $N = 44290$ kg, $S = 30650$ kg

$b = 100$ cm, $h = 60 + \frac{87}{3} = 89$ cm

$d = 84$ cm, $d' = 5$ cm.

$A_s = 10 - 16^\phi = 20.1$ cm²

$A_s' = 2.5 - 19^\phi = 7.1$ 〃

$p = 20.1/8400 = 0.00239$

$p' = 7.1/$ 〃 $= 0.00085$

$d'/d = 5/84 = 0.06$

$d/h = 84/89 = 0.944$

$d'/h = 5/89 = 0.056$ $u/h = 0.507$

$p_0 = 20.1/8900 = 0.00226$ $u = 0.507 \times 89 = 45.1$ cm

$p_0' = 7.1/8900 = 0.00080$ $d-u = 38.9$ 〃

$\frac{M}{N} = \frac{27580 \times 100}{44290} = 62.2$ cm

$d-u = 38.9$

$e = 101.1$ cm

$e' = e - 79 = 22.1$

$e'/e = 22.1/101.1 = 0.219$

$\frac{Ne}{bd^2} = \frac{44290 \times 101.1}{100 \times 84^2} = 6.340$

$k = 0.395$, $\frac{Ne}{bd^2\sigma_c} = 0.182$

$\sigma_c = 6.340 \div 0.182 = 34.9$ kg/cm²

$\sigma_s = 15 \times 34.9 \times \frac{.605}{.395} = 803$ 〃

$\tau = \frac{30650}{100 \times .868 \times 84} = 4.2$ 〃

$\tau_0 = \frac{30650}{50.3 \times .868 \times 84} = 8.4$ 〃

at (B) $M_{BA} = -27060$ kgm, $N = 44290$ kg, $S = 26350$ kg

$b = 100$ cm, $h = 60 + \frac{76}{3} = 85$ cm

$d = 80$ cm, $d' = 5$ cm.

$A_s = 10 - 16^\phi = 20.1$ cm²

$A_s' = 2.5 - 19^\phi = 7.1$ 〃

$p = 20.1/8000 = 0.00251$

$p' = 7.1/8000 = 0.00089$

$d'/d = 5/80 = 0.063$

$d/h = 80/85 = 0.941$

$d'/h = 5/85 = 0.059$ $u/h = 0.508$

$p_0 = 20.1/8500 = 0.00237$ $u = 0.508 \times 85 = 43.2$ cm

$p_0' = 7.1/8500 = 0.00084$ $d-u = 36.8$ 〃

$\frac{M}{N} = \frac{27060 \times 100}{44290} = 61.2$ cm

$d-u = 36.8$

$e = 98.0$ cm

$e' = e - 75 = 23.0$ 〃

$e'/e = 23/98 = 0.235$

$\frac{Ne}{bd^2} = \frac{44290 \times 98}{100 \times 80^2} = 6.782$

$k = 0.395$, $\frac{Ne}{bd^2\sigma_c} = 0.182$

$\sigma_c = 6.782 \div 0.182 = 37.3$ kg/cm²

$\sigma_s = 15 \times 37.3 \times \frac{.605}{.395} = 858$ 〃

$\tau = \frac{26350}{100 \times .868 \times 80} = 3.8$ 〃

$\tau_0 = \frac{26350}{50.3 \times .868 \times 80} = 7.5$ 〃

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CALCULATIONS FOR

上下二段式函型隧道 断面 A5號 土被4.0米

Wall C.G.

at (M8) $M_8 = 9050$ kgm, $N = 39400$ kg, $S = 0$ — Same section as for M_2

$\frac{M}{N} = \frac{9050 \times 100}{39400} = 23.0$ cm

d-u = 24.3

e = 47.3 cm

$e' = 50 - e = 2.7$ ″

$e'/e = 2.7/47.3 = 0.057$

$\frac{Ne}{bd^2} = \frac{39400 \times 47.3}{100 \times 55^2} = 6.165$

$k = 0.650$, $\frac{Ne}{bd^2\sigma_c} = 0.266$

$\sigma_c = 6.165 \div 0.266 = 23.2$ kg/cm²

$\sigma_s = 15 \times 23.2 \times \frac{.35}{.65} = 188$ ″

at (H14) $M = -8550$ kgm, $N = 39400$ kg, $S = 19040$ kg — Same section as for M_2

$\frac{M}{N} = \frac{8550 \times 100}{39400} = 21.7$ cm

d-u = 24.3

e = 46.0 cm

$e' = 50 - e = 4.0$ ″

$e'/e = 4.0/46.0 = 0.087$

$\frac{Ne}{bd^2} = \frac{39400 \times 46.0}{100 \times 55^2} = 5.995$

$k = 0.69$, $\frac{Ne}{bd^2\sigma_c} = 0.278$

$\sigma_c = 5.995 \div 0.278 = 21.6$ kg/cm²

$\sigma_s = 15 \times 21.6 \times \frac{.31}{.69} = 146$ ″

$\tau = \frac{19040}{100 \times 0.77 \times 55} = 4.5$ ″

$\tau_0 = \frac{19040}{50.3 \times .770 \times 55} = 8.9$ ″

at (H15) $M = -5690$ kgm, $N = 39400$ kg, $S = 19240$ kg — Same section as for M_2

$\frac{M}{N} = \frac{5690 \times 100}{39400} = 14.4$ cm

d-u = 24.3

e = 38.7 cm

$e' = 50 - e = 11.3$ ″

$e'/e = 11.3/38.7 = 0.292$

$\frac{Ne}{bd^2} = \frac{39400 \times 38.7}{100 \times 55^2} = 5.045$

$k = 0.920$, $\frac{Ne}{bd^2\sigma_c} = 0.321$

$\sigma_c = 5.045 \div 0.321 = 15.7$ kg/cm²

$\sigma_s = 15 \times 15.7 \times \frac{.08}{.92} = 21$ ″

$\tau = \frac{19240}{100 \times .693 \times 55} = 5.1$ ″

$\tau_0 = \frac{19240}{50.3 \times .693 \times 55} = 10.0$ ″

上下二段式函型隧道 断面 A5號 土被40米

at (G) $M_{GC} = -27490$ kgm, $N = 39400$ kg, $S = 30900$ kg.

same section as for M_{AB} see on page

$\frac{M}{N} = \frac{27490 \times 100}{39400} = 69.8$ cm

$d-u = 38.9$

$e = 108.7$ cm

$e' = e - 79 = 29.7$ "

$e'/e = 29.7/108.7 = 0.273$

$\frac{Ne}{bd^2} = \frac{39400 \times 108.7}{100 \times 84^2} = 6.070$

$k = 0.370$, $\frac{Ne}{bd^2 \sigma_c} = 0.173$

$\sigma_c = 6.07 \div 0.173 = 35.1$ kg/cm²

$\sigma_s = 15 \times 35.1 \times \frac{.63}{.37} = 896$ "

$\tau = \frac{30900}{100 \times .877 \times 84} = 4.2$ "

$\tau_o = \frac{30900}{50.3 \times .877 \times 84} = 8.4$ "

at (C) $M_{CG} = -25750$ kgm, $N = 39400$ kg, $S = 26100$ kg

$b = 100$ cm, $h = 60 + \frac{76}{3} = 85$ cm

$d = 80$ cm, $d' = 5$ cm

$A_s = 10-16\phi = 20.1$ cm²

$A_s' = 2.5-19\phi = 7.1$ "

$p = 20.1/8000 = 0.00251$

$p' = 7.1/8000 = 0.00089$

$d'/d = 5/80 = 0.063$

$d/h = 80/85 = 0.941$

$d'/h = 5/85 = 0.059$ $u/h = 0.508$

$p_o = 20.1/8500 = 0.00236$ $u = 0.508 \times 85 = 43.2$ cm

$p_o' = 7.1/8500 = 0.00084$ $d-u = 36.8$

$\frac{M}{N} = \frac{25750 \times 100}{39400} = 65.4$ cm

$d-u = 36.8$

$e = 102.2$ cm

$e' = e - 75 = 27.2$ "

$e'/e = 27.2/102.2 = 0.266$

$\frac{Ne}{bd^2} = \frac{39400 \times 102.2}{100 \times 80^2} = 6.290$

$k = 0.385$, $\frac{Ne}{bd^2 \sigma_c} = 0.177$

$\sigma_c = 6.290 \div 0.177 = 35.5$ kg/cm²

$\sigma_s = 15 \times 35.5 \times \frac{.615}{.385} = 851$ "

$\tau = \frac{26100}{100 \times .872 \times 80} = 3.7$ "

$\tau_o = \frac{26100}{50.3 \times .872 \times 80} = 7.4$ "

Bottom slab CF

at (M_7) $M_7 = 9830$ kgm, $N = 18290$ kg, $S = 0$

$b = 100$ cm, $h = 60$ cm

$d = 55$ ", $d' = 5$ "

section same as for M_F see on page 159

$\frac{M}{N} = \frac{9830 \times 100}{18290} = 53.8$ cm

$d-u = 24.3$

$e = 78.1$ cm

$e' = e - 50 = 28.1$ "

$e'/e = 28.1/78.1 = 0.360$

$\frac{Ne}{bd^2} = \frac{18290 \times 78.1}{100 \times 55^2} = 4.720$

$k = 0.400$, $\frac{Ne}{bd^2 \sigma_c} = 0.185$

$\sigma_c = 4.720 \div .185 = 25.6$ kg/cm²

$\sigma_s = 15 \times 25.6 \times \frac{.6}{.4} = 576$ "

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CALCULATIONS FOR

上下二段式函型隧断面 A5弾 土被4.0米

at (H12) $M = -3370$ kgm, $N = 18290$ kg, $S = 15380$ kg.

$d/h = 55/60 = 0.917$
$d'/h = 5/60 = 0.083$ $u/h = 0.507$
$p_0 = 15.1/6000 = 0.00252$ $u = 0.507 \times 60 = 30.4$ cm
$p_0' = 5.0/6000 = 0.00083$ $d-u = 24.6$

$\frac{M}{N} = \frac{3370 \times 100}{18290} = 18.5$ cm
$d-u = 24.6$
$e = 43.1$ cm
$e' = 50 - e = 6.9$
$e'/e = 6.9/43.1 = 0.160$
$\frac{Ne}{bd^2} = \frac{18290 \times 43.1}{100 \times 55^2} = 2.605$
$k = 0.730$, $\frac{Ne}{bd^2 \sigma_c} = 0.289$

$b = 100$ cm, $h = 60$ cm
$d = 55$", $d' = 5$"
$A_s = 7.5 - 16^\phi = 15.1$ cm²
$A_s' = 2.5 - 16^\phi = 5.0$
$p = 15.1/5500 = 0.00274$
$p' = 5.0/$ 〃 $= 0.00091$
$d'/d = 5/55 = 0.091$

$\sigma_c = 2.605 / 0.289 = 9.0$ kg/cm²
$\sigma_s = 15 \times 9.0 \times \frac{.27}{.73} = 50$ 〃
$\tau = \frac{15380}{100 \times .757 \times 55} = 3.7$ 〃
$\tau_0 = \frac{15380}{5.03 \times 7.5 \times .757 \times 55} = 9.8$ 〃

at (H13) $M = 2330$ kgm $N = 18290$ kg $S = 11500$ kg

$\frac{M}{N} = \frac{2330 \times 100}{18290} = 12.8$ cm
$d-u = 24.6$
$e = 37.4$ cm
$e' = 50 - e = 12.6$
$e'/e = 12.6/37.4 = 0.337$
$\frac{Ne}{bd^2} = \frac{18290 \times 37.4}{100 \times 55^2} = 2.260$
$k = 0.710$, $\frac{Ne}{bd^2 \sigma_c} = 0.282$

Same section as above

$\sigma_c = 2.260 \div 0.282 = 8.0$ kg/cm²
$\sigma_s = 15 \times 8.0 \times \frac{.29}{.71} = 49$ 〃
$\tau = \frac{11500}{100 \times .763 \times 55} = 2.7$ 〃
$\tau_0 = \frac{11500}{5.03 \times 7.5 \times .763 \times 55} = 7.3$ 〃

at (C) $M_{CF} = -9470$ kgm, $N = 18290$ kg. $S = 22360$ kg.

$d/h = 0.938$
$d'/h = 0.063$ $u/h = 0.505$
$p_0 = 0.00189$ $u = 40.4$ cm
$p_0' = 0.00063$ $d-u = 34.6$

$\frac{M}{N} = \frac{9470 \times 100}{18290} = 51.8$
$d-u = 34.6$
$e = 86.4$ cm
$e' = e - 70 = 16.4$
$e'/e = 16.4/86.4 = 0.190$
$\frac{Ne}{bd^2} = \frac{18290 \times 86.4}{100 \times 75^2} = 2.810$
$k = 0.390$, $\frac{Ne}{bd^2 \sigma_c} = 0.180$

$b = 100$ cm, $h = 60 + \frac{62}{3} = 80$ cm
$d = 75$ cm, 5 cm
$A_s = 7.5 - 16^\phi = 15.1$ cm²
$A_s' = 2.5 -$ 〃 $= 5.0$ 〃
$p = 15.1/7500 = 0.00201$
$p' = 0.00067$
$d'/d = 0.067$

$\sigma_c = 2.810 \div 0.180 = 15.6$ kg/cm²
$\sigma_s = 15 \times 15.6 \times \frac{.61}{.39} = 366$ 〃
$\tau = \frac{22360}{100 \times .87 \times 75} = 3.4$ 〃
$\tau_0 = \frac{22360}{5.03 \times 7.5 \times .87 \times 75} = 9.1$ 〃

上下二段式函型隧道 断面 As 鉄土被 40米

at (F) $M_{FC} = -14370$ kgm, $N = 18290$ kg, $S = 19990$ kg

$b = 100$ cm, $h = 60 + \frac{62}{3} = 80$ cm
$d = 75$ cm, $d' = 5$ cm
$A_s = 10-16^\phi = 20.1$ cm²
$A_s' = 2.5-16^\phi = 5.0$ "
$p = 0.00268$
$p' = 0.00067$
$d'/d = 0.067$

$d/h = 0.938$
$d'/h = 0.063$ $u/h = 0.507$
$p_0 = 0.00251$ $u = 40.6$ cm
$p_0' = 0.00063$ $d-u = 34.4$ "

$\frac{M}{N} = \frac{14370 \times 100}{18290} = 78.6$ cm
$d-u = 34.4$
$e = 113.0$ cm
$e' = e - 70 = 43.0$ "
$e'/e = 43/113 = 0.381$
$\frac{Ne}{bd^2} = \frac{18290 \times 113}{100 \times 75^2} = 3.673$
$k = 0.350$, $\frac{Ne}{bd^2\sigma_c} = 0.164$

$\sigma_c = 3.673 \div 0.164 = 22.4$ kg/cm²
$\sigma_s = 15 \times 22.4 \times \frac{.65}{.35} = 624$ "
$\tau = \frac{19990}{100 \times .883 \times 75} = 3.0$ "
$\tau_0 = \frac{19990}{50.3 \times .883 \times 75} = 6.0$ "

Top slab DE
at (M5) $M_5 = 6770$ kgm, $N = 13350$ kg, $S = 0$

$\frac{M}{N} = \frac{6770 \times 100}{13350} = 50.7$ cm
$d-u = 17.3$ -- see on page 137
$e = 68.0$ cm
$e' = e - 36 = 32.0$ "
$e'/e = 32/68 = 0.471$
$\frac{Ne}{bd^2} = \frac{13350 \times 68.0}{100 \times 41^2} = 5.400$
$k = 0.415$, $\frac{Ne}{bd^2\sigma_c} = 0.191$

$\sigma_c = 5.400 \div .191 = 28.3$ kg/cm²
$\sigma_s = 15 \times 28.3 \times \frac{.585}{.415} = 598$ "

at (H8) $M = -2090$ kgm, $N = 13350$ kg, $S = 12710$ kg

$\frac{M}{N} = \frac{2090 \times 100}{13350} = 15.7$ cm
$d-u = 17.5$ " -- see on page 137
$e = 33.2$ cm
$e' = 36 - e = 2.8$ "
$e'/e = 2.8/33.2 = 0.0843$
$\frac{Ne}{bd^2} = \frac{13350 \times 33.2}{100 \times 41^2} = 2.640$
$k = 0.720$ $\frac{Ne}{bd^2\sigma_c} = 0.299$

$\sigma_c = 2.640 \div 0.299 = 8.8$ kg/cm²
$\sigma_s = 15 \times 8.8 \times \frac{.28}{.72} = 51$ "
$\tau = \frac{12710}{100 \times 0.76 \times 41} = 4.1$ "
$\tau_0 = \frac{12710}{5.03 \times 7.5 \times .76 \times 41} = 10.8$ "

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CALCULATIONS FOR

上下二段式函型隧道 断面A5端 土被40米

at (Ha) $M=-2460$ kgm, $N=13350$ kg, $S=12950$ kg

$\frac{M}{N}=\frac{2460\times100}{13350}=18.4$ cm

$d-u = 17.5$ — see page 138

$e = 35.9$ cm

$e'=36-e = 0.1$ cm

$e'/e = 0.1/35.9 = 0.003$

$\frac{Ne}{bd^2}=\frac{13350\times35.9}{100\times41^2}=2.850$

$k=0.630$, $\frac{Ne}{bd^2\sigma_c}=0.263$

$\sigma_c = 2.850\div0.263 = 10.8$ kg/cm²

$\sigma_s = 15\times10.8\times\frac{.37}{.63} = 96$ 〃

$\tau=\frac{12950}{100\times.790\times41} = 4.0$ 〃

$\tau_0=\frac{12950}{5.03\times7.5\times.790\times41} = 10.6$ 〃

at (D) $M_{DE}=-11710$ kgm, $N=13350$ kg, $S=18350$ kg.

$\frac{M}{N}=\frac{11710\times100}{13350}=87.8$ cm

$d-u = 27.1$ — see on page 138

$e = 114.9$ cm

$e'=e-56 = 58.9$ 〃

$e'/e = 58.9/114.9 = 0.512$

$\frac{Ne}{bd^2}=\frac{13350\times114.9}{100\times61^2}=4.120$

$k=0.35$, $\frac{Ne}{bd^2\sigma_c}=0.165$

$\sigma_c = 4.120\div0.165 = 25.0$ kg/cm²

$\sigma_s = 15\times25.0\times\frac{.65}{.35} = 697$ 〃

$\tau=\frac{18350}{100\times.883\times61} = 3.4$ 〃

$\tau_0=\frac{18350}{50.3\times.883\times61} = 6.8$ 〃

at (E) $M_{ED}=-12220$ kgm, $N=13350$ kg, $S=18610$ kg

$\frac{M}{N}=\frac{12220\times100}{13350}=91.5$ cm

$d-u = 27.1$ ← See on page 138

$e = 118.6$ cm

$e'=e-56 = 62.6$ 〃

$e'/e = 62.6/118.6 = 0.524$

$\frac{Ne}{bd^2}=\frac{13350\times118.6}{100\times61^2}=4.250$

$k=0.340$, $\frac{Ne}{bd^2\sigma_c}=0.161$

$\sigma_c = 4.250\div0.161 = 26.4$ kg/cm²

$\sigma_s = 15\times26.4\times\frac{.66}{.34} = 769$ 〃

$\tau=\frac{18610}{100\times.887\times61} = 3.4$ 〃

$\tau_0=\frac{18610}{50.3\times.887\times61} = 6.8$ 〃

上下二段式函型隧道 断面A5號 土被40米

wall co

at (M4) $M_4 = 5660$ kgm, $N = 18350$ kg, $S = 0$.

$\frac{M}{N} = \frac{5660 \times 100}{18350} = 30.9$ cm

$d-u = 16.3$ --- See on page 139.

$e = 47.2$ cm

$e' = e - 34 = 13.2$ "

$e'/e = 13.2/47.2 = 0.280$

$\frac{Ne}{bd^2} = \frac{18350 \times 47.2}{100 \times 39^2} = 5.695$

$k = 0.490$, $\frac{Ne}{bd^2\sigma_c} = 0.219$

$\sigma_c = 5.695/0.219 = 26.1$ kg/cm²

$\sigma_s = 15 \times 26.1 \times \frac{.51}{.49} = 407$ "

at (H6) $M = -4060$ kgm, $N = 18350$ kg, $S = 12200$ kg

$\frac{M}{N} = \frac{4060 \times 100}{18350} = 22.2$ cm

$d-u = 16.3$ --- See on page 139

$e = 38.5$ cm

$e' = e - 34 = 4.5$ "

$e'/e = 4.5/38.5 = 0.117$

$\frac{Ne}{bd^2} = \frac{18350 \times 38.5}{100 \times 39^2} = 4.645$

$k = 0.580$, $\frac{Ne}{bd^2\sigma_c} = 0.249$

$\sigma_c = 4.645 \div 0.249 = 18.7$ kg/cm²

$\sigma_s = 15 \times 18.7 \times \frac{.42}{.58} = 203$ "

$\tau = \frac{12200}{100 \times .807 \times 39} = 3.9$ "

$\tau_0 = \frac{12200}{50.3 \times .807 \times 39} = 7.7$ "

at (H7) $M = -4280$ kgm, $N = 18350$ kg, $S = 10340$ kg

$\frac{M}{N} = \frac{4280 \times 100}{18350} = 23.4$ cm

$d-u = 16.3$ --- See on page 139

$e = 39.7$ cm

$e' = e - 34 = 5.7$ "

$e'/e = 5.7/39.7 = 0.144$

$\frac{Ne}{bd^2} = \frac{18350 \times 39.7}{100 \times 39^2} = 4.790$

$k = 0.560$, $\frac{Ne}{bd^2\sigma_c} = 0.243$

$\sigma_c = 4.790 \div 0.243 = 19.7$ kg/cm²

$\sigma_s = 15 \times 19.7 \times \frac{.44}{.56} = 232$ "

$\tau = \frac{10340}{100 \times .813 \times 39} = 3.3$ "

$\tau_0 = \frac{10340}{50.3 \times .813 \times 39} = 6.5$ "

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CALCULATIONS FOR

上下二段式函型隧道,断面A5 鉄土被40米

at Ⓒ $M_{CD} = -15,760$ kgm, $N = 18350$ kg, $S = 18680$ kg

$b = 100$ cm, $h = 44 + \frac{76}{3} = 69$ cm
$d = 64$, $d' = 5$ cm
$A_s = 10 - 16^{\phi} = 20.1$ cm²
$A_s' = 2.5 - 4 = 5.0$ "
$p = 20.1/6400 = 0.00314$
$p' = 5.0/6400 = 0.00078$
$d'/d = 5/64 = 0.078$

$d/h = 64/69 = 0.928$
$d'/h = 5/69 = .073$
$p_0 = 20.1/6900 = 0.00291$
$p_0' = 5.0/6900 = 0.00073$

$u/h = 0.511$
$u = 0.511 \times 69 = 35.2$ cm
$d - u = 28.8$ "

$\frac{M}{N} = \frac{15760 \times 100}{18350} = 86.0$ cm
$d - u = 28.8$
$e = 114.8$ cm
$e' = e - 59 = 55.8$ "
$e'/e = 55.8/114.8 = 0.486$ "
$\frac{Ne}{bd^2} = \frac{18350 \times 114.8}{100 \times 64^2} = 5.150$
$k = 0.340$, $\frac{Ne}{bd^2 \sigma_c} = 0.166$

$\sigma_c = 5.150 \div 0.166 = 31.1$ kg/cm²
$\sigma_s = 15 \times 31.1 \times \frac{.66}{.34} = 905$ "
$\tau = \frac{18680}{100 \times .887 \times 64} = 3.3$ "
$\tau_0 = \frac{18680}{50.3 \times .887 \times 64} = 6.6$ "

at Ⓓ $M_{DC} = -11,710$ kgm, $N = 18350$ kg, $S = 13150$ kg

For section, see on page 140

$\frac{M}{N} = \frac{11710 \times 100}{18350} = 63.8$ cm
$d - u = 26.6$
$e = 90.4$ cm
$e' = e - 55 = 35.4$
$e'/e = 35.4/90.4 = 0.392$
$\frac{Ne}{bd^2} = \frac{18350 \times 90.4}{100 \times 60^2} = 4.605$
$k = 0.380$ $\frac{Ne}{bd^2 \sigma_c} = 0.176$

$\sigma_c = 4.605 \div 0.176 = 26.2$ kg/cm²
$\sigma_s = 15 \times 26.2 \times \frac{.62}{.38} = 641$ "
$\tau = \frac{13150}{100 \times .873 \times 60} = 2.5$ "
$\tau_0 = \frac{13150}{50.3 \times .873 \times 60} = 5.0$ "

wall EF

at Ⓜ6 $M_6 = 6110$ kgm, $N = 18610$ kg, $S = 0$

~~for section,~~ see on page 140

$\frac{M}{N} = \frac{6110 \times 100}{18610} = 32.8$ cm
$d - u = 16.3$
$e = 49.1$ cm
$e' = e - 34 = 15.1$ "
$e'/e = 15.1/49.1 = 0.308$
$\frac{Ne}{bd^2} = \frac{18610 \times 49.1}{100 \times 39^2} = 6.01$
$k = .480$, $\frac{Ne}{bd^2 \sigma_c} = .215$

$\sigma_c = 6.01 \div 0.215 = 28.0$ kg/cm²
$\sigma_s = 15 \times 28.0 \times \frac{.52}{.48} = 455$ "

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CALCULATIONS FOR

上下二段式函型隧道，断面A5號 土被40米

at (H10) $M = -4540$ kgm, $N = 18610$ kg, $S = 10730$ kg

$\frac{M}{N} = \frac{4540\times100}{18610} = 24.4$ cm

For section, see on page 139.

$d-u = 16.3$

$e = 40.7$ cm

$e' = e - 34 = 6.7$ "

$e'/e = 6.7/40.7 = 0.165$

$\frac{Ne}{bd^2} = \frac{18610\times40.7}{100\times39^2} = 4.980$

$k = 0.56$, $\frac{Ne}{bd^2\sigma_c} = 0.242$

$\sigma_c = 4.980 \div 0.242 = 20.6$ kg/cm²

$\sigma_s = 15\times20.6\times\frac{.44}{.56} = 243$ "

$\tau = \frac{10730}{100\times.813\times39} = 3.4$ "

$\tau_0 = \frac{10730}{50.3\times.813\times39} = 6.7$ "

at (H11) $M = -2950$ kgm, $N = 18610$ kg, $S = 11810$ kg

$\frac{M}{N} = \frac{2950\times100}{18610} = 15.9$ cm

$d-u = 16.3$ ← See on page 139 M4

$e = 32.2$ cm

$e' = 34 - e = 1.8$ "

$e'/e = 1.8/32.2 = 0.056$

$\frac{Ne}{bd^2} = \frac{18610\times32.2}{100\times39^2} = 3.940$

$k = 0.73$; $\frac{Ne}{bd^2\sigma_c} = 0.292$

$\sigma_c = 394/0.292 = 13.5$ kg/cm²

$\sigma_s = 15\times13.5\times\frac{.27}{.73} = 75$ "

$\tau = \frac{11810}{100\times.757\times39} = 4.0$ "

$\tau_0 = \frac{11810}{50.3\times.757\times39} = 8.0$ "

at (E) $M_{EF} = -12220$ kgm , $N = 18610$ kg, $S = 13540$ kg

For section see on page 140 (D)

$\frac{M}{N} = \frac{12220\times100}{18610} = 65.7$ cm

$d-u = 26.6$

$e = 92.3$ cm

$e' = e - 55 = 37.3$ "

$e'/e = 37.3/92.3 = 0.404$

$\frac{Ne}{bd^2} = \frac{18610\times92.3}{100\times60^2} = 4.770$

$k = .380$, $\frac{Ne}{bd^2\sigma_c} = .177$

$\sigma_c = 4.770 \div 0.177 = 27.0$ kg/cm²

$\sigma_s = 15\times27.0\times\frac{.62}{.38} = 661.$ "

$\tau = \frac{13540}{100\times.873\times60} = 2.6$ "

$\tau_0 = \frac{13540}{50.3\times.873\times60} = 5.2$ "

上下二段式函型隧道 断面A5號 土被4.0米

at (F) $M_{FE} = -14370$ kgm, $N = 18610$ kg, $S = 18290$ kg

for section see on page 167 (MCD)

$\frac{M}{N} = \frac{14370 \times 100}{18610} = 77.2$ cm

$d-u = 28.8$

$e = 106.0$ cm

$e' = e - 59 = 47.0$

$e'/e = 47.0/106.0 = 0.444$

$\frac{Ne}{bd^2} = \frac{18610 \times 106.0}{100 \times 64^2} = 4.82$

$k = 0.360$, $\frac{Ne}{bd^2 \sigma_c} = .167$

$\sigma_c = 4.82 \div .167 = 28.9$ kg/cm²

$\sigma_s = 15 \times 28.9 \times \frac{.164}{.36} = 771$ 〃

$\tau = \frac{18290}{100 \times .880 \times 64} = 3.3$ 〃

$\tau_0 = \frac{18290}{50.3 \times .880 \times 64} = 6.5$ 〃

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CALCULATIONS FOR

上下二段式函型隧道 断面A5號 土被4.0米

鐵筋混凝土上下二段式函型隧道 断面A5號 土被四.0米　　其二

上下二段式函型隧道 應力度表
断面A5號ー 土被4.0米

	位置	下床(AG)			上床(BC)					側壁(AB)				側壁(CG)				
寸法	應力	H_1	M_1	H_{16}	B	H_4	M_3	H_5	C	A	H_2	M_2	H_3	G	H_{15}	M_8	H_{14}	C
断	b (cm)	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
	h (cm)	74	74	74	95	72	72	85	112	89	60	60	60	89	60	60	60	85
	d (cm)	69	69	69	90	67	67	80	107	84	55	55	55	84	55	55	55	80
	d' (cm)	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5
面	As (cm²)	21.3	28.4	21.3	20.1	21.3	28.4	21.3	28.4	20.1	20.1	20.1	20.1	20.1	20.1	20.1	20.1	20.1
	As' (cm²)	7.1	7.1	7.1	7.1	7.1	7.1	7.1	7.1	7.1	5.0	5.0	5.0	5.0	5.0	5.0	5.0	7.1
應	M (kgm)	2180	22860	590	27060	770	23990	1060	32030	27580	6000	8460	9670	27440	5690	9050	8550	25750
	N (kg)	30780	30780	30780	26350	26350	26350	26350	26350	44290	44290	44290	44290	39400	39400	39400	39400	39400
力	S (kg)	28700	0	27670	44290	30850	0	31000	46390	30780	18990	0	19290	30780	19240	0	19040	26100
應	σc (kg/cm²)	6.1	36.1	4.5	31.0	4.3	39.5	3.8	24.4	34.9	16.6	21.7	24.7	35.1	15.7	23.2	21.6	35.5
力	σs (kg/cm²)	87	796	66	988	63	967	55	711	803	16	109	175	896	21	188	146	851
度	τ (kg/cm²)	3.9	—	3.7	5.5	4.3	—	3.7	4.9	4.2	5.0	—	4.5	4.2	5.1	—	4.5	3.7
	τ₀ (kg/cm²)		—		10.9		—		8.2	8.4	10.0	—	9.0	8.4	10.0	—	8.9	7.4

	位置	下床(CF)				上床(DE)					側壁(CD)				側壁(EF)			
寸法	應力	C	H_{13}	M_7	H_{12}	D	H_8	M_5	H_9	E	C	H_6	M_4	H_7	H_{10}	M_6	H_{11}	F
断	b (cm)	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
	h (cm)	80	60	60	60	66	46	46	46	66	69	44	44	44	44	44	44	69
	d (cm)	75	55	55	55	61	41	41	41	61	64	39	39	39	39	39	39	64
	d' (cm)	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5
面	As (cm²)	15.1	15.1	20.1	15.1	20.1	15.1	20.1	15.1	20.1	20.1	20.1	20.1	20.1	20.1	20.1	20.1	20.1
	As' (cm²)	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0
應	M (kgm)	9470	2330	9830	3370	11710	2090	6770	2460	12220	15760	4060	5660	4280	4540	6110	2950	14370
	N (kg)	18290	18290	18290	18290	13350	13350	13350	13350	13350	18350	18350	18350	18350	18610	18610	18610	18610
力	S (kg)	22360	11500	0	15380	18350	12710	0	12950	18610	18680	12200	0	10340	10730	0	11810	18290
應	σc (kg/cm²)	15.6	8.0	25.6	9.0	25.0	8.8	28.3	10.8	26.4	31.1	18.7	26.1	19.7	20.6	28.0	13.5	28.9
力	σs (kg/cm²)	366	49	576	50	697	51	598	96	769	905	203	407	232	243	455	75	771
度	τ (kg/cm²)	3.4	2.7	—	3.7	3.4	4.1	—	4.0	3.4	3.3	3.9	—	3.3	3.4	—	4.0	3.3
	τ₀ (kg/cm²)	9.1	7.3	—	9.8	6.8	10.8	—	10.6	6.8	6.6	7.7	—	6.5	6.7	—	8.0	6.5

(9)

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MADE BY K. I. DATE 10-6-19 **FILE NO** 9
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CALCULATIONS FOR

巨型鐵構框

For positive moment. $m = 4160$ kgm per meter strip of slab.

Effective depth required $= 0.362\sqrt{\frac{4160\times100}{100}} = 23.35$ cm

Use 26 cm effective depth an insulation of 4 cm, total depth = 30 cm

Steel area required $= \frac{4160\times100}{1200\times\frac{7}{8}\times26} = 15.25$ cm²

Use 16mmϕ bars at 12.5 cm ctoc = 8@2.011 = 16.1 cm²

Steel ratio $p = \frac{16.10}{100\times26} = 0.0062$, $k = 0.348$, $j = 0.884$

Steel stress $= \frac{4160\times100}{16.10\times.884\times26} = 1137$ kg/cm²

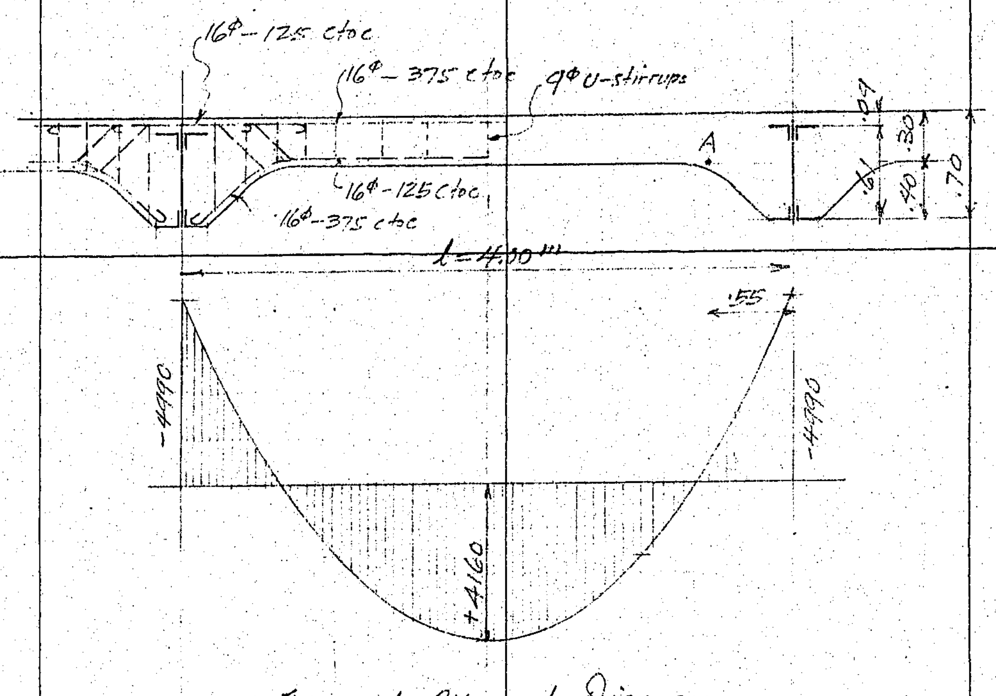
Concrete stress $= \frac{1137\times0.348}{15(1-0.348)} = 40.5$ 〃

For negative moment. $M = -4{,}990$ kgm

effective depth at support assumed as $(61+9) = 70 - 4 = 66$ cm

Steel area required $= \frac{4990\times100}{1200\times\frac{7}{8}\times66} = 7.21$ cm²

Use same reinforcement as for positive moment.



Assumed Moment Diagram.

End shear 6,240 kg

At support.

unit shear $= \frac{6240}{100\times\frac{7}{8}\times66} = 1.08$ kg/cm²

unit bond $= \frac{6240}{5.03\times8\times\frac{7}{8}\times66} = 2.69$ 〃

At end of fillet A.

Shear say $6240\times\frac{1.45}{2.00} = 4{,}530$ kg

Unit shear $= \frac{4530}{100\times0.884\times26} = 1.97$ kg/cm²

Unit bond $= \frac{4530}{5.03\times5\times.884\times26} = 7.84$ 〃

Use bent up bars.

Vertical stirrups

2-9ϕ U-stirrups $A_s = 4@0.636 = 2.54$ cm²

Spacing at support

$s = \frac{3}{2}\cdot\frac{2.54\times1200\times7/8\times66}{6240} = 42$ cm

Spacing at point A

$s' = \frac{3}{2}\cdot\frac{2.54\times1200\times.884\times26}{4530} = 23$ cm

Temperature bars. 0.20 % of the cross section of concrete.

$100\times30\times0.002 = 6.0$ cm²

Use 6-12ϕ bars = 6.78 cm² for one meter strip of slab. (上下ニ振分ケ)

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CALCULATIONS FOR

巨型鐵構框

Design of middle floor slab (中二階床版) Span length = 4.00 meters.

Dead Load — Concrete slab assumed as 20 cm @ 24 kg = 480

Live Load = 600

Total load on floor slab = 1080 kg/m^2

Bending moment on slab will be taken as

Positive moment $m = \frac{1}{12} \times 1080 \times 4.0^2 = 1440$ kgm per meter strip of slab.

Negative " $M = \frac{1}{10} \times 1080 \times 4.0^2 = 1730$ " "

End shear $V = \frac{1}{2} \times 1080 \times 4.0 = 2160$ kg "

Effective depth required $d = 0.362\sqrt{\frac{1440 \times 100}{100}} = 13.7$ cm

Use 17 cm effective depth with 3 cm insulation or total depth of 20 cm.

Steel area required $= \frac{1440 \times 100}{1200 \times \frac{7}{8} \times 17} = 8.07\ cm^2$

Use $12^{mm}\phi$ bars at 12.5 cm c to c $= 8 @ 1.13 = 9.03\ cm^2$

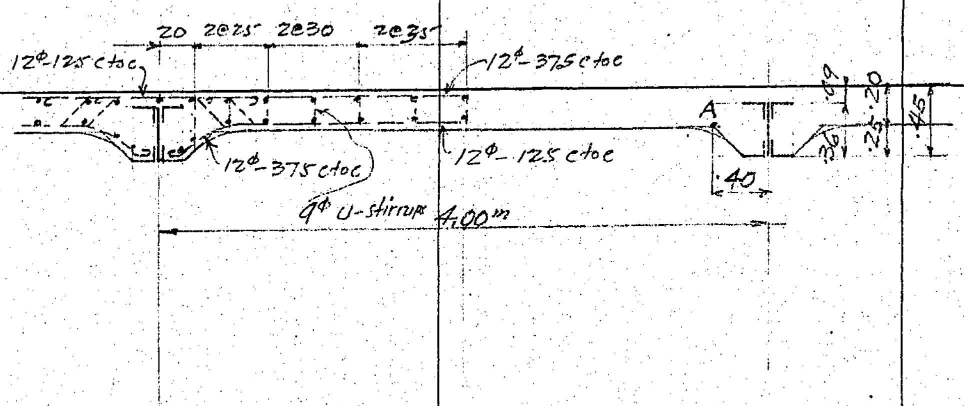
Steel ratio $p = \frac{9.03}{100 \times 17} = 0.0053$, $k = 0.327$, $j = 0.891$.

Steel stress $f_s = \frac{1440 \times 100}{9.03 \times .891 \times 17} = 1053\ kg/cm^2$

Concrete stress $f_c = \frac{1053 \times .327}{15(1 - .327)} = 34.1$ "

For negative moment,

Steel area required $= \frac{1730 \times 100}{1200 \times \frac{7}{8} \times 42} = 3.9\ cm^2$



End shear = 2160 kg

~~Unit shear $= \frac{2160}{100 \times \frac{7}{8} \times 42} = 0.59\ kg/cm^2$~~

Unit bond $= \frac{2160}{3.77 \times 8 \times \frac{7}{8} \times 42} = 1.95$ "

at end of fillet A.

shear say $2160 \times \frac{1.60}{2.00} = 1730$ kg

Unit shear $= \frac{1730}{100 \times .891 \times 17} = 1.14\ kg/cm^2$

Unit bond $= \frac{1730}{3.77 \times 5 \times .891 \times 17} = 6.06$ "

Vertical stirrups $2 - 9^{\phi}$ U-stirrups $= 4 @ .636 = 2.54\ cm^2 = A_s$

Spacing at support $s = \frac{3}{2} \cdot \frac{2.54 \times 1200 \times 7/8 \times 42}{2160} = 102$ cm c to c

Spacing at A $s' = \frac{3}{2} \times \frac{2.54 \times 1200 \times .891 \times 17}{1730} = 40$ "

} Use 25 ~ 40 cm spacings

Temperature bars, 0.2% of the cross section of concrete

$100 \times 20 \times 0.002 = 4.0\ cm^2$

Use $5 - 12^{\phi}$ bars $= 5.65\ cm^2$

Design of Bottom slab. span length 4.0 meters.

Dead Load.

due to top floor load 1,920
" " middle " " 480
2,400

Live Load.

due to top floor load 800×1.5 = 1200
" " middle " " 600
1,800

Summary of loads on bottom slab = 4,200 kg per square meter.

Bending moment on slab will be taken as

positive moment $m = \frac{1}{12} \times 4200 \times 4.0^2 = 5600$ kgm per meter strip

Negative moment $M = \frac{1}{10} \times 4200 \times 4.0^2 = 6720$ " "

End shear $V = \frac{1}{2} \times 4200 \times 4.0 = 8400$ kg "

Effective depth at center of span required $d = 0.362\sqrt{\frac{5600 \times 100}{100}} = 27.1$ cm.

Assuming the depth of steel member of the rahmen as 61 cm

Total depth of bottom slab

Depth of steel member 61
top insulation 9
bottom " 20
90 cm. Effective depth, say 82 cm

Steel area required for pos. moment $= \frac{5600 \times 100}{1200 \times \frac{7}{8} \times 82} = 6.51$

" " " neg. moment $= \frac{6720 \times 100}{1200 \times \frac{7}{8} \times 82} = 7.81$

Use 16 mmφ bars at 20.0 cm ctoc = 5@2.011 = 10.06 cm²

Steel ratio $p = \frac{10.06}{100 \times 82} = 0.0012$, $k = 0.173$, $j = 0.943$.

At center of span.

$f_s = \frac{5600 \times 100}{10.06 \times .943 \times 82} = 720$ kg/cm²

$f_c = \frac{720 \times .173}{15(1-.173)} = 10$ "

At support.

$f_s = \frac{6720 \times 100}{10.06 \times .943 \times 82} = 864$ kg/cm²

$f_c = \frac{864 \times .173}{15(1-.173)} = 12.1$ "

unit shear $= \frac{8400}{100 \times .943 \times 82} = 1.1$ "

Unit bond $= \frac{8400}{5.03 \times 5 \times .943 \times 82} = 4.31$ "

9φ U-stirrups $A_s = 2.5@.636 = 1.59$ cm²

Spacing at support $s = \frac{3}{2} \cdot \frac{1.59 \times 1200 \times .943 \times 82}{8400} = 26.3$ cm ctoc

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CALCULATIONS FOR

巨型鐵構框

Design of Sidewall. Span length = 4.00 meters.
Lower wall.

Depth of earth filling, at B: 3.97
Live Load surcharge $\frac{1200}{1600}$ = 0.75
4.72 m., 4.72 − 2.75 = 1.97 m under G.W.L.

Do. at A 4.72 + 5.00 = 9.72 ", 9.72 − 2.75 = 6.97 " "

Earth pressure at A.
1/3 × 1600 × 9.72 = 5180
1/3 × 400 × 6.97 = 930
6110 kg/m²

Earth pressure at B.
1/3 × 1600 × 4.72 = 2520
1/3 × 400 × 1.97 = 260
2780 "

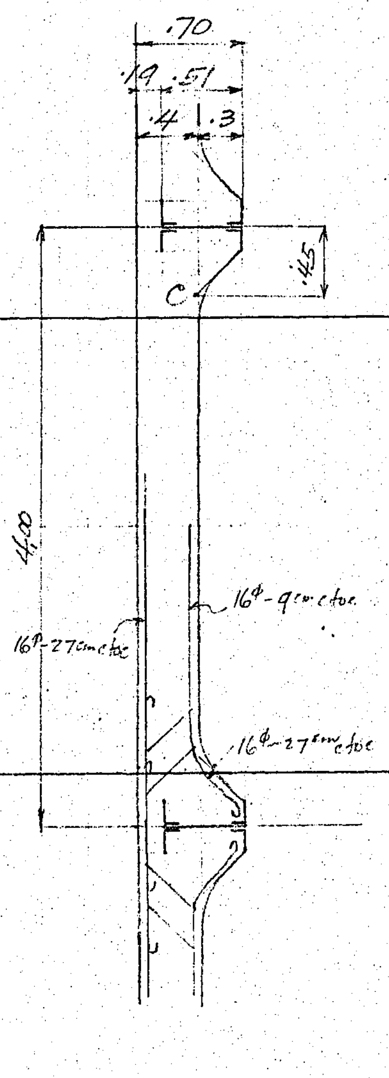
At point A. Positive moment $m = \frac{1}{12} \times 6110 \times 4.0^2 = 8150$ kgm
negative " $M = \frac{1}{10} \times 6110 \times 4.0^2 = 9780$ "
End shear $V = \frac{1}{2} \times 6110 \times 4.0 = 12220$ kg

Effective depth required for pos. moment $d = 0.362\sqrt{\frac{8150 \times 100}{100}} = 32.7$ cm.
Use 35 cm eff. depth with 5 cm insulation or 40 cm total depth.
Steel area required = $\frac{8150 \times 100}{1200 \times \frac{7}{8} \times 35} = 22.2$ cm²
16φ bars at 9 cm ctoc = 22.35 cm²

Total depth at support assumed as 51 + 19 = 70 cm, eff. depth being 65 cm.
Steel area reqd. = $\frac{9780 \times 100}{1200 \times 7/8 \times 65} = 14.33$ cm²

Use same reinforcement as for pos. moment.
Unit shear = $\frac{12220}{100 \times \frac{7}{8} \times 65} = 2.15$ kg/cm²

Unit bond = $\frac{12220}{\frac{5.03}{0.09} \times \frac{7}{8} \times 65} = 3.84$ "



End shear = 12220 kg
Horizontal stirrups 4 − 9φ = 4 @ .636 = 2.54 cm²
Spacing $s = \frac{3}{2} \times \frac{2.54 \times 1200 \times 7/8 \times 65}{12220} = 21.3$ cm ctoc

Shear at end of fillet, C = $12220 \times \frac{1.55}{2.00} = 9460$ kg
Unit shear = $\frac{9460}{100 \times \frac{7}{8} \times 35} = 3.09$ kg/cm²
Unit bond = $\frac{9460}{\frac{5.03}{13.5} \times \frac{7}{8} \times 35} = 8.3$ " ($9^{cm} \times \frac{3}{2} = 13.5$)

Stirrup spacing $s' = \frac{3}{2} \frac{2.54 \times 1200 \times 7/8 \times 35}{9460} = 14.8$ cm ctoc

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CALCULATIONS FOR

巨型鐵構框

At point B. (B点直下ノ断面)

positive moment $m = \frac{1}{12} \times 2780 \times 4.0^2 = 3700$ kgm
negative 〃 $M = \frac{1}{10} \times 2780 \times 4.0^2 = 4350$ 〃
End shear $V = \frac{1}{2} \times 2780 \times 4.0 = 5560$ kg

Effective depth same as for point A.

Steel area required for pos. m $= \frac{3700 \times 100}{1200 \times \frac{7}{8} \times 35} = 10.07$ cm²

Use 16φ bars at 20 cm c/c = 10.06 cm²

$p = \frac{10.06}{100 \times 35} = 0.0029$, $k = 0.255$, $j = 0.915$

$f_s = \frac{3700 \times 100}{10.06 \times .915 \times 35} = 1148$ kg/cm²

$f_c = \frac{1148 \times .255}{15(1-.255)} = 26.2$ 〃

Steel area required for neg. moment $= \frac{4350 \times 100}{1200 \times \frac{7}{8} \times 65} = 6.37$ cm²

Use same reinforcement as for pos. moment.

Unit shear $= \frac{5560}{100 \times \frac{7}{8} \times 65} = 0.98$ kg/cm²

Unit bond $= \frac{5560}{5.03 \times 5 \times \frac{7}{8} \times 65} = 3.9$ 〃

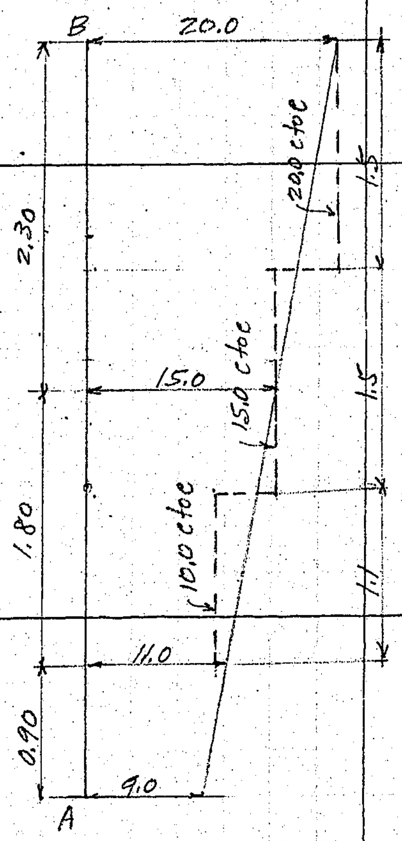
Shear at end of fillet C. $= 5560 \times \frac{1.55}{2.00} = 4300$ kg

Unit shear $= \frac{4300}{100 \times .915 \times 35} = 1.34$ kg/cm²

Unit bond $= \frac{4300}{5.03 \times 5 \times .915 \times 35} = 5.34$ 〃

Stirrup spacing $s' = \frac{3}{2} \times \frac{2.54 \times 1200 \times .915 \times 35}{4300} = 34$ cm c/c. (4-9φ)

Steel spacing diagram



Upper wall.

Depth of earth filling at C = 0.93
Live load surcharge = 0.75
= 1.68 m.

Earth pressure $= \frac{1}{3} \times 1600 \times 1.68 = 900$ kg/m²
positive moment $= \frac{1}{12} \times 900 \times 4.0^2 = 1200$ kgm
negative 〃 $= \frac{1}{10} \times 900 \times 4.0^2 = 1440$ 〃
end shear $= \frac{1}{2} \times 900 \times 4.0 = 1800$ kg

Effective depth required for pos. moment $= 0.362 \sqrt{\frac{1200 \times 100}{100}} = 12.6$ cm.
use effective depth of 25 cm with 5 cm insulation, or 30 cm in total.

Steel area required $= \frac{1200 \times 100}{1200 \times \frac{7}{8} \times 25} = 4.57$ cm²

Use 16φ bars at 20 cm c/c = 5@2.011 = 10.06 cm²

Shear at end of fillet $= 1800 \times \frac{1.45}{2.0} = 1300$ kg
Unit shear $= \frac{1300}{100 \times \frac{7}{8} \times 25} = 0.60$ kg/cm²

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CALCULATIONS FOR
巨型鐵構框

At point B (B点直上ノ断面)

positive moment = 3,700 kgm see on page 6
negative " = 4,350 " "
end shear = 5560 kg "

Steel area req'd for pos. m = $\frac{3700 \times 100}{1200 \times \frac{7}{8} \times 25}$ = 14.1 cm²

Use 16φ bars at 12.5 cm c to c = 16.1 cm²

$p = \frac{16.1}{100 \times 25} = 0.0064$, $k = 0.353$, $j = 0.883$

$f_s = \frac{3700 \times 100}{16.1 \times .883 \times 25} = 1041$ kg/cm²

$f_c = \frac{1041 \times .353}{15(1 - .353)} = 37.9$ "

at support

Unit shear = $\frac{5560}{100 \times \frac{7}{8} \times 65} = 0.98$ kg/cm²

unit bond = $\frac{5560}{5.03 \times 8 \times \frac{7}{8} \times 65} = 2.4$ "

Shear at end of fillet C = $5560 \times \frac{1.45}{2.00} = 4030$ kg

Unit shear = $\frac{4030}{100 \times .883 \times 25} = 1.83$ kg/cm²

Unit bond = $\frac{4030}{5.03 \times 4 \times .883 \times 25} = 9.08$ " use bent-up bars.

Stirrup spacing $s' = \frac{3}{2} \times \frac{2.54 \times 1200 \times .883 \times 25}{4030} = 25.1$ cm c to c. (4-9φ)

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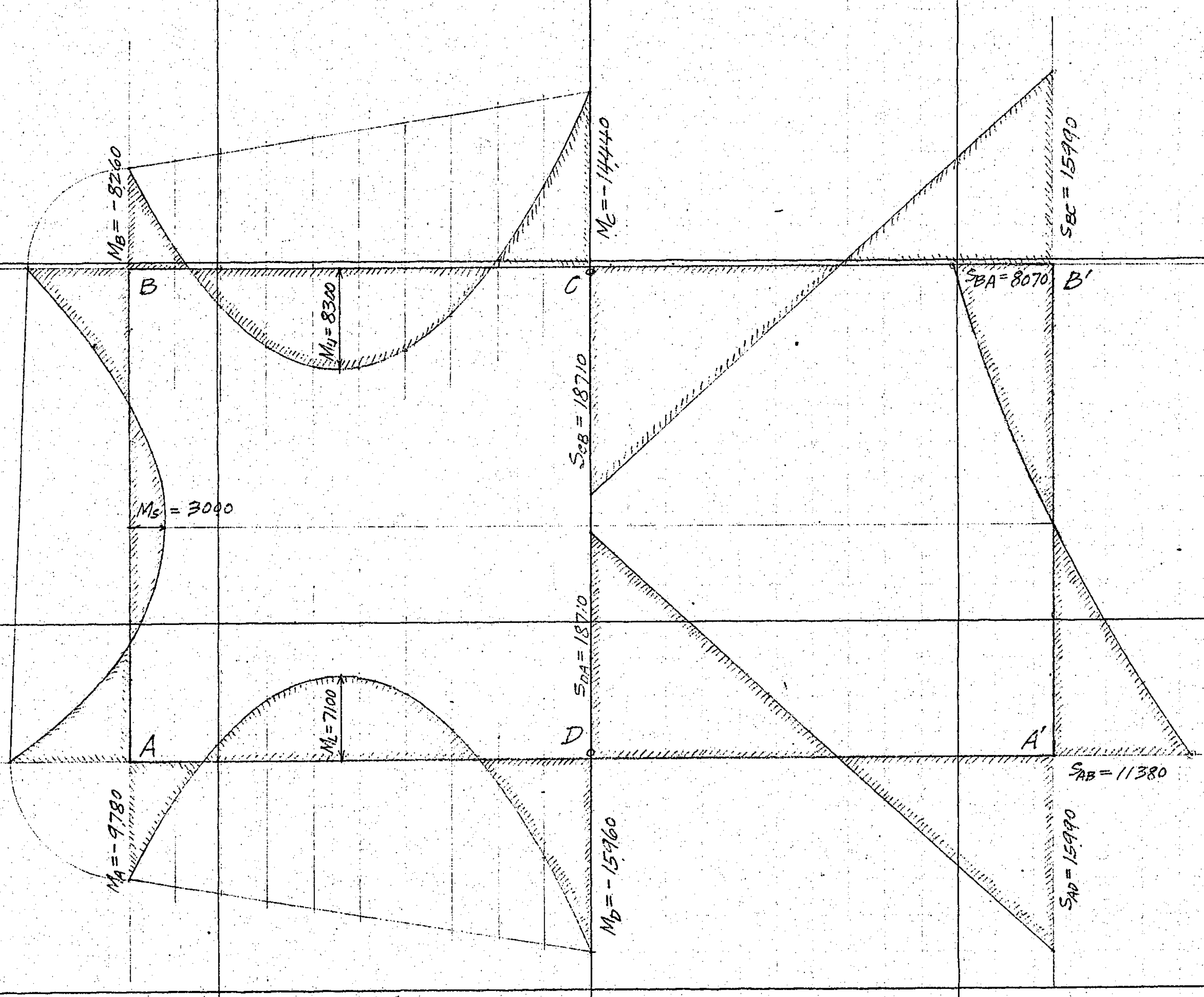
CALCULATIONS FOR

鐵筋混凝土口型ノ三隧道

Axial compression in each member.

Top slab	$N_{BC} = S_{BA} =$	8,070 kg	for one meter strip.	
bottom slab	$N_{AD} = S_{AB} =$	11,380 "	"	
Side walls	$N_{AB} = S_{BC} =$	15,990 "	"	
Center column	$N_{CD} = 2S_{CB} =$	37,420 "	"	
	$37420 \times 2.5 =$	93,550 "	for one column.	

Bending moment and shear diagrams.

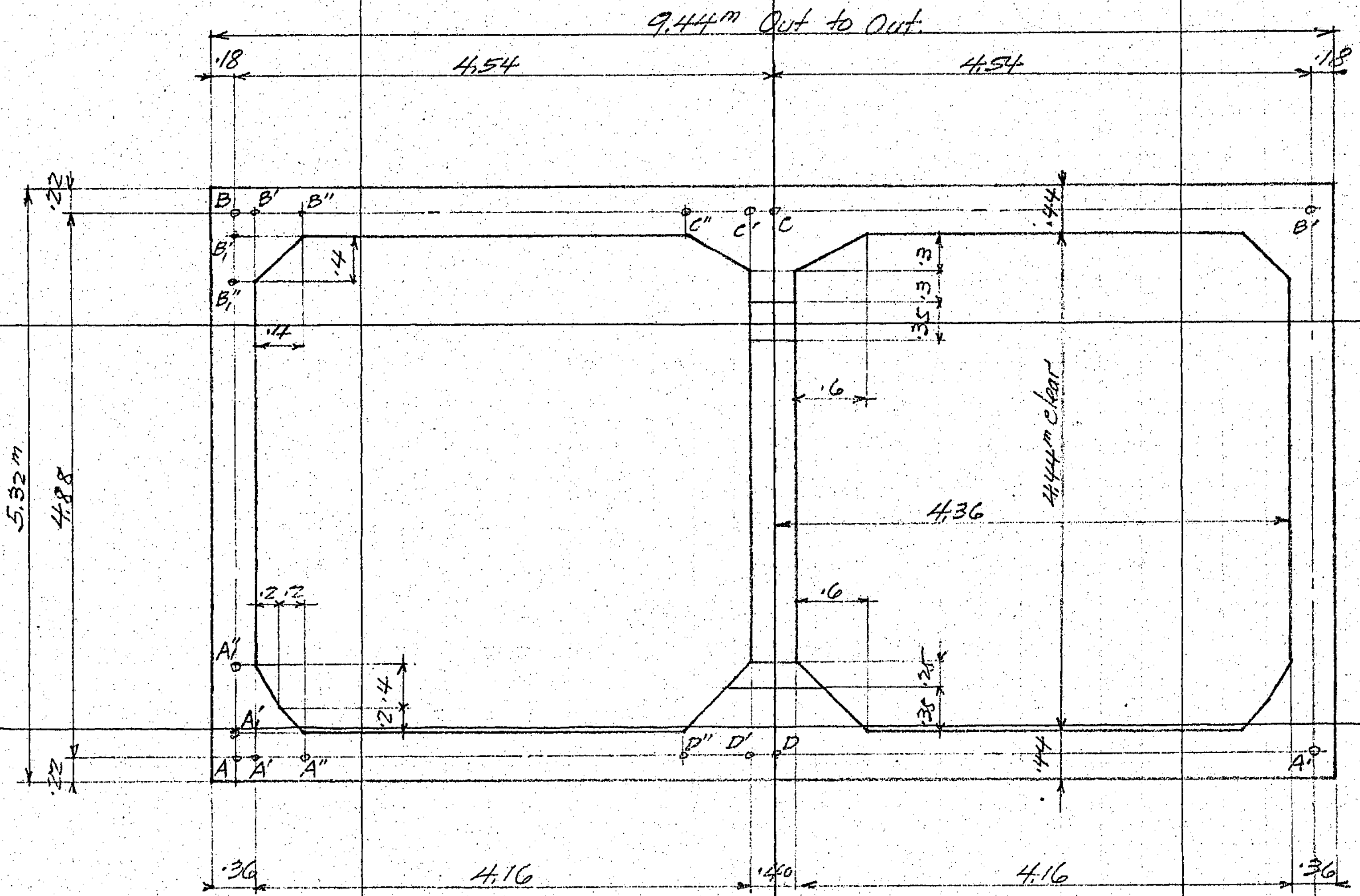


Scale of space 1:60
" " moment 1/50" = 10,000 kgm.
" " shear 1/50" = 10,000 kg.

CALCULATIONS FOR

鐵筋混凝土口型ノ三隧道

Assumed cross section of the Tunnel.



Unit stress calculations.

Top and Bottom slab.

max. positive moment $M_U = 8300$ kgm, axial compression $N_{BC} = 8070$ kg,

" $M_L = 7{,}100$ " , " $N_{DA} = 11380$ " .

Use 44cm slab, of which effective depth 39cm, insulation being 5cm.

Steel area required for moment $= \dfrac{8300 \times 100}{1200 \times \frac{7}{8} \times 39} = 20.2$ cm² per meter strip of slab,

Use 10-16mmϕ bars = 20.11 cm²

$p = \dfrac{20.11}{100 \times 39} = 0.0052$, $k = 0.325$, $j = 0.892$;

$f_s = \dfrac{8300 \times 100}{20.11 \times .892 \times 39} = 1185$ kg/cm²

$f_c = \dfrac{1185 \times 0.339}{15(1-0.339)} = 40.5$

Direct stress say $\dfrac{8070}{100 \times 44} = \dfrac{1.8}{42.3}$ kg/cm²

Use same arrangement of reinforcements for Top and Bottom slabs.

Max. negative moments $M_C = -14440$ kgm, axial compression $N_{BC} = 8070$ kg,

" $M_D = -15{,}960$ " , " " $N_{AD} = 11{,}380$ " .

For Top slab.

Use effective depth of 69 cm with 5cm insulation (see above sketch)

Steel area required for moment $= \dfrac{14440 \times 100}{1200 \times \frac{7}{8} \times 69} = 19.92$ cm²

Use 10-16mmϕ bars = 20.11 cm²

$p = \dfrac{20.11}{100 \times 69} = 0.0029$, $k = 0.255$, $j = 0.915$

$f_s = \frac{144440 \times 100}{20.11 \times 0.915 \times 69} = 1137$ kg/cm²

$f_c = \frac{1137 \times 0.255}{15(1-0.255)} = 25.9$

Direct stress say $\frac{8070}{100 \times 74} = \frac{1.1}{27.0}$ kg/cm²

moment at end of haunch C″, $M_{C''} = -2000$ kgm (measured from moment diagram)
$N_{CB} = 8090$ kg C.

Use 7-16φ bars = 14.1 cm² (for bond stress)

Unit shear and bond stress in top slab.
Shear at point C′ and D′ = 17300 kg
〃 C″ and D″ = 12400 〃

Unit shear
at C′ $v = \frac{17300}{100 \times 0.915 \times 69} = 2.7$ kg/cm²

at C″ $v = \frac{12400}{100 \times 7/8 \times 39} = 3.6$ 〃

Unit bond
at C′ $u = \frac{17300}{50.3 \times .915 \times 69} = 5.4$ 〃

at C″ $u = \frac{12400}{50.3 \times 7 \times \frac{7}{8} \times 39} = 10.3$ 〃 use bent-up bars.

Vertical stirrups.
Using 3-U-stirrups of 9mmφ per meter strip, for which $A_s = 6 \times .636 = 3.81$ cm²
Stirrup spacing at point C′, $s' = \frac{3}{2} \cdot \frac{3.81 \times 1200 \times .915 \times 69}{17300} = 25.0$ cm c to c.

〃 〃 〃 C″, $s'' = \frac{3}{2} \cdot \frac{3.81 \times 1200 \times \frac{7}{8} \times 39}{12400} = 18.9$ 〃 〃

For Bottom slab.
Use 74 cm effective depth with 5cm insulation. (see on the last page).
Steel 10-16φ = 20.11 cm²

$p = \frac{20.11}{100 \times 74} = 0.0027$, $k = 0.247$, $j = 0.918$.

$f_s = \frac{15960 \times 100}{20.11 \times .918 \times 74} = 1168$ kg/cm²

$f_c = \frac{1168 \times .247}{15(1-.247)} = 25.6$

Direct stress say $\frac{11380}{79 \times 100} = \frac{1.4}{27.0}$ 〃

Use simillar arrangement of reinforcements as for Top slab.

鐵筋混凝土口型ノ三隧道

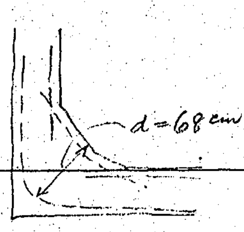
Details design of side walls.

Negative moment at bottom, $M_A = -9780$ kgm, $N_{AB} = 15990$ kg c
" " " top, $M_B = -8260$ " " " "

At point A.

Effective depth taken as 68 cm, steel area 10-16φ bars = 20.11 cm²

$p = \frac{20.11}{100 \times 68} = 0.003$, $k = 0.258$, $j = 0.914$.



$f_s = \frac{9780 \times 100}{20.11 \times .914 \times 68} = 782$ kg/cm²

$f_c = \frac{782 \times .258}{15(1-.258)} = 18.0$

Direct stress say $\frac{15990}{73 \times 100} = \frac{2.2}{20.2}$ "

unit shear $v = \frac{11380}{100 \times .914 \times 68} = 1.8$ kg/cm²

unit bond $u = \frac{11380}{50.27 \times .914 \times 68} = 3.6$ "

At point B. Use the same reinforcements as for A.

Moment at end of haunch A_1'', $M_{A_1}'' = -2400$ kgm, $N = 15990$ kg c,
" " " B_1'', $M_{B_1}'' = -3900$ ", $N =$ " "

Taking effective depth as 31 cm and steel 6.67-16φ bars = 13.4 cm² (15 cm c to c average)

$p = 0.0043$, $k = 0.300$, $j = 0.900$

$f_s = \frac{3900 \times 100}{13.4 \times .900 \times 31} = 1044$ kg/cm²

$f_c = \frac{1044 \times .30}{15(1-.30)} = 29.7$

Direct stress say $\frac{15990}{100 \times 36} = \frac{4.4}{34.1}$ "

shear at end of haunch $A_1'' = 7100$ kg
" $B_1'' = 6600$ "

unit shear, $v = \frac{7100}{100 \times .90 \times 31} = 2.5$ kg/cm²

unit bond, $u = \frac{7100}{5.03 \times 6.67 \times .90 \times 31} = 7.6$ " Use bent-up bars.

Horizontal stirrups in side wall.

use 5-9φ stirrups (2.5-U), $A_s = 5 \times 6.36 = 3.18$ cm² per meter strip of wall.

Stirrup spacing at $A_1'' = \frac{3}{2} \cdot \frac{3.18 \times 1200 \times 0.900 \times 31}{7100} = 22.5$ cm c to c.

Note:

Reinforcements for positive moment in side wall will be governed by seismic positive moment, see the calculations on page 46

CALCULATIONS FOR

鐵筋混凝土口型三隧道

Center column.

Axial compression = 93550 kg. on one column.
Use 40×70 cm cross section with 18-16φ bars.
Transformed section of column = 3343 cm² of concrete (see on page 30)

Unit compression on concrete $f_c = \frac{93550}{3343} = 28.0$ kg/cm²,

" " " steel $f_s = 15 \times 28.0 = 420.$ "

Use 9 mmφ hoops whose spacing not over 19 cm c to c.
Use 10 cm spacings at top and bottom for a few spaces.

Design of longitudinal beams on top and bottom of column.
Span length = 2.50 meter continuous.
Load on beam = 37,420 kg per lin meter. (see on page 37)

Bending moments assumed as $\pm \frac{wl^2}{12} = \frac{37420 \times 2.5^2}{12} = \pm 19{,}500$ kgm

For Top beam.

At center of span.
Effective depth req'd, as a rectangular beam $d = 0.362\sqrt{\frac{19500 \times 100}{160}} = 40$ cm

Use 99 cm effective depth with an insulation of 5 cm. or 104 cm in total.
Steel area req'd. $= \frac{19{,}500 \times 100}{1200 \times \frac{7}{8} \times 99} = 19.8$ cm²

Use 8-19 mmφ bars = 22.7 cm²

For this case, neutral axis passes through the flange, design as a rectangular beam.
$p = \frac{22.7}{160 \times 99} = 0.0014$, $k = 0.185$, $j = 0.938$

$f_s = \frac{19500 \times 100}{22.7 \times .938 \times 99} = 925$ kg/cm²

$f_c = \frac{925 \times .185}{15(1-.185)} = 14.0$ "

At support.
Effective depth required $= 0.362\sqrt{\frac{19500 \times 100}{40}} = 79.9$ cm

Use 134 cm effective depth with 5 cm insulation.
Steel area required $= \frac{19500 \times 100}{1200 \times \frac{7}{8} \times 134} = 13.86$ cm²

Use 8-19φ bars = 22.70 cm²
$p = \frac{22.7}{40 \times 134} = 0.0042$, $k = 0.298$, $j = 0.901$.

$f_s = \frac{19500 \times 100}{22.70 \times .901 \times 134} = 711$ kg/cm²

$f_c = \frac{711 \times .298}{15(1-.298)} = 20.2$ "

Shear at end of haunch = 37420 × 0.55 = 20,600 kg
" " face of column = 37420 × 0.90 = 33,700 "
Unit shear at end of haunch $v = \frac{20600}{40 \times \frac{7}{8} \times 99} = 5.94$ kg/cm²

Use 12 mmφ U-stirrups $A_s = 2 \times 1.13 = 2.26$ cm²

CALCULATIONS FOR

鐵筋混凝土口型ノ三隧道

spacing $= \frac{3}{2} \cdot \frac{2.26 \times 1200 \times \frac{7}{8} \times 99}{20600} = 17.1$ cm c/c.

unit bond $u = \frac{20600}{8 \times 5.97 \times \frac{7}{8} \times 99} = 5.0$ kg/cm² use bent-up bars.

Unit shear at face of column, $v = \frac{33700}{40 \times .901 \times 134} = 7.0$ kg/cm²

spacing of 12φ U-stirrups $= \frac{3}{2} \cdot \frac{2.26 \times 1200 \times .901 \times 134}{33700} = 14.6$ cm c/c.

unit bond $u = \frac{33700}{8 \times 5.97 \times .901 \times 134} = 5.9$ kg/cm² use bent-up bars.

For Bottom beam.

At center of span.

Effective depth being taken as 74 cm with 5 cm insulation,

steel area required $= \frac{19500 \times 100}{1200 \times \frac{7}{8} \times 74} = 25.1$ cm² as a rectangular beam.

Use 10-19φ = 28.35 cm²

Neutral axis being in the flange.

$p = \frac{28.35}{160 \times 74} = 0.0024$, $k = 0.235$, $j = 0.922$.

$f_s = \frac{19500 \times 100}{28.35 \times .922 \times 74} = 1008$ kg/cm²

$f_c = \frac{1008 \times .235}{15(1-.235)} = 20.7$ 〃

At support.

Effective depth assumed as 99 cm, width of beam = 40 cm (at top of beam)

Steel area required $= \frac{19500 \times 100}{1200 \times \frac{7}{8} \times 99} = 18.8$ cm²

Use 10-19φ = 28.35 cm²

$p = \frac{28.35}{40 \times 99} = 0.0072$, $k = 0.369$, $j = 0.877$.

$f_s = \frac{19500 \times 100}{28.35 \times .877 \times 99} = 793$ kg/cm²

$f_c = \frac{793 \times .369}{15(1-.369)} = 30.9$ 〃

Unit shear at face of column $v = \frac{33700}{90 \times .877 \times 99} = 4.3$ kg/cm² (Effective width for shear assumed as 90 cm)

4-12mmφ U-stirrup spacing $= \frac{3}{2} \times \frac{4 \times 1.13 \times 1200 \times .912 \times 99}{33700} = 21.8$ cm c/c.

Unit bond. $u = \frac{33700}{10 \times 5.97 \times .912 \times 99} = 6.3$ kg/cm² Use bent-up bars.

at end of haunch $v = \frac{20600}{90 \times \frac{7}{8} \times 74} = 3.5$ kg/cm²

4-12φ U-stirrup spacing $= \frac{3}{2} \frac{4 \times 1.13 \times 1200 \times \frac{7}{8} \times 74}{20600} = 25.6$ cm c/c

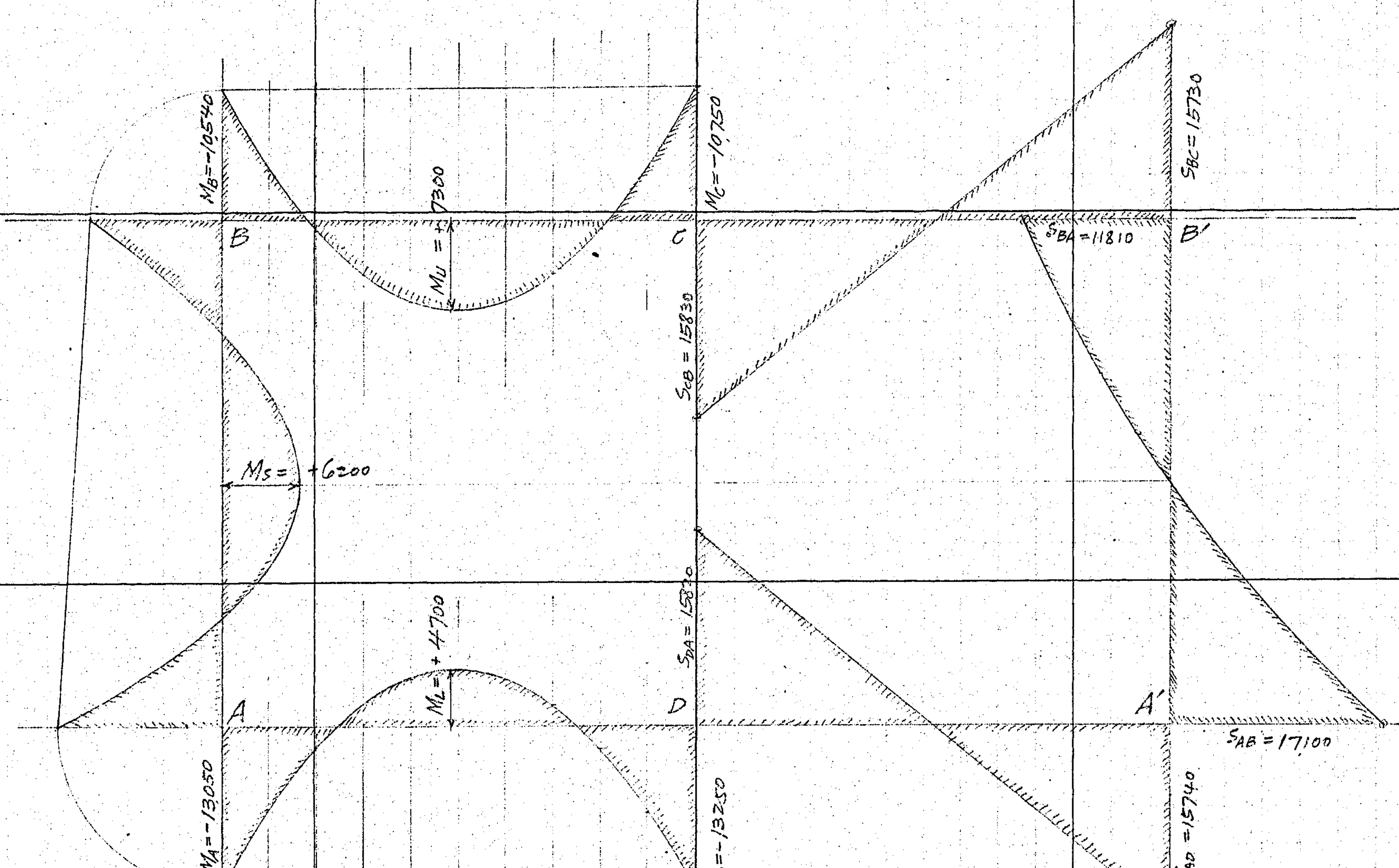
Unit bond $u = \frac{20600}{8 \times 5.97 \times \frac{7}{8} \times 74} = 6.7$ kg/cm² use bent-up bars.

鐵筋混凝土口型ノ三隧道

Axial compression in each member.

Top slab	$N_{BC} = S_{BA}$	=	11,810 kg	for one meter strip.
bottom "	$N_{AD} = S_{AB}$	=	17,100 "	"
Side walls	$N_{AB} = S_{BC}$	=	15,730 "	"
Center column	$N_{CD} = 2S_{CB}$	=	31,660 "	"
	31660 × 2.50	=	79,200 "	for one column.

Bending moment and shear diagram.



Scale of space 1:60
" " moment 1/50" = 10,000 kgm
" " shear 1/50" = 10000 kg.

Comparing this diagram with the one shown on page 37 (for normal state), we will find that the seismic stress which govern the section is $M_s = +6200$ kgm only.

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MADE BY K. I. DATE 10-5-21 FILE NO. 4
CHECKED BY ______ DATE ______ PAGE NO. 46

CALCULATIONS FOR

鐵筋混凝土口型ノ三隧道

Stress in side wall due to seismic positive moment.

$M_S = +6{,}200$ kgm for which axial compression $N_{BA} = 15740$ kg

Allowable unit stresses being taken as 1.8 times of those for normal state.

$f_s = 2160$ kg/cm², $f_c = 85$ kg/cm²

Effective depth required for moment $= 0.269\sqrt{\frac{6200 \times 100}{100}} = 21.2$ cm

Use 31 cm effective depth with 5 cm insulation.

Steel area required for moment $= \frac{6200 \times 100}{2160 \times \frac{7}{8} \times 31} = 10.6$ cm²

Use 10-16φ bars = 20.11 cm²

$p = \frac{20.11}{31 \times 100} = 0.0065$, $k = 0.355$, $j = 0.882$

$f_s = \frac{6200 \times 100}{20.11 \times .882 \times 31} = 1128$ kg/cm²

$f_c = \frac{1128 \times .355}{15(1-.355)} = 41.4$

Direct stress say $\frac{15740}{36 \times 100} = \underline{4.4}$

45.8 "

All assumed sections are ample to carry seismic stresses.

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MADE BY K. I DATE 10-5-16 FILE NO 3
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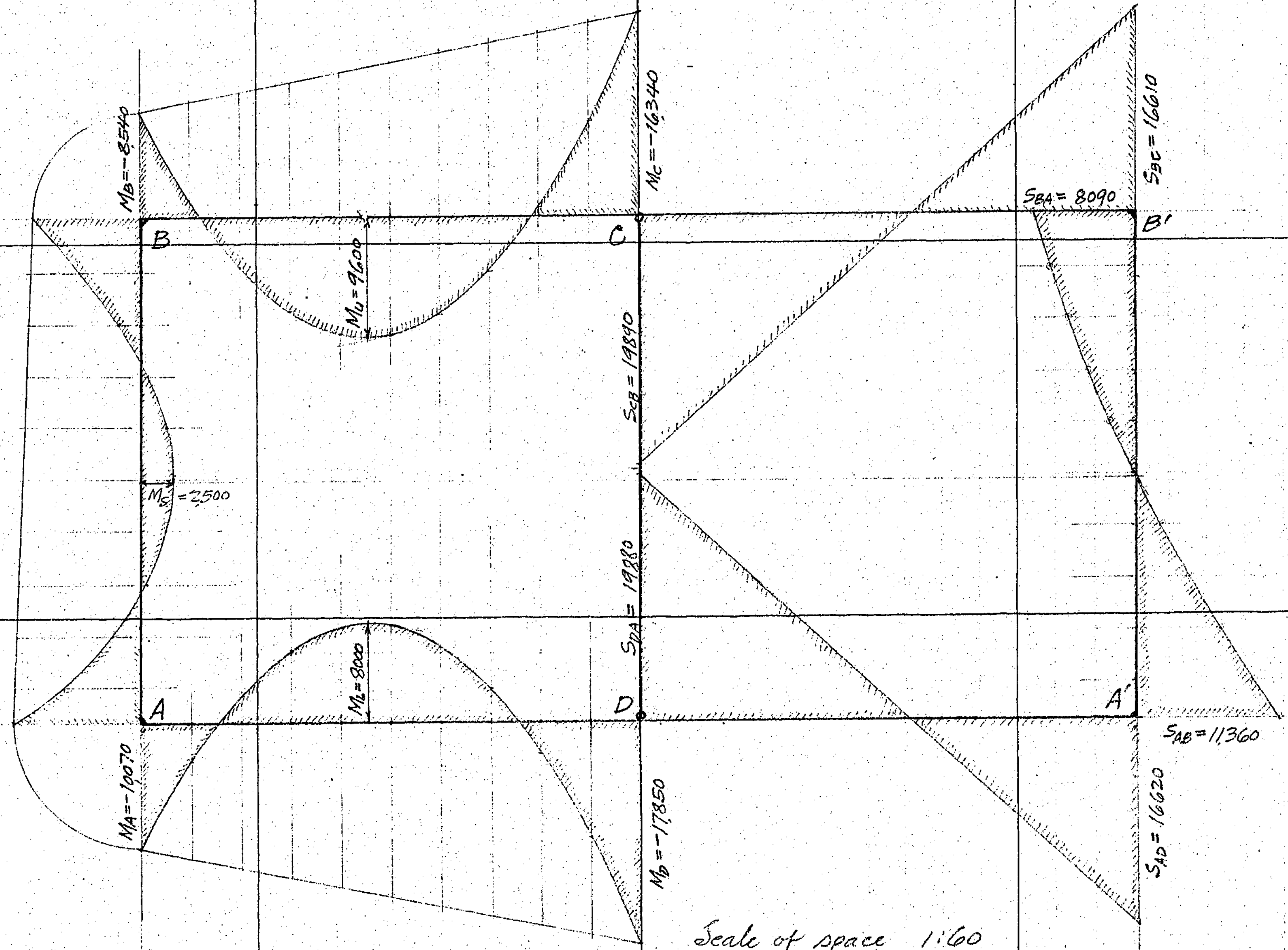
CALCULATIONS FOR

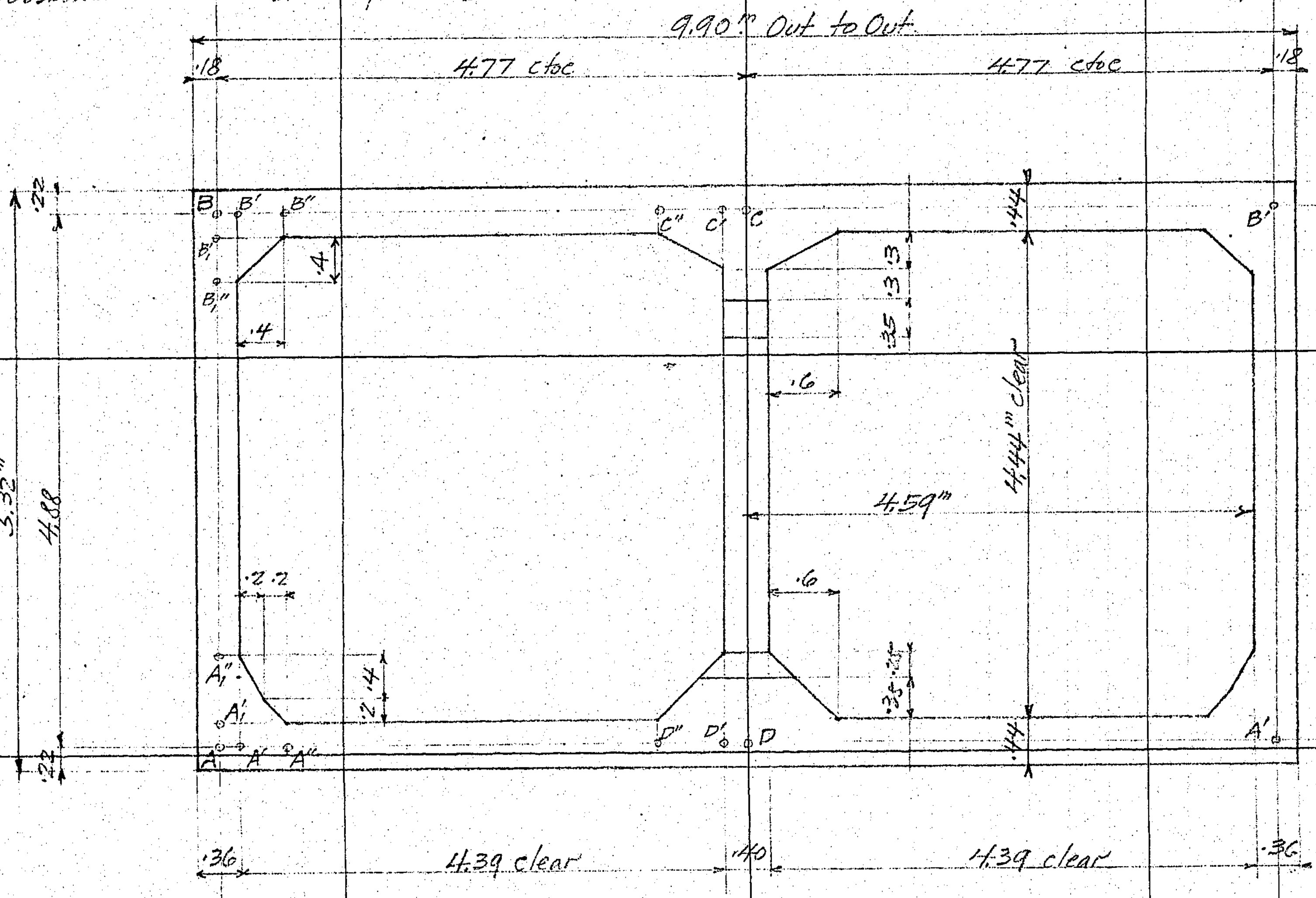
鐵筋混凝土口型ノ穴隧道.

Bending moment and shear diagram.



Scale of space 1:60
" " moment 1/50m = 10,000 kgm
" " shear 1/50m = 10000 kg.

Assumed Cross section of the Tonnel.



Scale 1:60.

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CALCULATIONS FOR

鐵筋混凝土口型ノ穴隧道

Unit stress calculations.

Top and Bottom slab.

Max. positive moment $M_U = 9600$ kgm, axial compression $N_{BC} = 8090$ kg,
〃 〃 〃 $M_L = 8000$ 〃, 〃 〃 $A_{DA} = 11360$ 〃.

Use 44 cm slab, of which effective depth 39 cm, insulation being 5 cm.

Steel area required for bending $= \frac{9600 \times 100}{1200 \times \frac{7}{8} \times 39} = 23.45$ cm² per meter strip of slab,

Use 10-19$^{mm\phi}$ bars $= 28.35$ cm²

$p = \frac{28.35}{39 \times 100} = 0.0073$, $k = 0.371$, $j = 0.876$

$f_s = \frac{9600 \times 100}{28.35 \times .876 \times 39} = 992$ kg/cm²

$f_c = \frac{992 \times .371}{15(1-.371)} = 39.0$

Direct stress say $\frac{8090}{44 \times 100} = 1.8$

40.8 kg/cm²

Use same arrangement of reinforcements for Top and Bottom slabs.

Max. negative moment $M_C = -16340$ kgm, axial compression $N_{BC} = 8090$ kg,
〃 〃 〃 $M_D = -17850$ 〃, 〃 〃 $N_{AD} = 11360$ 〃.

For Top slab.

Use effective depth of 69 cm with 5 cm insulation.

Steel area required for moment $= \frac{16340 \times 100}{1200 \times \frac{7}{8} \times 69} = 22.6$ cm² per meter strip of slab.

Use 10-19$^{mm\phi}$ bars $= 28.35$ cm²

$p = \frac{28.35}{69 \times 100} = 0.0041$, $k = 0.295$, $j = 0.902$

$f_s = \frac{16340 \times 100}{28.35 \times .902 \times 69} = 927$ kg/cm²

$f_c = \frac{927 \times .295}{15(1-.295)} = 25.9$

Direct stress say $\frac{8090}{74 \times 100} = 1.1$

27.0 kg/cm²

moment at end of haunch C", $M_C'' = -3600$ kgm, (measured from moment diagram)
$N_{CB} = 8090$ kg C

Use 7 - 19$^{\phi}$ bars at least (for bond stress).

Unit shear and bond stress in top slab.

Shear at point C' and D' $= 18300$ kg,
〃 〃 C" 〃 D" $= 13600$ 〃.

Unit shear

at C' $v = \frac{18300}{100 \times .902 \times 69} = 2.9$ kg/cm²

at C" $v = \frac{13600}{100 \times 7/8 \times 39} = 4.0$ 〃

Unit bond

at C' $u = \frac{18300}{59.69 \times .902 \times 69} = 4.9$ kg/cm²

at C" $u = \frac{13600}{59.7 \times 7 \times \frac{7}{8} \times 39} = 9.5$ 〃 Use 7 bars with bent up bars.

Vertical stirrups.
Using 3-U-stirrups of 9mmφ per meter strip, for which $A_s = 6 @ .636 = 3.81 cm^2$
Stirrup spacing at point C'

$$S' = \frac{3}{2}\frac{3.81 \times 1200 \times 0.902 \times 69}{18300} = 23.3 \text{ cm ctoc.}$$

Do. at point C''

$$S'' = \frac{3}{2}\cdot\frac{3.81 \times 1200 \times \frac{7}{8} \times 39}{13600} = 17.2 \quad " \quad "$$

For Bottom slab.
Use 74 cm effective depth.
Steel 10-19φ bars = 28.35 cm²

$$p = \frac{28.35}{100 \times 74} = 0.0038, \quad k = 0.285, \quad j = 0.905.$$

$$f_s = \frac{17850 \times 100}{28.35 \times .905 \times 74} = 941 \text{ kg/cm}^2$$

$$f_c = \frac{941 \times .285}{15(1-.285)} = 25.0$$

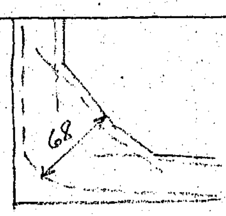
Direct stress say $\frac{11360}{79 \times 100} = \frac{1.4}{26.4}$ "

Use a simillar arrangement of reinforcements as for Top slab.

Detail design of Side walls.
Negative moment at bottom $M_A = -10,070$ kgm, axial compression $N_{AB} = 16610$ kg
" " " top $M_B = -8540$ " , " " " "

At Point A.
Effective depth taken as 68 cm, steel area 10-16φ bars = 20.11 cm²

$$p = \frac{2011}{100 \times 68} = 0.0030, \quad k = 0.258, \quad j = 0.914$$



$$f_s = \frac{10070 \times 100}{20.11 \times .914 \times 68} = 805 \text{ kg/cm}^2$$

$$f_c = \frac{805 \times .258}{15(1-.258)} = 18.7$$

Direct stress say $\frac{16610}{100 \times 73} = \frac{2.3}{21.0}$ "

Unit shear $v = \frac{11360}{100 \times .914 \times 68} = 1.8$ "

Unit bond $u = \frac{11360}{50.27 \times .914 \times 68} = 3.6$ "

Moment at end of haunch A_1'' $M_{A_1}'' = -2600$ kgm, $N = 16620$ kg.
" " " " B_1'' $M_{B_1}'' = -4100$ " , $N =$ "
Taking effective depth as 31 cm and steel 6.67-16mmφ bars = 13.4 cm² (15 cm ctoc average)

$$p = \frac{13.40}{31 \times 100} = 0.0043, \quad k = 0.300, \quad j = 0.900.$$

$$f_s = \frac{4100 \times 100}{13.4 \times .90 \times 31} = 1097 \text{ kg/cm}^2$$

$$f_c = \frac{1097 \times .300}{15(1-.300)} = 31.3$$

Direct stress say $\frac{16620}{100 \times 36} = \frac{4.6}{35.9}$ kg/cm²

Shear at point A," = 7100 kg
" B," = 6600 "

unit shear $v = \frac{7100}{100 \times 0.90 \times 31} = 2.5$ kg/cm²

unit bond $u = \frac{7100}{5.03 \times 6.67 \times .90 \times 31} = 7.6$ " use bent-up bars.

Horizontal stirrups in side wall.
Use 5- 9φ stirrups (2.5-U) $A_s = 5 \times .636 = 3.18$ cm² per meter strip.

Stirrup spacing at A," $= \frac{3}{2} \cdot \frac{3.18 \times 1200 \times 0.900 \times 31}{7100} = 22.5$ cm c/c.

Note: Reinforcements for positive moment will be governed by seismic positive moment; see the calculations on page 34.

Center column.
Axial compression = 99500 kg for one column.
Use 40 × 70 cm cross section with 18 - 16φ bars
Transformed section of column.
Concrete 40 × 70 = 2,800
steel 18 @ 2.011 × 15 = 543
3,343 cm² of concrete

Unit compression on concrete $f_c = \frac{99500}{3343} = 29.8$ kg/cm²

" " " steel $f_s = 29.8 \times 15 = 446$ "

Use 9mmφ hoops, spacing not over 12 × 16 = 19 cm c/c.
Use 10 cm spacings at top and bottom for a few spaces.

Design of longitudinal beams on top and bottom of column.
Span length = 2.50 meters.
Load on beam = 39780 kg per lin. meter of span. see on page 26.
Bending moments assumed as $\pm \frac{wl^2}{12} = \frac{39780 \times 2.5^2}{12} = \pm 20700$ kgm

Shear at end of haunch = 39780 × 0.55 = 21800 kg
" " face of column = 39780 × 0.90 = 35700 "

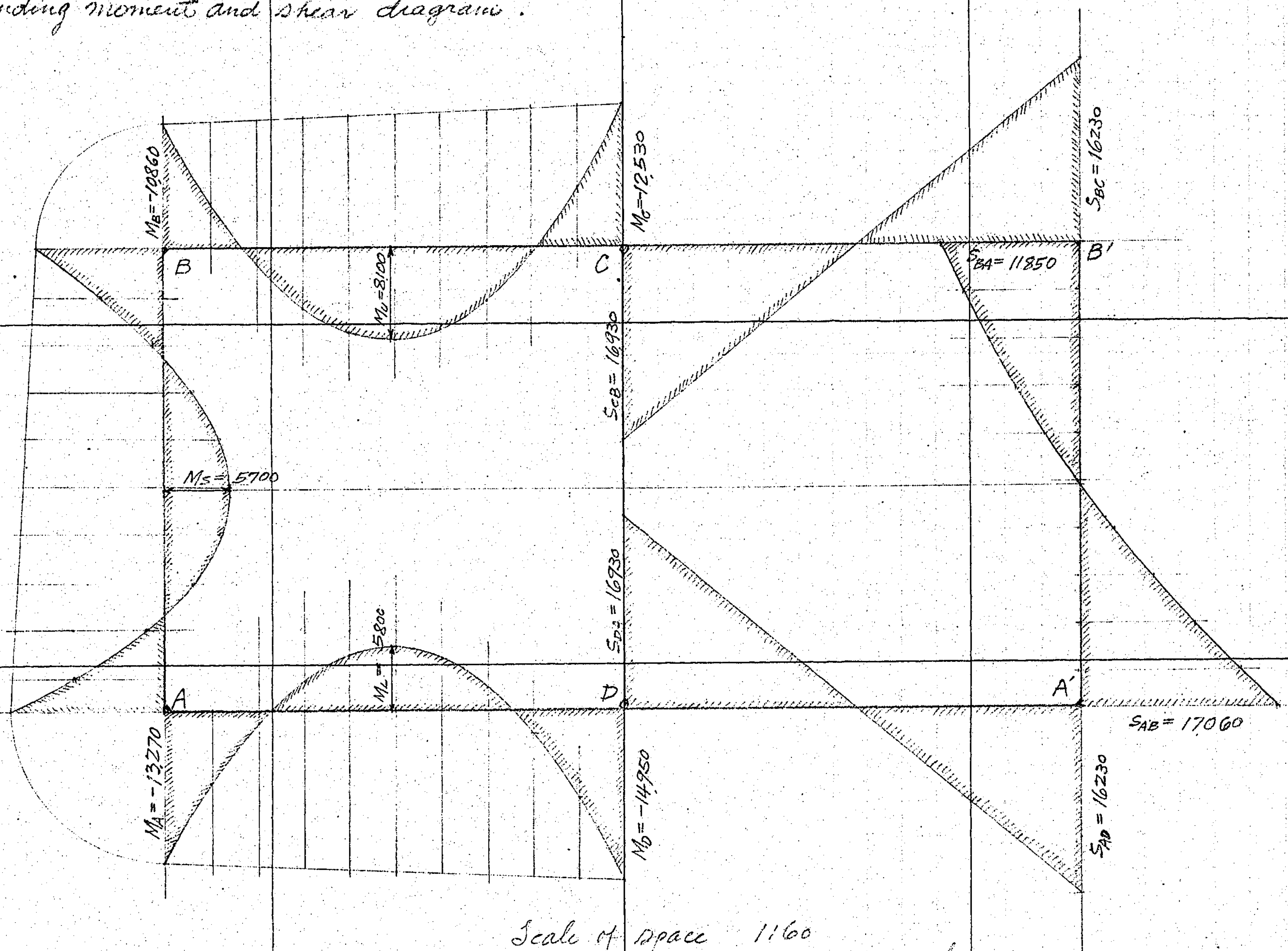
Use same arrangement of reinforcements as for (口型ノ下)

CALCULATIONS FOR
鐵筋混凝土口型ノ穴隧道

Axial compression in each member.

Top slab	$N_{BC} = S_{BA}$	=	11850 kg	for one meter strip
bottom slab	$N_{AD} = S_{AB}$	=	17060 "	"
Side walls	$N_{AB} = S_{BC}$	=	16230 "	"
Center column	$N_{CD} = 2S_{CB}$	=	33860 "	"
	33860×2.5	=	84700 "	for one column.

Bending moment and shear diagram:



Scale of space 1:60
" " moment 1/50ᵐ = 10,000 kgm
" " shear 1/50ᵐ = 10000 kg

Comparing this diagram with the one shown on page 27 (for normal state), we will find that the seismic stress which govern the section is $M_S = 5700$ kgm only.

Stress in side wall due to seismic positive moment.

$M_S = 5,700$ kgm for which axial compression $N_{AB} = 16230$ kg

Allowable unit stress being taken as 1.8 times of those for normal state.

$f_s = 1200 \times 1.8 = 2160$ kg/cm², $f_c = 47 \times 1.8 = 85$ kg/cm²

Effective depth required for moment $= 0.269\sqrt{\frac{5700 \times 100}{100}} = 20.3$ cm

use 31 cm effective depth with 5 cm insulation

CALCULATIONS FOR

鐵筋混凝土口型ノ穴隧道

Steel area required for moment $= \frac{5700 \times 100}{2160 \times \frac{7}{8} \times 31} = 9.73$ cm²

use 10 - 16φ bars = 20.11 cm²

$p = \frac{20.11}{31 \times 100} = 0.0065$, $k = 0.355$, $j = 0.882$

$f_s = \frac{5700 \times 100}{20.11 \times .882 \times 31} = 1035$ kg/cm²

$f_c = \frac{1035 \times .355}{15(1-.355)} = 38.0$

Direct stress say $\frac{16230}{100 \times 36} = \frac{4.5}{42.5}$ kg/cm²

All assumed sections are ample to carry seismic stresses.

鐵筋混凝土口型ノ十隧道

End shears.

$S_{BC} = \frac{7800 \times 5.18}{2} + \frac{-20310 + 9370}{5.18} = 20200 - 2110 = +18{,}090$ kg

$S_{CB} = -(20200 + 2110) = -22{,}310$ 〃

$S_{AD} = -20200 + \frac{21880 - 10940}{5.18} = -20200 + 2110 = -18{,}090$ 〃

$S_{DA} = 20200 + 2110 = +22{,}310$ 〃

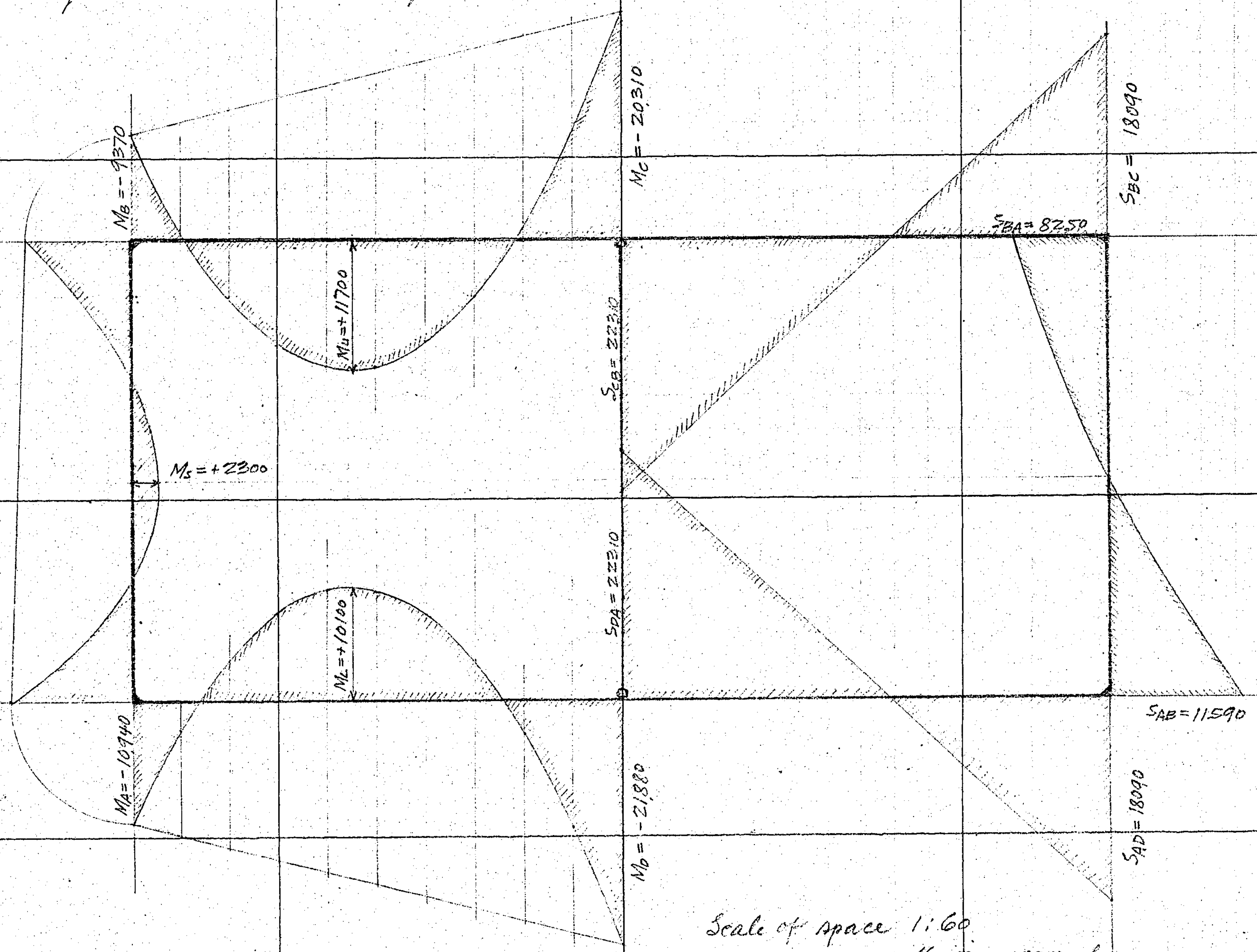
$S_{BA} = -8570 - \frac{-10940 + 9370}{4.94} = -8570 + 320 = -8250$ 〃

$S_{AB} = 11270 + 320 = +11{,}590$ 〃

Axial compression in each member.

Top slab N_{BC} = 8250 kg c for one meter strip of slab.
bottom 〃 N_{AD} = 11,590 〃 〃 〃
Side walls N_{AB} = 18,090 〃 〃 〃 wall
Center column N_{CD} = 44,620 〃 〃 〃 tunnel.
44620 × 2.5 = 111,600 kg c for one column.

Bending moment and shear diagram.

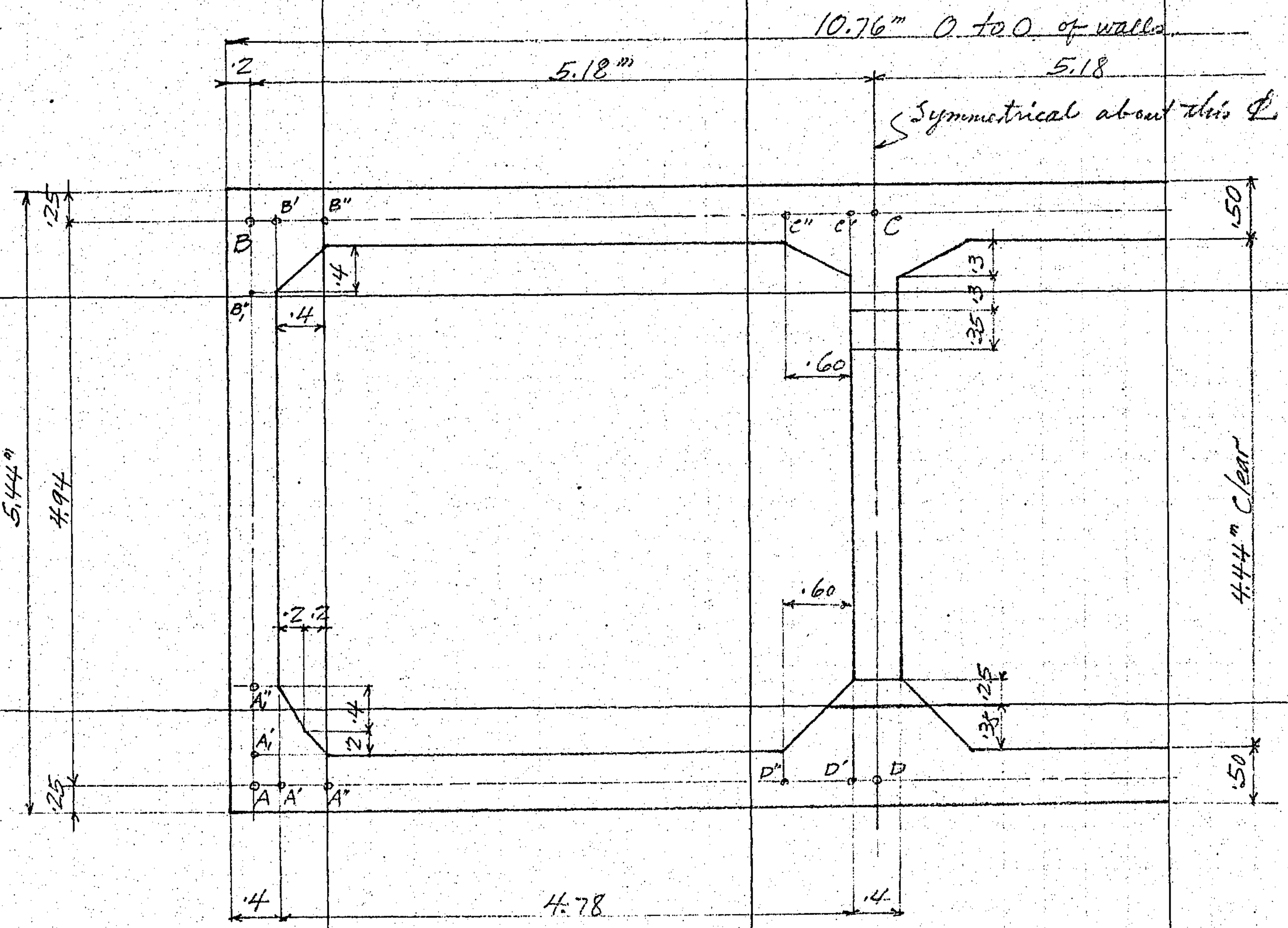


Scale of space 1:60
〃 〃 moment 1/50" = 10,000 kgm
〃 〃 shear 1/50" = 10,000 kg.

鐵筋混凝土口型ノ十隧道

Unit stress calculations.

Assumed cross section of the Tunnel, as shown below.



scale 1:60

Top and Bottom slab.

max. positive moment $M_U = + 11700$ kgm, axial compression $N_{BC} = 8250$ kg see page 16

" $M_L = + 10,100$ " , " " $N_{AD} = 11,590$ " "

Use 50 cm slab of which effective depth equals 45 cm, insulation being 5 cm.

Steel area required for bending $= \frac{11700 \times 100}{1200 \times 7/8 \times 45} = 24.75$ cm² per meter strip of slab,

Use 10 – 19mm⌀ bars = 28.35 cm²

$p = \frac{28.35}{100 \times 45} = 0.0063$, $k = 0.350$, $j = 0.883$.

$f_s = \frac{11700 \times 100}{28.35 \times .883 \times 45} = 1038$ kg/cm²

$f_c = \frac{1038 \times 0.35}{15(1-.35)} = 37.3$

direct comp. say $\frac{8250}{100 \times 50} = \underline{1.7}$

39.0 kg/cm²

Use same arrangement for both top and bottom slabs.

CALCULATIONS FOR

鐵筋混凝土口型ノ十隧道

Max. negative moment $M_C = -20310$ kgm, Axial compression $N_{BC} = 8250$ kg,
" $M_D = -21880$ " , " $N_{AD} = 11590$ "

For Top slab.
Use effective depth of 75 cm with 5 cm insulation.
Steel area required $= \frac{20310 \times 100}{1200 \times \frac{7}{8} \times 75} = 25.80$ cm² per meter strip.
Use 10-19mmφ bars = 28.35 cm²
$p = 0.0038$, $k = .285$, $j = .905$

$f_s = \frac{20310 \times 100}{28.35 \times .905 \times 75} = 1056$ kg/cm²

$f_c = \frac{1056 \times .285}{15 \times (1-.285)} = 28.1$

Direct stress say $\frac{8250}{80 \times 100} = \frac{1.0}{29.1}$ kg/cm²

moment at end of haunch C", $M_C'' = -5300$ kgm (measured in the moment diagram).
Axial compression $N_C'' = 8250$ kg.
use 7-19φ bars at least (for bond stress)

Vertical stirrups required.
Shear at point C' and D' = 20800 kg
" C" and D" = 16200 "

Using 3-U-stirrups of 9mmφ per meter strip, for which $A_s = 6 @ 0.636 = 3.81$ cm²

Stirrup spacing at point C'
$S' = \frac{3}{2} \cdot \frac{3.81 \times 1200 \times \frac{7}{8} \times 75}{20800} = 21.6$ cm. c to c

Stirrup spacing at point C"
$S' = \frac{3}{2} \cdot \frac{3.81 \times 1200 \times \frac{7}{8} \times 45}{16200} = 16.7$ cm c to c

Unit shear and bond stresses in top slab.
Unit shear
at C' $v = \frac{20800}{100 \times 0.905 \times 75} = 3.1$ kg/cm²

at C" $v = \frac{16200}{100 \times \frac{7}{8} \times 45} = 4.1$ "

Unit bond.
at C' $u = \frac{20800}{59.69 \times .905 \times 75} = 5.1$ kg/cm²

at C" $u = \frac{16200}{59.7 \times 7 \times \frac{7}{8} \times 45} = 9.8$ " use bent up bars.

鐵筋混凝土口型ノ十隧道

For Bottom slab.

Use 80 cm effective depth.

Steel 10-19φ = 28.35 cm²

Steel ratio $p = 0.0035$, $k = 0.276$ and $j = 0.908$

$f_s = \frac{21880 \times 100}{28.35 \times 0.908 \times 80} = 1,062$ kg/cm²

$f_c = \frac{1062 \times 0.276}{15(1-0.276)} = 27.0$

Direct stress say $\frac{11590}{85 \times 100} = \frac{1.4}{28.4}$ kg/cm²

Use simillar arrangement of reinforcements as for top slab.

Detail design of Side wall.

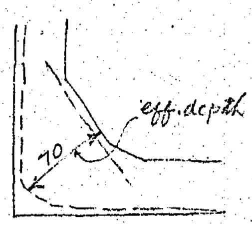
negative moment at bottom M_A = −10,940 kgm, axial compression N_{BA} = 18,090 kg

" " " top M_B = − 9,370 " , " " "

At point A.

Use 70 cm effective depth, 10-16φ bars = 20.11 cm²

$p = 0.0029$, $k = 0.255$, $j = 0.915$.



$f_s = \frac{10940 \times 100}{20.11 \times 0.915 \times 70} = 850$ kg/cm²

$f_c = \frac{850 \times 0.255}{15(1-0.255)} = 19.4$

direct stress say $\frac{18090}{100 \times 75} = \frac{2.4}{21.8}$ "

Unit shear $v = \frac{11590}{100 \times .915 \times 70} = 1.8$ "

Unit bond $u = \frac{11590}{50.27 \times .915 \times 70} = 3.6$ "

moment at end of haunch A_1'' $M_{A_1''}$ = − 2700 kgm, N = 18090 kg,

" " B_1'' $M_{B_1''}$ = − 4300 " , N = " " .

Using effective depth of 35 cm, and steel 6.67−16 mmφ bars = 13.4 cm² (15 cm ctoc average)

$p = 0.0038$, $k = 0.285$, and $j = 0.905$

$f_s = \frac{4300 \times 100}{13.4 \times 0.905 \times 35} = 1013$ kg/cm²

$f_c = \frac{1013 \times .285}{15(1-.285)} = 26.9$

direct stress say $\frac{18090}{100 \times 40} = \frac{4.5}{31.4}$ kg/cm².

Shear at A_1'' = 7,500 kg

" B_1'' = 6,500 "

Unit shear $v = \frac{7500}{100 \times .905 \times 35} = 2.4$ kg/cm²

Unit bond $u = \frac{7500}{5.03 \times 6.67 \times .905 \times 35} = 7.1$ " Use bent-up bars.

Reinforcements for positive moment will be governed by seismic moment, see on page 23.

Horizontal stirrups in side wall.
Use 5-9 mm φ stirrups (2.5 U) $A_s = 5@.636 = 3.18$ cm² per meter strip.

Stirrup spacing at A_1'' = $\frac{3}{2} \cdot \frac{3.18 \times 1200 \times \frac{7}{8} \times 35}{7500}$ = 23.3 cm c/c.

Center column.
Axial compression = 111,600 kg
Use same section as for 口型ノ十=.
Transformed section of column.
Concrete area 40 × 80 = 3200
Steel area equivalent to 20@2.011 × 15 = 603
3803 cm² of concrete

Unit compressive stress in concrete $f_c = \frac{111600}{3803} = 29.4$ kg/cm²

" " " in steel f_s = 29.4 × 15 = 440.

Use 9 mm φ hoops, spacing to be less than 12 × 16 = 19 cm c/c.
Use 10 cm spacings at top and bottom few spaces.

Design of longitudinal beams on top and bottom of column.
Span length = 2.50 meters.
Load on beam = 44620 kg per lin meter of span. see on page 16.
For top beam, use 105 cm effective depth with 5 cm insulation or 110 cm in total depth.
positive moment = $\frac{44620 \times 2.5^2}{12}$ = 23,300 kgm.

Use steel 8-19φ bars = 22.7 cm² neutral axis in flange.
$p = \frac{22.7}{160 \times 105} = 0.0014$, $k = 0.185$, and $j = 0.938$

$f_s = \frac{23300 \times 100}{22.7 \times .938 \times 105}$ = 1042 kg/cm²

$f_c = \frac{1042 \times .185}{15(1-.185)}$ = 15.8 "

Negative moment at support assumed as -23,300 kgm
Use effective depth of of 140 cm.
8-19φ bars = 22.7 cm²
$p = \frac{22.7}{40 \times 140} = 0.0041$, $k = 0.295$, and $j = 0.902$

$f_s = \frac{23300 \times 100}{22.7 \times .902 \times 140}$ = 813 kg/cm²

$f_c = \frac{813 \times .295}{15(1-.295)}$ = 22.7 "

Shear at end of haunch = 44620 × 0.5 m = 22,310 kg
" " face of column = 44620 × 0.85 = 37,900 "
Unit stress
at end of haunch. unit shear $v = \frac{22310}{40 \times \frac{7}{8} \times 105}$ = 6.1 kg/cm²

Use 12 mm φ U-stirrups, A_s = 2@1.13 = 2.26 cm²
Spacing = $\frac{3}{2} \cdot \frac{2.26 \times 1200 \times \frac{7}{8} \times 105}{22310}$ = 15.2 cm c/c.

Unit bond $u = \frac{22310}{8 \times 5.97 \times \frac{7}{8} \times 105}$ = 5.1 kg/cm²

at face of column. $v = \frac{37900}{40 \times 0.902 \times 140}$ = 7.5 kg/cm², $u = \frac{37900}{8 \times 5.97 \times .902 \times 140}$ = 6.3 kg/cm²

12φ U-stirrup spacing $s = \frac{3}{2} \cdot \frac{2.26 \times 1200 \times .902 \times 140}{37900}$ = 13.5 cm c/c.

CALCULATIONS FOR

鐵筋混凝土口型ノ十隧道

For Bottom Beam.

At center of span.

Effective depth being taken as 80 cm with 5 cm insulation.

$$\text{Steel area required} = \frac{23300 \times 100}{1200 \times 7/8 \times 80} = 27.8 \text{ cm}^2$$

use 10 – 19 mm φ bars = 28.35 cm²

$$p = \frac{28.35}{160 \times 80} = 0.0022, \quad k = 0.226, \quad j = 0.925$$

$$f_s = \frac{23300 \times 100}{28.35 \times .925 \times 80} = 1110 \text{ kg/cm}^2$$

$$f_c = \frac{1110 \times .226}{15(1-.226)} = 21.6 \text{ kg/cm}^2$$

At support.

Effective depth assumed as 105 cm with 5 cm insulation (width of beam 40 cm at top)

$$\text{Steel area required} = \frac{23300 \times 100}{1200 \times 7/8 \times 105} = 21.15 \text{ cm}^2$$

use 10 – 19 mm φ bars = 28.35 cm²

$$p = \frac{28.35}{40 \times 105} = .0068, \quad k = .361, \quad j = .88$$

$$f_s = \frac{23300 \times 100}{28.35 \times .88 \times 105} = 890 \text{ kg/cm}^2$$

$$f_c = \frac{890 \times .361}{15(1-.361)} = 33.6 \text{ "}$$

Unit shear at face of column, (Effective width of beam for shear assumed as 90 cm)

$$v = \frac{37900}{90 \times .88 \times 105} = 4.6 \text{ kg/cm}^2$$

$$\text{4–12 mm φ U-stirrup spacing} = \frac{3}{2} \cdot \frac{4 \times 1.13 \times 1200 \times .88 \times 105}{37900} = 19.8 \text{ cm ctoc}$$

$$\text{unit bond } u = \frac{37900}{10 \times 5.97 \times .88 \times 105} = 6.9 \text{ kg/cm}^2$$

Unit shear at end of haunch.

$$v = \frac{22310}{90 \times 7/8 \times 80} = 3.5 \text{ kg/cm}^2$$

$$\text{4–12φ U-stirrup spacing} = \frac{3}{2} \cdot \frac{4 \cdot 1.13 \times 1200 \times 7/8 \times 80}{22310} = 25.6 \text{ cm ctoc}$$

$$\text{Unit bond } u = \frac{22310}{8 \times 5.97 \times 7/8 \times 8} = 6.7 \text{ kg/cm}^2$$ use bent-up bars,

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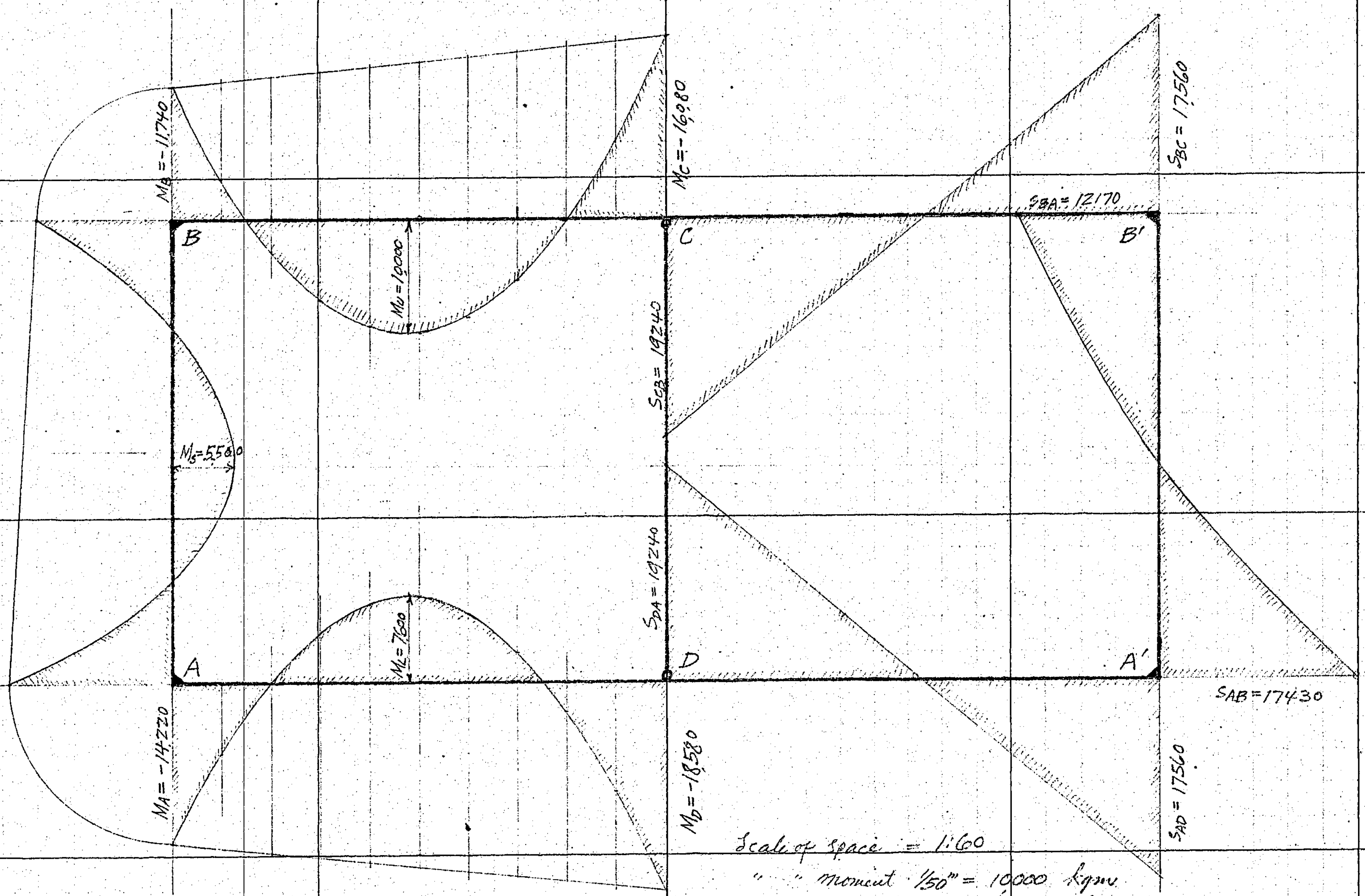
CALCULATIONS FOR

鐵筋混凝土口型ノ十隧道.

Moment and shear diagram.



note:
Seismic stress which govern the section is $M_s = 5500$ kgm only.

Stress in side wall due to seismic positive moment.

$M_S = 5500$ kgm, axial compression $N_{AB} = 17560$ kg.

Allowable stresses being taken as 1.8 times of those for normal state. $f_s = 2160$, $f_c = 85$ kg/cm²

Effective depth required for moment

$$d = 0.255\sqrt{\frac{5500\times100}{100}} = 18.9 \text{ cm}.$$

Use 35 cm effective depth with 5 cm insulation.

Steel area required for moment $= \frac{5500\times100}{2160\times\frac{7}{8}\times35} = 8.3$ cm²

Use 10 - 16φ bars = 20.11 cm²

$p = \frac{20.11}{35\times100} = 0.0058$, $k = 0.339$, and $j = 0.887$

$f_s = \frac{5500\times100}{20.11\times.887\times35} = 882$ kg/cm²

$f_c = \frac{882\times0.339}{15(1-.339)} = 30.1$

direct stress say $\frac{17560}{40\times100} = \underline{4.4}$

34.5 kg/cm²

All assumed sections are ample to carry seismic stresses.

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鐵筋混凝土口型ノ十二隧道

End shears.

$S_{BC} = \frac{wl}{2} + \frac{M_C - M_B}{l} = \frac{7800 \times 5.37}{2} + \frac{-22710 + 10350}{5.37} = 20950 - 2300 = +18650$ kg

$S_{CB} = \frac{wl}{2} + \frac{M_B - M_C}{l} = -(20950 + 2300) = -23250$ "

$S_{AD} = \frac{wl}{2} + \frac{M_D - M_A}{l} = 20950 + \frac{-23030 + 10670}{5.37} = -(20950 - 2300) = -18650$ kg

$S_{DA} = 20950 + 2300 = +23250$ "

$S_{BA} = R_{Bh} + \frac{M_A - M_B}{h} = 8560 + \frac{-10670 + 10350}{4.94} = -(8560 - 60) = -8500$ kg

$S_{AB} = R_{Ah} + \frac{M_B - M_A}{h} = 11270 + 60 = +11330$ "

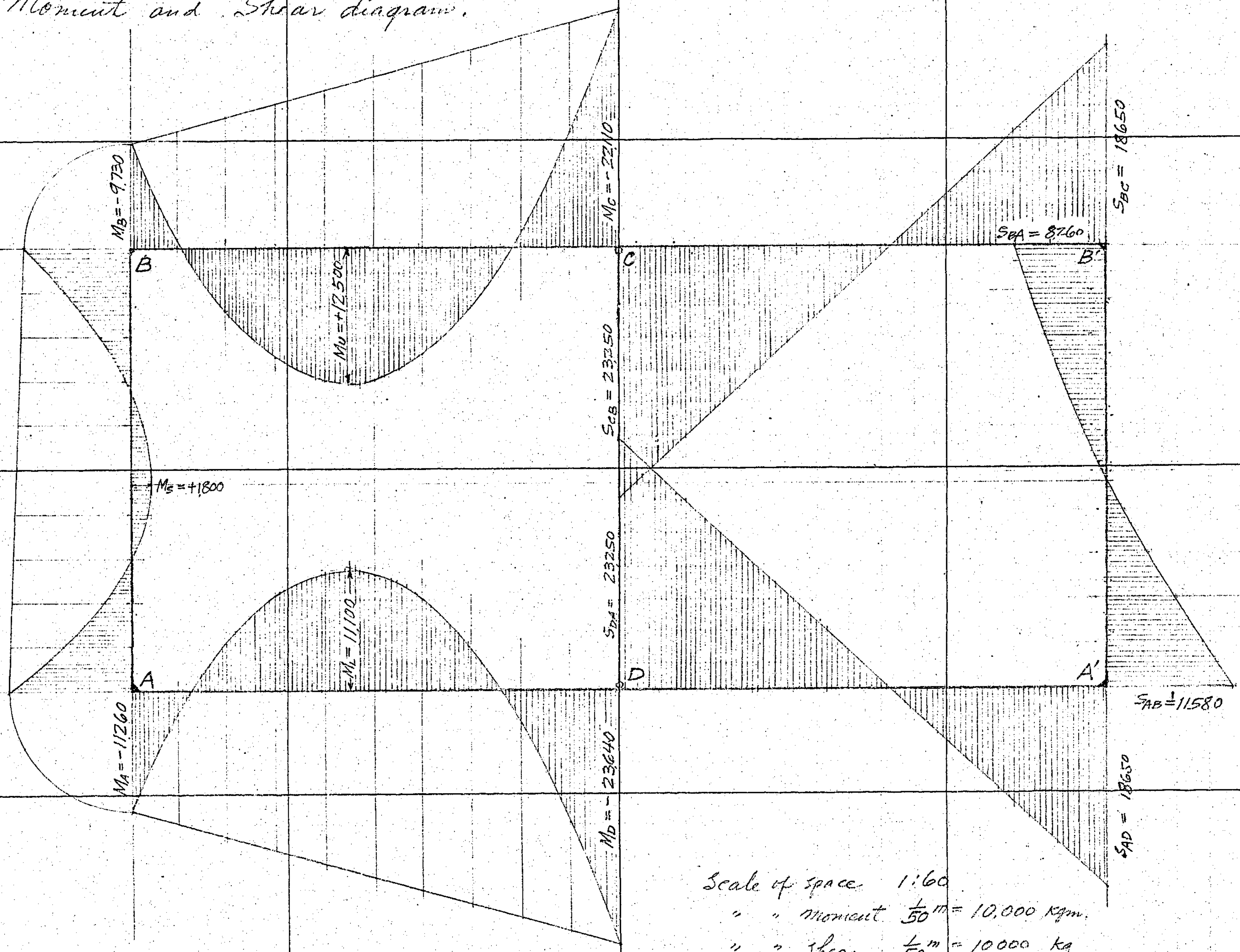
Axial compression in each member.

Top slab $N_{BC} = S_{BA} = 8500$ kg c for one meter strip of tunnel.
bottom slab $N_{AD} = S_{AB} = 11330$ " c "

Side walls. $N_{AB} = S_{BC} = 18650$ " c "

Center column $N_{CD} = 2 S_{CB} = 46500$ " c "
$46500 \times 2.5 = 116300$ " c for one center column.

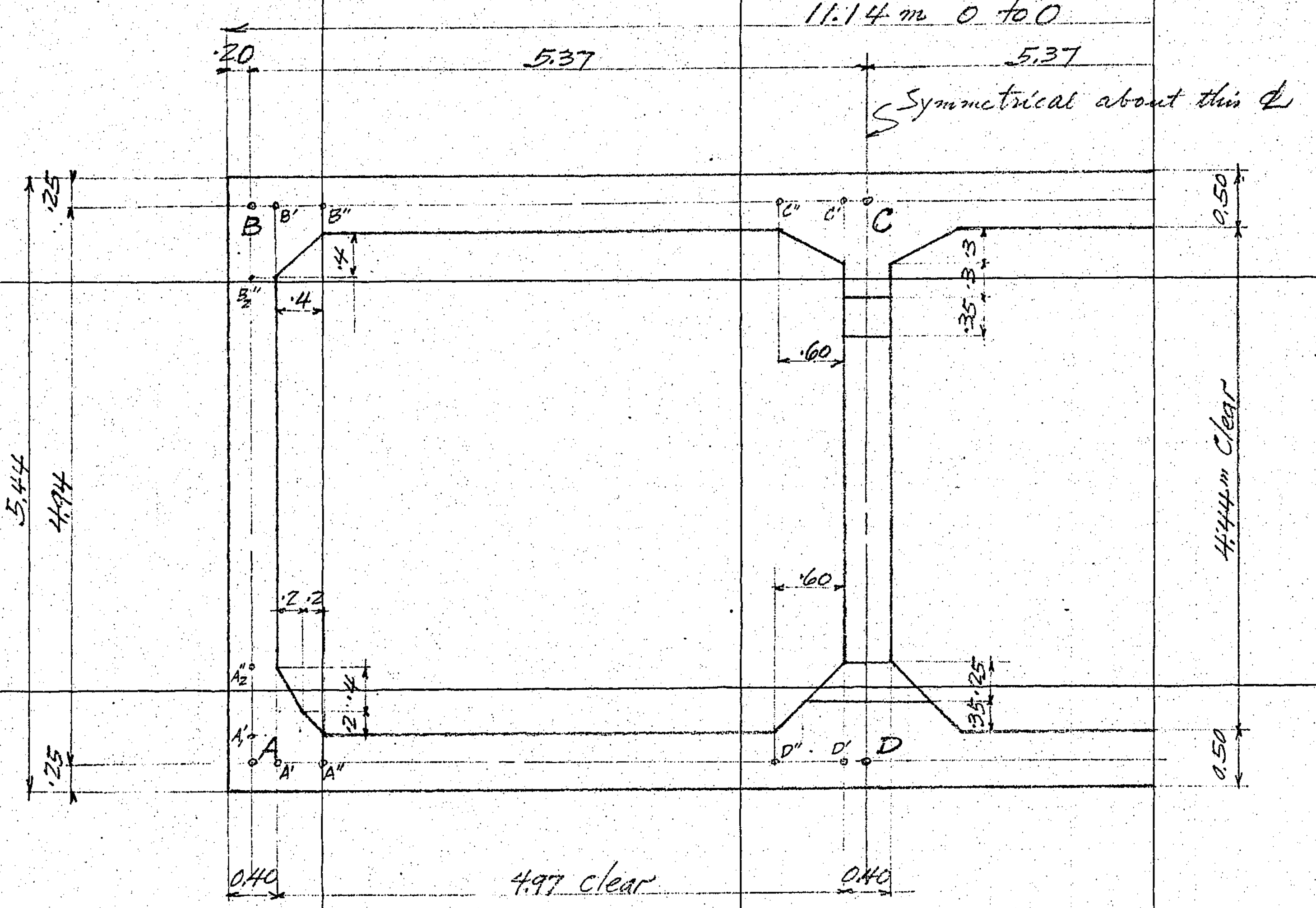
Moment and Shear diagram.



Scale of space 1:60
" " moment $\frac{1}{50}$m = 10,000 kgm.
" " shear $\frac{1}{50}$m = 10,000 kg.

CALCULATIONS FOR
鐵筋混凝土口型ノ什二隧道

Unit stress calculations.
Assumed cross section of the Tunnel.



Scale 1:60.

Top and Bottom slab.

max. positive moment $M_U = +12,500$ kgm axial compression $N_{BC} = 8260$ kg see moment diagram
" " " $M_L = +11,100$ " " " $N_{AD} = 11,580$ " on page 4

Effective depth required for bending moment $d = C_1\sqrt{\frac{M}{b}}$ where $b = 100$ cm, $C_1 = 0.362$ for $\{f_s = 1200,\ f_c = 47\}$

$$d = 0.362\sqrt{\frac{12500\times100}{100}} = 40.5 \text{ cm}$$

use 45 cm effective depth with an insulation of 5 cm; total depth = 50 cm.

Steel area required $= \frac{12500\times100}{1200\times\frac{7}{8}\times45} = 26.45$ cm² per meter strip of slab.

use 10 − 19 mmφ bars = 28.35 cm² " "

Steel ratio $p = \frac{28.35}{100\times45} = 0.0063$, $k = 0.350$, $j = 0.883$

Steel stress $f_s = \frac{12500\times100}{28.35\times0.883\times45} = 1,110$ kg/cm²

Concrete stress $f_c = \frac{1,110\times0.350}{15(1-0.350)} = 39.8$

direct stress $= \frac{8260}{100\times50} = \frac{1.7}{41.5}$ kg/cm²

Use same arrangement for both top and bottom slabs.

CALCULATIONS FOR

鐵筋混凝土口型ハ十二隧道

Max. negative moment $M_C = 22{,}110$ kgm, axial compression $N_{BC} = 8260$ kg
" " " $M_D = 23{,}640$ " " " $N_{AD} = 11{,}580$ "

For Top slab.

Effective depth required $= 0.362\sqrt{\frac{22110\times100}{100}} = 53.8$ cm

Use 75 cm effective depth.

Steel area req'd. for bending $= \frac{22110\times100}{1200\times\frac{7}{8}\times75} = 28.10$ cm² per meter strip of slab.

Use 10-19 mmφ bars $= 28.35$ cm²

Steel ratio $p = \frac{28.35}{75\times100} = 0.0038$, $k = 0.285$, $j = 0.905$

$f_s = \frac{22110\times100}{28.35\times0.905\times75} = 1{,}148$ kg/cm²

$f_c = \frac{1148\times0.285}{15(1-0.285)} = 30.5$

direct stress $\frac{8260}{80\times100} = \frac{1.0}{31.5}$ kg/cm²

Moment at the end of haunch C", $M_{C''} = -6000$ kgm (measured in the moment diagram)
axial compression $N_{C''} = 8260$ kg C

Use 7-19φ bars at least.

Stirrups required.
Shear at point C' and D' $= 21{,}700$ kg $= V$
" " C" and D" $= 18{,}200$ " = "

Using 3 - U-stirrups of 9 mmφ for which $A_s = 6 @ 0.636 = 3.81$ cm² per m. strip.

Stirrup spacing req'd. at point C'

$s' = \frac{3}{2}\cdot\frac{A_s f_s j d}{V} = \frac{3}{2}\cdot\frac{3.81\times1200\times\frac{7}{8}\times75}{21700} = 20.8$ cm c to c.

Stirrup spacing req'd. at point C"

$s'' = \frac{3}{2}\cdot\frac{3.81\times1200\times\frac{7}{8}\times45}{18200} = 14.8$ cm c to c

Unit shear and bond stress in top slab.

Unit shear

at C' $v = \frac{21700}{100\times0.905\times75} = 3.2$ kg/cm²

at C" $v = \frac{18200}{100\times\frac{7}{8}\times45} = 4.6$ "

Unit bond

at C' $u = \frac{21700}{59.69\times.905\times75} = 5.35$ kg/cm²

at C" $u = \frac{18200}{5.97\times7\times\frac{7}{8}\times45} = 11.00$ " use bent up bars.

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CALCULATIONS FOR

鐵筋混凝土口型/十二隧道

For Bottom slab.

Use 80 cm effective depth.

steel 10 - 19 mmϕ bars = 28.35 cm²

steel ratio $p = \frac{28.35}{80 \times 100} = 0.0035$ $k = 0.276$, $j = 0.908$

$f_s = \frac{23640 \times 100}{28.35 \times 0.908 \times 80} = 1148$ kg/cm²

$f_c = \frac{1148 \times .276}{15(1-.276)} = 29.2$

direct stress $= \frac{11580}{85 \times 1000} = \underline{1.4}$
30.6 "

Use simillar arrangement of reinforcements as for top slab.

Detail design of side wall.

negative moment at bottom $M_A = -11260$ kgm, axial compression $N_{BA} = 18650$ kg

" " " top $M_B = -9730$ " , " " $N_{AB} = 18650$ "

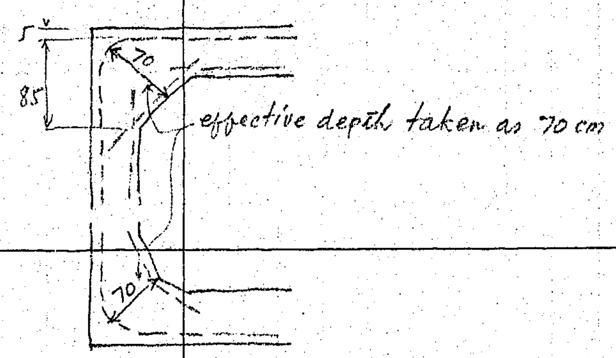
At Point A.

Effective depth required $= 0.362 \sqrt{\frac{11260 \times 100}{100}} = 38.4$ cm, use 70 cm

Steel area required $= \frac{11260 \times 100}{1200 \times \frac{7}{8} \times 70} = 15.3$ cm² for one meter strip of wall,

Use 10 - 16 mmϕ bars = 20.11 cm²

$p = \frac{20.11}{100 \times 70} = 0.0029$, $k = 0.255$, $j = 0.915$



$f_s = \frac{11260 \times 100}{20.11 \times .915 \times 70} = 873$ kg/cm²

$f_c = \frac{873 \times 0.255}{15(1-0.255)} = 19.9$

direct stress $= \frac{18650}{100 \times 75} = \underline{2.5}$
22.4 "

Unit shear $v = \frac{11580}{100 \times 0.915 \times 70} = 1.8$ kg/cm²

unit bond $u = \frac{11580}{50.27 \times 0.915 \times 70} = 3.6$ "

At end of haunch A_1'' $M_{A_1}'' \doteqdot -4000$ kgm, axial compression = 18650 kg

" " B_1'' $M_{B_1}'' \doteqdot -5000$ " " "

Effective depth reqd. $= 0.362 \sqrt{\frac{5000 \times 100}{100}} = 25.6$ cm use $d = 35$ cm

Steel area required $= \frac{5000 \times 100}{1200 \times \frac{7}{8} \times 35} = 13.6$ cm²

use 6.67 bars of 16 mmϕ (15 cm ctoc average) = 13.4 cm²

$p = \frac{13.4}{35 \times 100} = 0.0038$, $k = 0.285$, $j = 0.905$

$f_s = \frac{5000 \times 100}{13.4 \times 0.905 \times 35} = 1177$ kg/cm²

$f_c = \frac{1177 \times .285}{15(1-.285)} = 31.3$

direct stress $= \frac{18650}{100 \times 40} = \underline{4.7}$
36.0 kg/cm²

Reinforcements for Positive moment will be governed by seismic moment, see on page 13.

Shear at A_1'' = 7500 kg,
B_1'' = 6500 "

unit shear = $\frac{7500}{100 \times 0.905 \times 35}$ = 2.4 kg/cm²

unit bond = $\frac{7500}{5.03 \times 6.67 \times .905 \times 35}$ = 7.1 " use bent up bars.

Horizontal stirrups in side wall.
use 5 − 9 mm φ bars, As = 5 @ 0.636 = 3.18 cm² per meter strip

Stirrup spacing at A_1'' = $\frac{3}{2} \frac{3.18 \times 1200 \times \frac{7}{8} \times 35}{7500}$ = 23.3 cm c to c.

Design of Center column.
Axial compression on one column = 116300 kg
Try a column section of 40×80 cm with 20−16φ reinforcements.
Transformed area of section
concrete 40×80 = 3200
steel 20 @ 2.011 × 15 = 603
3803 cm²

unit compressive stress f_c = $\frac{116300}{3803}$ = 30.6 kg/cm²
" " f_s = 30.6 × 15 = 460 "

use 9φ hoops, spacings to be less than 12×16 = 19 cm c to c.
use 10 cm spacings for top and bottom few spaces.

Design of longitudinal beams on top and bottom of column.
Span length = 2.5 meter

Load on beam 46500 kg per lin meter, see on page 4.
moment assumed as ± $\frac{wl^2}{12}$ = $\frac{46500 \times 2.5^2}{12}$ = ±24200 kgm
For Top Beam.
At center of span.
Effective depth reqd. as a rectangular beam $d = 0.362\sqrt{\frac{24200 \times 100}{160}}$ = 44.5 cm

use 105 cm eff. depth with an insulation of 5 cm, or 110 cm in total.

Steel area reqd = $\frac{24200 \times 100}{1200 \times \frac{7}{8} \times 105}$ = 22.0 cm²

use 8−19φ bars = 22.7 cm²

For this case neutral axis in the flange, design as a rectangular beam.
$p = \frac{22.7}{160 \times 105}$ = 0.0014, k = .185, j = .938

$f_s = \frac{24200 \times 100}{22.7 \times .938 \times 105}$ = 1082 kg/cm²

$f_c = \frac{1082 \times .185}{15(1-.185)}$ = 16.4 kg/cm²

For negative moment at support
Effective depth required = $0.362\sqrt{\frac{24200 \times 100}{40}}$ = 89.0 cm

use effective depth of 140 cm

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CALCULATIONS FOR

鐵筋混凝土口型トンネル隧道

Steel area reqd. = $\frac{24200 \times 100}{1200 \times \frac{7}{8} \times 140}$ = 16.50 cm²

use 8-19φ = 22.7 cm²

$p = \frac{22.7}{40 \times 140}$ = 0.0041 , k = 0.295 , j = 0.902

$f_s = \frac{24200 \times 100}{22.7 \times 0.902 \times 140}$ = 844 kg/cm²

$f_c = \frac{844 \times .295}{15(1-.295)}$ = 23.6 "

Shear at end of haunch = 46500 × 0.5" = 23300 kg

" " face of column = 46500 × 0.85 = 39500 "

Unit stress

at end of haunch $v = \frac{23300}{40 \times 7/8 \times 105}$ = 6.3 kg/cm²

use 12mmφ U-stirrups A_s = 2 × 1.13 = 2.26 cm²

Spacing = $\frac{3}{2} \cdot \frac{2.26 \times 1200 \times \frac{7}{8} \times 105}{23300}$ = 16.0 cm c to c.

~~Unit bond = u = $\frac{23300}{8 \times 5.97 \times \frac{7}{8} \times 105}$ = 5.3 kg/cm² use bent-up bars~~

at face of column. $v = \frac{39500}{40 \times 0.902 \times 140}$ = 7.8 "

Spacing of 12φ U-stirrups = $\frac{3}{2} \cdot \frac{2.26 \times 1200 \times .902 \times 140}{39500}$ = 13.0 cm c to c.

Unit bond u = $\frac{39500}{8 \times 5.97 \times 0.902 \times 140}$ = 6.5 kg/cm² use bent-up bars

For Bottom Beam.

At center of span. Effective depth being taken as 80 cm with 5 cm insulation.

Steel area reqd. = $\frac{24200 \times 100}{1200 \times \frac{7}{8} \times 80}$ = 28.8 cm²

use 10-19mmφ bars = 28.35 cm²

$p = \frac{28.35}{160 \times 80}$ = 0.0022 , k = .226 , j = .925 .

$f_s = \frac{24200 \times 100}{28.35 \times .925 \times 80}$ = 1152 kg/cm²

$f_c = \frac{1152 \times .226}{15(1-.226)}$ = 22.4 "

At support. Effective depth assumed as 105 cm with 5 cm insulation. (width of beam 40 cm at top)

Steel area reqd. = $\frac{24200 \times 100}{1200 \times \frac{7}{8} \times 105}$ = 22.0 cm²

~~use 10-19φ bars = 28.35 cm²~~

$p = \frac{28.35}{40 \times 105}$ = 0.0068 , k = .361 , j = .880 .

$f_s = \frac{24200}{28.35 \times .880 \times 105}$ = 924 kg/cm²

$f_c = \frac{924 \times .361}{15(1-.361)}$ = 34.8 "

Unit shear at face of column $v = \frac{39500}{90 \times .880 \times 105}$ = 4.8 kg/cm² (Effective width for shear assumed as 90 cm)

4-12φ U-Stirrup spacing = $\frac{3}{2} \times \frac{4 \times 1.13 \times 1200 \times .880 \times 105}{39500}$ = 19.0 cm c to c.

Unit bond u = $\frac{39500}{10 \times 5.97 \times .88 \times 105}$ = 7.2 kg/cm² use bent-up bars

Unit shear at end of haunch $v = \frac{23300}{90 \times \frac{7}{8} \times 80}$ = 3.7 kg/cm²

4-12φ U-Stirrup spacing = $\frac{3}{2} \times \frac{4 \times 1.13 \times 1200 \times 7/8 \times 80}{23300}$ = 24.4 cm c to c.

Unit bond u = $\frac{23300}{8 \times 5.97 \times \frac{7}{8} \times 80}$ = 7.0 kg/cm² use bent-up bars.

CALCULATIONS FOR

鐵筋混凝土口型ノ十二隧道

End shears.

$S_{BC} = \frac{7100 \times 5.37}{2} + \frac{-17750+12050}{5.37} = 19080 - 1060 = +18020$ kg

$S_{CB} = -19080 - 1060 = -20140$ 〃

$S_{AD} = -19080 + \frac{20190-14480}{5.37} = -19080 + 1060 = -18020$ 〃

$S_{DA} = 19080 + 1060 = +20140$ 〃

$S_{BA} = -12650 + \frac{14480-12050}{4.94} = -12650 + 490 = -12160$ 〃

$S_{AB} = 16950 + 490 = +17440$ 〃

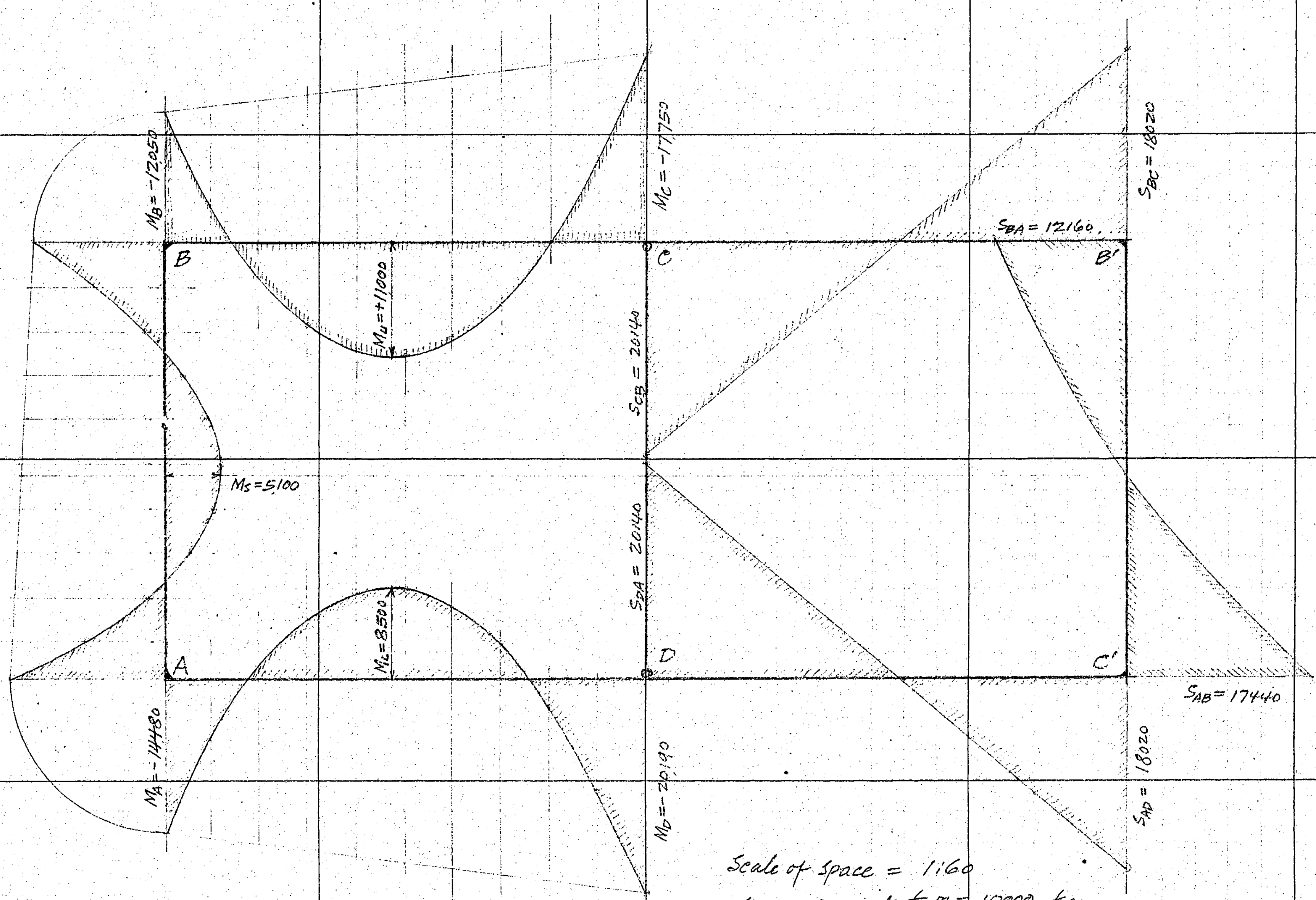
Axial compression in each member.

Top slab. $N_{BC} = S_{BA} = 12160$ kg c for one meter strip of tunnel.
bottom 〃 $N_{AD} = S_{AB} = 17440$ 〃 〃 〃

Side walls $N_{AB} = S_{BC} = 18020$ 〃 〃 〃

Center column $N_{CD} = 2S_{CB} = 40280$ 〃 〃 〃
$40280 \times 2.5 = 100700$ 〃 〃 for one column.

Moment and shear diagram.



Scale of space = 1:60
〃 〃 moment $\frac{1}{50}$ m = 10000 kgm
〃 〃 Shear $\frac{1}{50}$ m = 10000 kg

Note: Seismic stress which govern the section is Ms = 5100 kgm only.

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CALCULATIONS FOR

鐵筋混凝土口型ハ十二隧道

Stresses in side wall due to seismic positive moment.

M_s = 5100 kgm, axial compression N_{AB} = 18020 kg

Allowable stress being taken as $f_s = 1200 \times 1.8 = 2160$, $f_c = 47 \times 1.8 = 85$ kg/cm², $C_1 \doteqdot 0.255$ (by curve).

Effective depth required for moment = $0.255 \sqrt{\frac{5100 \times 100}{100}}$ = 18.2 cm

Use 35 cm effective depth with an insulation of 5 cm

Steel area req'd, for moment = $\frac{5100 \times 100}{2160 \times \frac{7}{8} \times 35}$ = 7.7 cm²

Use 10 - 16 mmφ bars = 20.11 cm²

$p = \frac{20.11}{35 \times 100} = 0.0058$, $k = 0.339$, $j = 0.887$

$f_s = \frac{5100 \times 100}{20.11 \times .887 \times 35}$ = 817 kg/cm²

$f_c = \frac{817 \times .339}{15(1 - .339)}$ = 27.9

Direct stress say $\frac{18020}{100 \times 40}$ = 4.5

32.4 "

All assumed sections are ample for seismic stresses.

鐵筋混凝土イ型ノ十二隧道

Top and Bottom slab

Max. positive moment M_{U1} = + 9,400 kgm axial compression N_{BC} = 8,700 kgs see moment digram on page 5

" " " M_{L1} = + 9,100 " " " N_{AD} = 11,620 "

" " " M_{U2} = + 3,300 " " " $N_{CC'}$ = 8,700 "

" " " M_{L2} = + 3,500 " " " $N_{DD'}$ = 11,620 "

For slab BC,

Effective depth required for bending moment $d = C_1\sqrt{\frac{M}{b}}$ where $b = 100^{cm}$, $C_1 = 0.362$ for $f_s = 1200$, $f_c = 47$

$d = 0.362 \times \sqrt{\frac{9400\times100}{100}} = 35.1^{cm}$

Use 39 cm effective depth with an insulation of 5 cm, total depth = 44 cm

Steel area required $= \frac{9400\times100}{1200\times 7/8\times39} = 22.95\ cm^2$ per meter strip of slab

use 10 - 19$^{mm\phi}$ bars = 28.35 cm² per meter strip of slab

steel ratio $p = \frac{28.35}{100\times39} = 0.00727$, $k = 0.371$, $j = 0.876$

steel stress $f_s = \frac{9400\times100}{28.35\times0.876\times39} = 971\ kgs/cm^2$

concrete stress $f_c = \frac{971\times0.371}{15(1-0.371)} = 38.2\ kgs/cm^2$

direct stress $= \frac{8700}{100\times44} = 2.0$

$40.2\ kg/cm^2$

For slab DD',

Slab depth same as for slab BC,

Steel area required $= \frac{3500\times100}{1200\times7/8\times39} = 8.55\ cm^2$ per meter strip of slab

use 19$^{mm\phi}$ Spacings 13.3 cm c. to c. 7.50 × 2.835 = 21.2 cm² "

steel ratio $p = \frac{21.2}{100\times39} = 0.00544$, $k = 0.330$, $j = 0.890$

steel stress $f_s = \frac{3500\times100}{21.2\times0.890\times39} = 475\ kg/cm^2$

Concrete stress $f_c = \frac{475\times0.330}{15(1-0.330)} = 15.6$ "

direct stress $= \frac{11620}{100\times44} = 2.6$ "

$18.2\ kg/cm^2$

Use same arrangement for both top and bottom slabs.

Max. negative moment M_C = 13,090 kgm, axial compression $N_{BC} = N_{CC'}$ = 8,700 kgs

" " " M_D = 12,940 " , " " $N_{AD} = N_{DD'}$ = 11,620 "

For Top slab

Effective depth required $= 0.362\sqrt{\frac{13090\times100}{100}} = 41.4$ cm

use 69 cm effective depth

steel area required for Bending $= \frac{13090\times100}{1200\times7/8\times69} = 18.06\ cm^2$

use 19$^{mm\phi}$ Spacings 10 cm c. to c. 10 × 2.835 = 28.35 cm²

steel ratio $p = \frac{28.35}{100\times69} = 0.00411$ $k = 0.295$, $j = 0.902$

steel stress $f_s = \frac{13090\times100}{28.35\times0.902\times69} = 742\ kg/cm^2$

Concrete stress $f_c = \frac{742\times0.295}{15(1-0.295)} = 20.7$ "

direct stress $= \frac{8700}{100\times74} = 1.2$ "

$21.9\ kg/cm^2$

For bottom slab

use 64^{cm} effective depth

$A_s = \frac{12940\times100}{1200\times7/8\times64} = 19.25^{cm^2}$

$p = \frac{28.35}{100\times64} = 0.0044$

$k = .303$, $j = .899$

$f_s = \frac{12940\times100}{28.35\times.899\times64} = 793\ kg/cm^2$

$f_c = \frac{793\times.303}{15(1-.303)} = 23.0$ "

direct C $= \frac{11620}{100\times69} = 1.7$ "

24.7 "

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CALCULATIONS FOR

鐵筋混凝土イ型,十二隧道

Moment at the haunch C_2' $M_{C_2'} = -2600$ kgm (measured in the moment digram)
Axial compression $N_{C_2'} = 9800$ kgs

Use 19 mmφ bars, spacing 13.3 cm c. to c.

Shearing and bond stresses in top and bottom slab

shear at point	B_1 =	16,100 kgs = V	✓
〃 〃 〃	A_1 =	16,300 〃	〃 ✓
〃 〃 〃	A_2 =	13,000 〃	〃 ✓
〃 〃 〃	B_2 =	12,800 〃	〃 ✓
〃 〃 〃	C_1 =	17,600 〃	〃
〃 〃 〃	C_2 =	12,700 〃	〃
〃 〃 〃	D_1 =	17,400 〃	〃
〃 〃 〃	D_2 =	12,500 〃	〃
〃 〃 〃	C_1', D_1' =	14,800 〃	〃
〃 〃 〃	C_2', D_2' =	10,000 〃	〃

Unit shear

at B_1 $v = \dfrac{16,100}{100 \times 7/8 \times 79} = 2.33$ kg/cm²

at A_2 $v = \dfrac{13000}{100 \times 7/8 \times 39} = 3.80$ 〃

at C_1 $v = \dfrac{17,600}{100 \times 0.902 \times 69} = 2.83$ 〃

at C_2 $v = \dfrac{12700}{100 \times 7/8 \times 39} = 3.72$ 〃

unit bond

at C_1 $u = \dfrac{17,600}{10 \times 5.96 \times 0.902 \times 69} = 4.75$ kg/cm²

at C_2 $u = \dfrac{12700}{7.5 \times 5.96 \times 7/8 \times 39} = 8.32$ 〃 use bent up bars

Stirrups required

Using 3-U-stirrups of 9 mmφ for which $6 \times 0.636 = 3.81$ cm² per meter strip.

Stirrup spacing required at point C_1

$S_1 = \dfrac{3}{2} \dfrac{A_s f_s j d}{V} = \dfrac{3}{2} \times \dfrac{3.81 \times 1200 \times 7/8 \times 69}{17,600} = 23.5$ cm c. to c.

Stirrup spacing required at point C_2

$S_2 = \dfrac{3}{2} \times \dfrac{3.81 \times 1200 \times 7/8 \times 39}{12,700} = 18.4$ cm c. to c.

Detail design of side wall.

negative moment at bottom $M_A = -10,050$ kgm, axial compression $N_{BA} = 17,570$ kgs
〃 〃 〃 top $M_B = -9,370$ 〃, 〃 〃 N_{AB} = 〃 〃

at point A

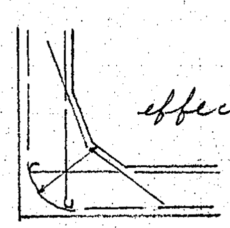
Effective depth required $= 0.362 \sqrt{\dfrac{10050 \times 100}{100}} = 36.3$ cm use 68 cm

Steel area required $= \dfrac{10050 \times 100}{1200 \times 7/8 \times 68} = 14.08$ cm² for one meter strip of wall

use 10-16 mmφ bars = 20.11 cm²

$p = \dfrac{20.11}{100 \times 68} = 0.00296$, $k = 0.258$

$j = 0.914$



effective depth taken as 68 cm

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$f_s = \frac{10050 \times 100}{2011 \times 0.914 \times 68} = 804 \text{ kg/cm}^2$

$f_c = \frac{804 \times 0.258}{15(1-0.258)} = 18.64$ 〃

direct stress $= \frac{17570}{100 \times 68} = \underline{2.58}$ 〃

21.22 kg/cm²

unit shear $v = \frac{11620}{100 \times .914 \times 68} = 1.87$ 〃

unit bond $u = \frac{11620}{50.27 \times .914 \times 68} = 3.72$ 〃

at end of haunch $A_2' = 2,500$ kgm, axial compression $N_{BA} = 17,570$ kgs
$B_2' = 4,500$ 〃 〃 〃 〃

Effective depth required $= 0.362\sqrt{\frac{4500 \times 100}{100}} = 24.3$ cm use 31 cm

Steel area required $= \frac{4500 \times 100}{1200 \times 7/8 \times 31} = 13.8 \text{ cm}^2$ for one meter strips of wall.
use 10-16 mmφ bars = 20.11 cm²

$p = \frac{20.11}{100 \times 31} = 0.00649$, $k = 0.355$, $j = 0.882$

$f_s = \frac{4500 \times 100}{20.11 \times 0.882 \times 31} = 820 \text{ kg/cm}^2$

$f_c = \frac{820 \times 0.355}{15(1-0.355)} = 30.10$ 〃

direct stress $= \frac{17570}{100 \times 36} = \underline{4.88}$ 〃

34.98 kg/cm²

Reinforcement for positive moment will be governed by seismic moment,

shear at $A_2' = 7200$ kgs
$B_2' = 7,000$ 〃

unit shear $v = \frac{7200}{100 \times .882 \times 31} = 2.64 \text{ kg/cm}^2$

unit bond $u = \frac{7200}{50.27 \times .882 \times 31} = 5.25$ 〃

unit bond at B_2

$u = \frac{12800}{50.27 \times 7/8 \times 39} = 7.45$ 〃 use bent up bars

Design of Center Columns
axial compression on one column = 89,100 kgs
Try a column section of 40 × 60 cm with 16-16φ reinforcements.
tranformed area of section

Concrete	40 × 60	=	2400
steel	16 e 20.11 × 14	=	450
			2850 cm²

unit compressive stress $f_c = \frac{89100}{2850} = 31.3 \text{ kg/cm}^2$

〃 〃 〃 $f_s = 15 \times 31.3 = 470$ 〃

Use 9φ hoops, spacings to be less than 12 × 16 = 19 cm c. to c.
use 10 cm spacings for top and bottom few spaces.

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CALCULATIONS FOR

鐵筋混凝土イ型ノ十二隧道

Design of longitudinal beams on top and bottom of column
Span length 2.50 meters

Load on beam 35,660 kgs per lin. meter, see page 5.
moment assumed as $\pm \frac{wl^2}{12} = \frac{35660 \times 2.50^2}{12} = \pm 18,550$ kgm

at center of span
Effective depth req'd as a rectangular beam $d = 0.362\sqrt{\frac{18550 \times 100}{160}} = 39.0$ cm

For top beam 96.5 cm effective depth with an insulation of 7.5 cm or 104 cm in total.

steel area required $= \frac{18550 \times 100}{1200 \times 7/8 \times 96.5} = 18.3$ cm²

use 8-19mmφ bars = 22.7 cm²

For this case neutral axis in the flange, design as a rectangular beam.
$p = \frac{22.7}{160 \times 96.5} = 0.0015$, $k = .191$, $j = 0.936$

$f_s = \frac{18550 \times 100}{22.7 \times 0.936 \times 96.5} = 903$ kg/cm²

$f_c = \frac{903 \times .191}{15(1-.191)} = 14.3$ "

For negative moment at support
Effective depth required $= 0.362\sqrt{\frac{18550 \times 100}{40}} = 77.9$ cm

use effective depth of 131.5 cm

steel area req'd $= \frac{18550 \times 100}{1200 \times 7/8 \times 131.5} = 13.45$ cm²

use 8-19mmφ bars = 8 × 2.835 = 22.70 cm²

$p = \frac{22.70}{40 \times 131.5} = 0.0043$, $k = 0.300$, $j = 0.900$

$f_s = \frac{18550 \times 100}{22.70 \times 0.900 \times 131.5} = 690$ kg/cm²

$f_c = \frac{690 \times 0.300}{15(1-0.300)} = 19.7$ "

Shear at end of haunch = 35,660 × 0.6 = 21,400 kgs
" " face of column = 35,660 × 0.95 = 33,880 "

unit stress
at end of haunch $v = \frac{21400}{40 \times 7/8 \times 96.5} = 6.3$ kg/cm²

use 12φ U-stirrups As = 2 × 1.13 = 2.26 cm²
spaing $= \frac{3}{2} \times \frac{2.26 \times 1200 \times 7/8 \times 96.5}{21400} = 16.1$ cm c. to c.

unit bond $u = \frac{21400}{6 \times 5.97 \times 7/8 \times 96.5} = 7.07$ kg/cm² use bent up bars

at face of column $v = \frac{33880}{40 \times 7/8 \times 131.5} = 7.4$ kg/cm²

spacings of 12φ U-stirrups $= \frac{3}{2} \times \frac{2.26 \times 1200 \times 7/8 \times 131.5}{33880} = 13.8$ cm c. to c.

unit bond $u = \frac{33880}{6 \times 5.97 \times 7/8 \times 131.5} = 8.3$ kg/cm² use bent up bars

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CALCULATIONS FOR
鐵筋混凝土イ型，十二隧道

For Bottom beam 61.5 cm effective depth with an insulation of 7.5cm or 69 cm in total
steel area required $= \frac{18550 \times 100}{1200 \times 7/8 \times 61.5} = 28.7\ cm^2$

use 12 - 19 mmφ = 34.00 cm²

We shall be design as a rectangular beam.

$P = \frac{34.00}{110 \times 61.5} = 0.00503$, K = 0.320, j = .894

$f_s = \frac{18550 \times 100}{34.0 \times 0.894 \times 61.5} = 996\ kgs/cm^2$

$f_c = \frac{996 \times 0.320}{15(1-0.320)} = 31.3$ 〃

For negative moment at support
Effective depth required $= 0.362\sqrt{\frac{18550 \times 100}{110}} = 47.0$ cm

use effective depth of 96.5cm

steel area required $= \frac{18550 \times 100}{1200 \times 7/8 \times 96.5} = 18.3\ cm^2$

~~use 10-19 mmφ bars = 10 c 2.835 = 28.35 cm²~~

$P = \frac{28.35}{40 \times 96.5} = 0.0073$, K = 0.371, j = 0.876

$f_s = \frac{18550 \times 100}{28.35 \times 0.876 \times 96.5} = 773\ kg/cm^2$

$f_c = \frac{773 \times 0.371}{15(1-.371)} = 30.5$ 〃

Shear at end of haunch = 21,400 kgs
〃 〃 face of column = 33,880 〃

unit stress
at end of haunch $v = \frac{21400}{110 \times 7/8 \times 61.5} = 3.6\ kg/cm^2$

unit bond $u = \frac{21400}{8 \times 5.97 \times 7/8 \times 61.5} = 8.33\ kg/cm^2$ use bent up bars

at face of column $v = \frac{33880}{110 \times 0.876 \times 96.5} = 3.65\ kg/cm^2$

unit bond $u = \frac{33880}{8 \times 5.97 \times 0.876 \times 96.5} = 8.4\ kgs/cm^2$ use bent up bars

Stresses in side wall due to seismic positive moment
$M_s = 6000$ kgm, axial compression $N_{BA} = 17010$ kgs

allowable stress being taken as $f_s = 1200 \times 1.8 = 2160$, $f_c = 47 \times 1.8 = 85$ kgs/cm²
$C_1 = 0.269$

Effective depth required for moment $= 0.269\sqrt{\frac{6000 \times 100}{100}} = 20.8$ cm

Use 31 cm effective depth with an insulation of 5 cm

Steel area required for moment $= \frac{6000 \times 100}{2160 \times 7/8 \times 31} = 10.2$ cm²

use 10 - 16 mmφ bars = 20.11 cm²

$p = \frac{20.11}{31 \times 100} = 0.0065$, $k = 0.355$, $j = 0.882$

$f_s = \frac{6000 \times 100}{20.11 \times 0.882 \times 31} = 1090$ kg/cm²

$f_c = \frac{1090 \times 0.355}{15(1-.355)} = 40$ "

direct stress $= \frac{17010}{36 \times 100} = 4.7$ "
44.7 kg/cm²

All assumed sections are ample for seismic stresses.

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CALCULATIONS FOR
鐵筋混凝土イ型ノ九隧道

Top and Bottom slab.

Max. Positive moment M_{U1} = +9900 kgm, axial compression N_{BC} = 8,700 kgs, see moment diagram on page 20.
" " " M_{L1} = +9,700 " " N_{AD} = 11,620 "
" " " M_{U2} = 530 " " $N_{CC'}$ = 8,700 "
" " " M_{L2} = 690 " " $N_{DD'}$ = 11,620 "

For slab BC.
Effective depth required for bending moment $d = C_1\sqrt{\frac{M}{b}}$

$$d = 0.362 \times \sqrt{\frac{9900 \times 100}{100}} = 36.0\ cm$$

use 39 cm effective depth with an insulation of 5 cm, total depth = 44 cm

Steel area required $= \frac{9900 \times 100}{1200 \times 7/8 \times 39} = 24.2\ cm^2$ per meter strip of slab.

use 10-19 mm φ bars = 28.35 cm² per meter strip of slab.
steel ratio $p = \frac{28.35}{100 \times 39} = 0.00727$, $k = 0.371$, $j = 0.876$

steel stress $f_s = \frac{9900 \times 100}{28.35 \times 0.876 \times 39} = 1023\ kg/cm^2$

Concrete stress $f_c = \frac{1023 \times 0.371}{15(1-0.371)} = 40.2$ "

direct stress $= \frac{8700}{100 \times 44} = 2.0$ "
42.2 kg/cm²

For slab DD',
Slab depth same as for slab BC.

Steel area required $= \frac{690 \times 100}{1200 \times 7/8 \times 39} = 1.69\ cm^2$ per meter strip of slab

use 19 mm φ bars spacing 13.3 cm c. to c. 7.5 × 2.835 = 21.2 cm²
steel ratio $p = \frac{21.2}{100 \times 39} = 0.00544$, $k = 0.330$, $j = 0.890$

steel stress $f_s = \frac{690 \times 100}{21.2 \times 0.890 \times 39} = 126\ kg/cm^2$

Concrete stress $f_c = \frac{126 \times 0.330}{15(1-0.330)} = 4.1$ "

direct stress $= \frac{11620}{100 \times 44} = 2.6$ "
6.7 kg/cm²

Use same arrangement for both top and bottom slabs.

Max. negative moment M_C = −11,750 kgm, axial compression N_{BC} = 8,700 kgs
" " " M_D = −11,590 " " N_{AD} = 11,620 "

For Top slab,
Effective depth required $= 0.362\sqrt{\frac{11750 \times 100}{100}} = 39.2\ cm$

use 69 cm effective depth

steel area required for bending moment $= \frac{11750 \times 100}{1200 \times 7/8 \times 69} = 16.2\ cm^2$

use 19 mm φ bars spacing 10 cm. c. to c. 10.0 × 2.835 = 28.35 cm²
steel ratio $p = \frac{28.35}{100 \times 69} = 0.00411$, $k = 0.295$, $j = 0.902$

steel stress $f_s = \frac{11750 \times 100}{28.35 \times 0.902 \times 69} = 667\ kgs/cm^2$

For bottom slab
use 64 effective depth

$A_s = \frac{11590 \times 100}{1200 \times 7/8 \times 64} = 17.3\ cm^2$

$p = 0.0044$, $k = .303$
$j = .899$

$f_s = \frac{11590 \times 100}{28.35 \times .899 \times 64} = 710\ kg/cm^2$

鐵筋混凝土ノ型ノ九隧道

Concrete stress $f_c = \frac{667 \times 0.295}{15(1-0.295)} = 18.6$ kg/cm²
direct stress $= \frac{8700}{100 \times 74} = 1.2$ 〃
19.8 kg/cm²

$f_c = \frac{710 \times 0.303}{15(1-.303)} = 20.6$ kg/cm²
direct c $= \frac{11620}{100 \times 69} = 1.7$ 〃
22.3 〃

use same arrangement for bottom slab.

Moment at the haunch C2'　$M_{C2'} = -3,100$ kgm (measured in the moment diagram)
axial compression　$N_{CC'} = 8,700$ 〃

use 19mmφ bars, spacing 13.3 cm c. to c.

Shearing and bond stress in top and bottom slab.

shear at point $B_1 = 16,400$ kgs $= V$
〃 $A_1 = 16,600$ 〃 〃
〃 $B_2 = 13,200$ 〃 〃
〃 $A_2 = 13,300$ 〃 〃
〃 $C_1 = 17,200$ 〃 〃
〃 $C_2 = 12,400$ 〃 〃
〃 $D_1 = 17,100$ 〃 〃
〃 $D_2 = 17,300$ 〃 〃
〃 $C_1', D_1' = 12,600$ 〃 〃
〃 $C_2', D_2' = 7,600$ 〃

Unit shear

at B_1　$v = \frac{16400}{100 \times 7/8 \times 79} = 2.37$ kg/cm²

at A_2　$v = \frac{13,300}{100 \times 7/8 \times 39} = 3.90$ 〃

at C_1　$v = \frac{17200}{100 \times 902 \times 69} = 2.76$ 〃

at C_2　$v = \frac{12400}{100 \times 7/8 \times 39} = 3.63$ 〃

unit bond

at C_1　$u = \frac{17,200}{10 \times 5.96 \times 0.902 \times 69} = 4.63$ 〃

at C_2　$u = \frac{12400}{7.5 \times 5.96 \times 7/8 \times 39} = 8.13$ 〃 use bent up bars

Stirrups required

using 3-U stirrups of 9mmφ for whitch $6 \times 0.636 = 3.81$ cm² per meter strip
Stirrup spacing required at point C_1

$$S_1 = \frac{3}{2} \times \frac{3.81 \times 1200 \times 7/8 \times 69}{17,200} = 24.1 \text{ cm c. to c.}$$

Stirrup spacing required at point C_2

$$S_2 = \frac{3}{2} \times \frac{381 \times 1200 \times 7/8 \times 39}{12,400} = 18.9 \text{ cm c. to c.}$$

Detail Design of side wall.

negative moment at bottom $M_A = -10,220$ kgm, axial compression $N_{BA} = 17,910$ kgs
〃 〃 at top $M_B = -9,540$ 〃, 〃 〃

CALCULATIONS FOR

鐵筋混凝土イ型ノ九隧道

at point A

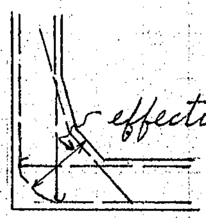
Effective depth required $= 0.362\sqrt{\frac{10220\times100}{100}} = 36.6$ cm use 68 cm

Steel area required $= \frac{10220\times100}{1200\times7/8\times68} = 14.32\ cm^2$ for one meter strip of wall

use 10-16mmφ bars = 20.11 cm²

$P = \frac{20.11}{100\times68} = 0.00296$, $K = 0.258$

$j = 0.914$



effective depth taken as 68 cm

$f_s = \frac{10220\times100}{20.11\times0.914\times68} = 817\ kg/cm^2$

$f_c = \frac{817\times0.258}{15(1-0.258)} = 18.95$ 〃

direct stress $= \frac{17910}{100\times68} = \underline{2.63}$ 〃

21.58 kg/cm²

unit shear $v = \frac{11620}{100\times.914\times68} = 1.87$ 〃

unit bond $u = \frac{11620}{10\times5.027\times.914\times68} = 3.72$ 〃

at end of haunch $A_2' = -2,600$ kgm, axial compression $N_{BA} = 17,910$ kgs

$B_2' = -4,700$ 〃 , 〃 〃

Effective depth required $= 0.362\sqrt{\frac{4700\times100}{100}} = 24.8$ cm use 31 cm

steel area required $= \frac{4700\times100}{1200\times7/8\times31} = 14.4\ cm^2$ for one meter strip of wall

use 10-16mmφ bars = 20.11 cm²

$P = \frac{20.11}{100\times31} = 0.00649$, $K = 0.355$, $j = 0.882$

$f_s = \frac{4700\times100}{20.11\times0.882\times31} = 855\ kg/cm^2$

$f_c = \frac{855\times0.355}{15(1-0.355)} = 31.4$ 〃

direct stress $= \frac{17910}{100\times36} = \underline{4.98}$ 〃

36.38 kg/cm²

Reinforcement for positive moment will governed by seismic moment.

Shear at $A_2' = 7200$ kgs

$B_2' = 7000$ 〃

unit shear $v = \frac{7200}{100\times.882\times31} = 2.60\ kg/cm^2$

unit bond $u = \frac{7200}{10\times5.027\times.882\times31} = 5.20$ 〃

unit bond at B_2

$u = \frac{13200}{50.27\times7/8\times39} = 7.69$ 〃 use bent up bars

Design of Center Columns

Axial compression on one column = 82,700 kgs

Try a column section of 40×60 cm with 16-16φ reinforcement

Transformed area of section

Concrete 40 × 60 = 2,400

steel 16 × 2.011 × 14 = 450

2,850 cm^2

unit compressive stress $f_c = \frac{82,700}{2850} = 29.0\ kg/cm^2$

" " $f_c = 1.5 \times 29.0 = 43.5$ "

use 9φ hoops, spacing to be less than 12 × 16 = 19 cm c. to c.

use 10 cm spacings for top and bottom few spaces.

Design of longitudinal beams on top and bottom of column

Span length 2.50 meters

Load on beam 33,100 kgs per lin. meter, see page 20.

moment assumed as $\frac{33,100 \times 2.50^2}{12} = \pm 17,240$ kgm

at Center of span

Effective depth req'd as a rectangular beam $d = 0.362\sqrt{\frac{17240 \times 100}{160}} = 37.5$ cm

For top beam 96.5 cm effective depth with an insulation of 7.5 cm or 104 cm in total.

steel area required $= \frac{17240 \times 100}{1200 \times 7/8 \times 96.5} = 17.1\ cm^2$

use 8-19mmφ bars = 22.7 cm^2

~~For this case neutral axis in the flange, design as a rectangular beam,~~

$P = \frac{22.7}{160 \times 96.5} = 0.0015$; $k = .191$, $j = .936$

$f_s = \frac{17240 \times 100}{22.7 \times 0.936 \times 96.5} = 840\ kg/cm^2$

$f_c = \frac{840 \times 0.191}{15(1-0.191)} = 13.3$ "

For negative moment at support

Effective depth required $= 0.362\sqrt{\frac{17240 \times 100}{40}} = 75.1$ cm

use effective depth of 131.5 cm

steel area required $= \frac{17240 \times 100}{1200 \times 7/8 \times 131.5} = 12.50\ cm^2$

use 8-19mmφ bars = 8 × 2.835 = 22.70 cm^2

$P = \frac{22.70}{40 \times 131.5} = 0.0043$, $k = 0.300$, $j = 0.900$

$f_s = \frac{17240 \times 100}{22.70 \times 0.900 \times 131.5} = 641\ kg/cm^2$

$f_c = \frac{641 \times 0.300}{15(1-0.300)} = 18.3$ "

Shear at end of haunch = 33,100 × 0.6 = 19,860 kgs

" face of column = 33,100 × 0.95 = 31,450 "

unit stress

at end of haunch $v = \frac{19,860}{40 \times 7/8 \times 96.5} = 5.88\ kg/cm^2$

use 12mmφ U-stirrup $A_s = 2 \times 1.13 = 2.26\ cm^2$

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CALCULATIONS FOR

鐵筋混凝土イ型ノ九隧道

Spacing $= \frac{3}{2} \times \frac{226 \times 1200 \times 7/8 \times 96.5}{19,860} = 17.3$ cm c. to c.

unit bond $u = \frac{19860}{6 \times 5.97 \times 7/8 \times 96.5} = 6.57$ kg/cm² use bent up bars

at face of column $v = \frac{31,450}{40 \times 7/8 \times 131.5} = 6.84$ "

spacing of 12φ U-stirrup $= \frac{3}{2} \times \frac{226 \times 1200 \times 7/8 \times 131.5}{31,450} = 14.9$ cm c. to c.

unit bond $u = \frac{31,450}{6 \times 5.97 \times 7/8 \times 131.5} = 7.65$ kg/cm² use bent up bars.

For Bottom beam 61.5cm effective depth with an insulation of 7.5cm or 69 cm in total.

Steel area required $= \frac{17240 \times 100}{1200 \times 7/8 \times 61.5} = 26.7$ cm²

use 10 - 19 mmφ $= 10 \times 2.835 = 28.35$ cm²

We shall be design as a rectangular beam.

$p = \frac{28.35}{110 \times 61.5} = 0.00418$, $k = 0.298$, $j = 0.901$

$f_s = \frac{17240 \times 100}{28.35 \times .901 \times 61.5} = 1,098$ kg/cm²

$f_c = \frac{1098 \times 0.298}{15(1-0.298)} = 31.1$ "

For negative moment at support

Effective depth required $= 0.362\sqrt{\frac{17240 \times 100}{110}} = 45.3$ cm

use effective depth of 96.5 cm

steel area required $= \frac{17240 \times 100}{1200 \times 7/8 \times 96.5} = 17.0$ cm²

use 10 - 19 mmφ bars $= 10 \times 2.835 = 28.35$ cm²

$P = \frac{28.35}{40 \times 96.5} = 0.0073$, $k = 0.371$, $j = 0.876$

$f_s = \frac{17240 \times 100}{28.35 \times 0.876 \times 96.5} = 703$ kg/cm²

$f_c = \frac{703 \times 0.371}{15(1-0.371)} = 27.7$ "

Shear at end of haunch = 19,860 kgs

" face of column = 31,450 "

unit stress

at end of haunch $v = \frac{19860}{110 \times 7/8 \times 61.5} = 3.35$ kg/cm²

unit bond $u = \frac{19860}{8 \times 5.97 \times 7/8 \times 61.5} = 7.73$ " use bent up bars

at face of column $v = \frac{31,450}{110 \times 0.876 \times 96.5} = 3.38$ "

unit bond $u = \frac{31,450}{8 \times 5.97 \times 0.876 \times 96.5} = 7.80$ " use bent up bars

Stresses in side wall due to seismic positive moment.

M_S = +5,800 kgm, axial compression N_{BA} = 17,330 kgs

allowable stress being taken as $f_s = 1200 \times 1.8 = 2160$, $f_c = 47 \times 18 = 85$ kg/cm²
$C_1 = 0.269$

Effective depth required for moment $= 0.269\sqrt{\frac{5800 \times 100}{100}} = 20.5$ cm

use 31 cm effective depth with an insulation of 5 cm

Steel area required for moment $= \frac{5800 \times 100}{2160 \times 7/8 \times 31} = 9.9$ cm²

use 10-16 mmφ bars = 20.11 cm²

$p = 0.0065$, $k = 0.355$, $j = 0.882$

$$f_s = \frac{5800 \times 100}{20.11 \times 0.882 \times 31} = 1055 \text{ kgs/cm}^2$$

$$f_c = \frac{1055 \times 0.355}{15(1-0.355)} = 38.7 \text{ ″}$$

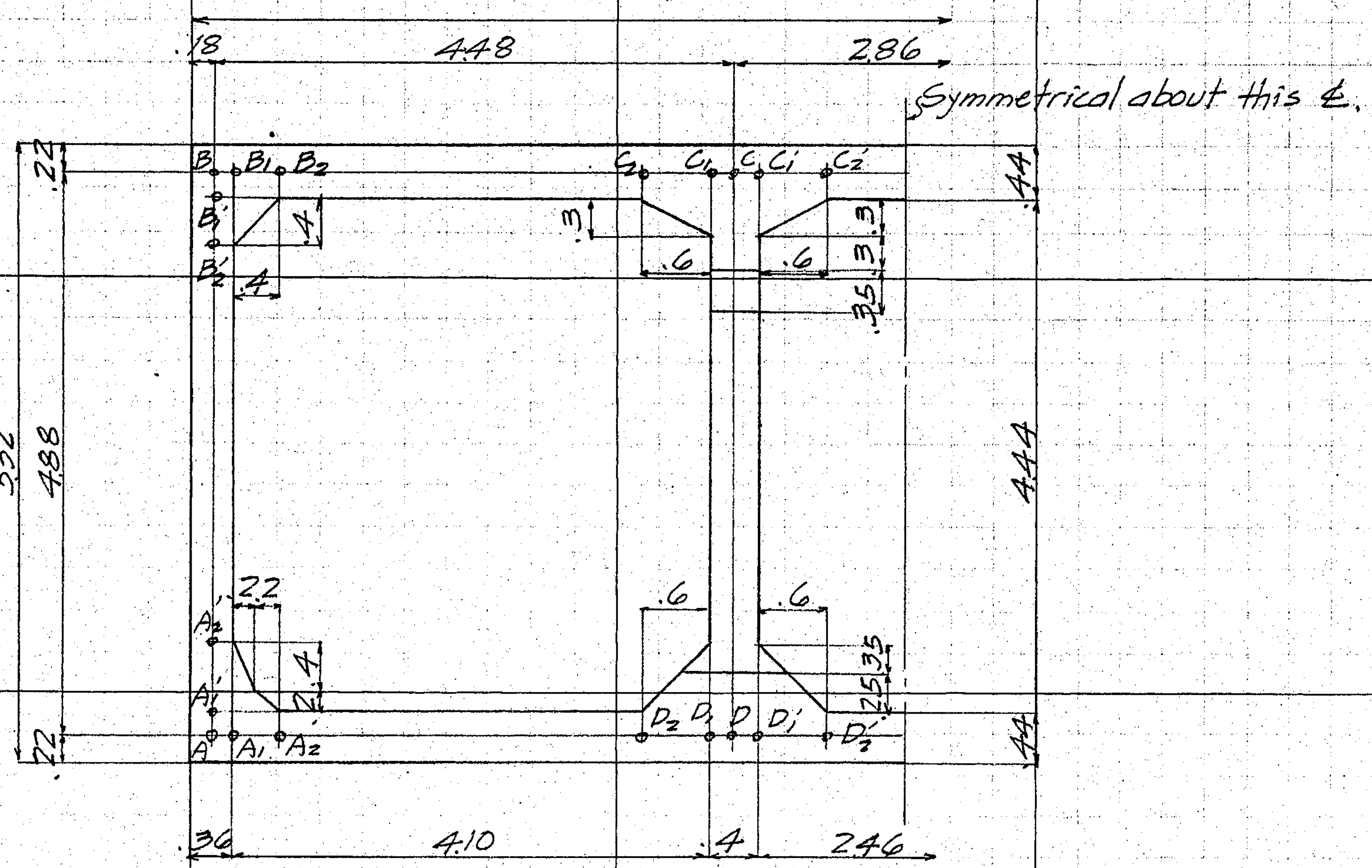
$$\text{direct stress} = \frac{17330}{100 \times 36} = 4.8 \text{ ″}$$

43.5 kg/cm²

All assumed section are ample for seismic stresses.

CALCULATIONS FOR
鐵筋混凝土イ型ノ大隧道

Unit stress caluculation
assumed cross section of the tonnel



Scale 1:60

Top and bottom slab
Max. positive moment M_{U_1} = 10,00 kgm, axial compression N_{BC} = 8,700 kgs see moment
" M_{L_1} = 10,00 " , " N_{AD} = 11,620 " diagram
on page 35

For slab BC,
Effective depth required for bending moment. $= 0.362 \times \sqrt{\frac{10400 \times 100}{100}} = 36.9$ cm

use 39 cm effective depth with an insulation of 5 cm, total depth = 44 cm

steel area required $= \frac{10400 \times 100}{1200 \times 7/8 \times 39} = 25.4\ cm^2$ per meter strip of slab

use 10-19mmφ bars = 28.35 cm^2 per meter strip of slab.

steel ratio $p = 0.00727$, $k = 0.371$, $j = 0.876$

steel stress $f_s = \frac{10400 \times 100}{28.35 \times 0.876 \times 39} = 1,075\ kg/cm^2$

Concrete stress $f_c = \frac{1075 \times 0.371}{15(1-0.371)} = 42.2$ "

direct stress $= \frac{8700}{100 \times 44} = 2.0$

44.2 kg/cm^2

use same arrangement for both top and bottom slab.

Max. negative moment M_C = 10,810 kgm, axial compression N_{BC} = 8,700 kgs.
" M_D = 10,630 " " N_{AD} = 11,620 "

For Top slab.

Effective depth required $= 0.362\sqrt{\frac{10810 \times 100}{100}} = 37.7$ cm

use 69 cm effective depth

Steel area required for bending $= \frac{10,810 \times 100}{1200 \times 7/8 \times 69} = 14.93$ cm²

Use 19mmφ spacings 10 cm c. to c. 10 × 2.835 = 28.35 cm²

steel ratio p = 0.00411, k = 0.295, j = 0.902

steel stress $f_s = \frac{10,810 \times 100}{28.35 \times 0.902 \times 69} = 613$ kg/cm²

concrete stress $f_c = \frac{613 \times 0.295}{15(1-0.295)} = 17.2$ "

direct stress $= \frac{8,700}{100 \times 74} = 1.2$ "

18.4 kg/cm²

For bottom slab.

use 64cm effective depth

$A_s = \frac{10630 \times 100}{1200 \times 7/8 \times 64} = 15.8$ cm²

p = 0.0044, k = .303
j = .899

$f_s = \frac{10,630 \times 100}{28.35 \times .899 \times 64} = 652$ kg/cm²

$f_c = \frac{652 \times .303}{15(1-.303)} = 18.9$ "

direct c $= \frac{11620}{100 \times 69} = 1.7$ "

20.6 "

moment at the haunch C₂′ $M_{C2'}$ = −4,000 kgm (measured in the moment diagram)
axial compression $N_{CC'}$ = 8,700 kgs

use 19mmφ bars spacings 13.3 cm. c. to c.

Shearing and bond stress in top and bottom slab.

shear at point	A_1	= 16,900 kgs	= V
"	A_2	= 13,600 "	"
"	B_1	= 16,700 "	"
"	B_2	= 13,400 "	"
"	C_1	= 17,000 "	"
"	C_2	= 12,100 "	"
"	D_1	= 16,800 "	"
"	D_2	= 11,900 "	"
"	C_1', D_1'	= 10,000 "	"
"	C_2', D_2'	= 5,100 "	"

Unit shear

at B_1 $v = \frac{16900}{100 \times 7/8 \times 79} = 2.45$ kg/cm²

at A_2 $v = \frac{13600}{100 \times 7/8 \times 39} = 3.99$ "

at C_1 $v = \frac{17000}{100 \times .902 \times 69} = 2.73$ "

at C_2 $v = \frac{12,100}{100 \times 7/8 \times 39} = 3.55$ "

unit bond

at C_1 $u = \frac{17,000}{10 \times 5.96 \times 0.902 \times 69} = 4.58$ kg/cm²

at C_2 $u = \frac{12,100}{7.5 \times 5.96 \times 7/8 \times 39} = 7.91$ " use bent up bars

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CALCULATIONS FOR

鐵筋混凝土イ型ノ大隧道

Stirrups required

Using 3-U-stirrups of 9mmφ for which 6 c 0.636 = 3.81 cm² per meter strip.

Stirrup spacing required at point C_1.

$$S_1 = \frac{3}{2} \times \frac{3.81 \times 1200 \times 7/8 \times 69}{17{,}000} = 24.4 \text{ cm c. to c.}$$

Stirrup spacing required at point C_2.

$$S_2 = \frac{3}{2} \times \frac{3.81 \times 1200 \times 7/8 \times 39}{12{,}100} = 19.4 \text{ cm c. to c.}$$

Detail design of side wall.

negative moment at bottom $M_A = -10{,}340$ kgm, axial compression $N_{BA} = 18{,}140$ kgs

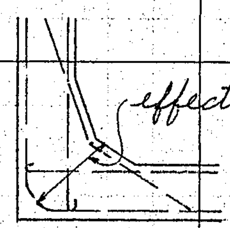
" " " top $M_B = -9{,}650$ " , " "

at point A

Effective depth required $= 0.362\sqrt{\frac{10{,}340 \times 100}{100}} = 36.8$ cm² use 68 cm

Steel area required $= \frac{10340 \times 100}{1200 \times 7/8 \times 68} = 14.5$ cm² for one meter strip of wall

use 10-16mmφ bars = 20.11 cm²


effective depth taken as 68cm

$\therefore P = 0.00296$, $K = 0.258$, $j = 0.914$

$$f_s = \frac{10{,}340 \times 100}{20.11 \times 0.914 \times 68} = 827 \text{ kg/cm}^2$$

$$f_c = \frac{827 \times 0.258}{15(1-0.258)} = 19.2 \text{ "}$$

$$\text{direct stress} = \frac{18{,}140}{100 \times 68} = 2.7 \text{ "}$$

21.9 kg/cm²

$$\text{unit shear } v = \frac{11{,}620}{100 \times .914 \times 68} = 1.87 \text{ kg/cm}^2$$

$$\text{unit bond } u = \frac{11620}{50.27 \times .914 \times 68} = 3.72 \text{ "}$$

At end of haunch $A_2' = -2{,}700$ kgm, axial compression $N_{BA} = 18{,}140$ kgs

$B_2' = -4{,}900$ " , " "

Effective depth required $= 0.362\sqrt{\frac{4900 \times 100}{100}} = 25.4$ cm use 31 cm

steel area required $= \frac{4900 \times 100}{1200 \times 7/8 \times 31} = 15.1$ cm² for one meter strip of wall

use 10-16mmφ bars = 20.11 cm²

$P = 0.00649$, $K = 0.355$, $j = 0.882$

$$f_s = \frac{4{,}900 \times 100}{20.11 \times 0.882 \times 31} = 891 \text{ kg/cm}^2$$

$$f_c = \frac{891 \times 0.355}{15(1-0.355)} = 32.7 \text{ "}$$

$$\text{direct stress} = \frac{18{,}140}{100 \times 36} = 5.0$$

37.7 kg/cm²

Reinforcement for positive moment will be governed by seismic moment.

Shear at $A_2' = 7200$ kgs

$B_2' = 7{,}000$ "

$$\text{unit shear } v = \frac{7200}{100 \times .882 \times 31} = 2.6 \text{ kg/cm}^2$$

unit bond $u = \frac{7200}{5027 \times .882 \times 31} = 5.2\ kg/cm^2$

unit bond at B_2

$u = \frac{13400}{5027 \times 7/8 \times 39} = 7.8$ 〃 use bent up bars

Design of center columns

Axial compression on one column = 76,000 kgs

Try a column section of 40×60 cm with $16 - 16^{\phi}$ reinforcements

transformed area of section

concrete $40 \times 60 = 2400$

steel $16 \text{ c } 2.011 \times 14 = \underline{450}$

$2850\ cm^2$

unit compressive stress $f_c = \frac{76000}{2850} = 26.7\ kg/cm^2$

〃 〃 〃 $f_s = 15 \times 26.7 = 400$ 〃

use 9^{ϕ} hoops, spacing to be less than $12 \times 16 = 19$ cm c. to c.

use 10 cm spacings for top and bottom few spaces.

Design of longitudinal beams on top and bottom of column

Span length 2.50 meters

Load on beam 30410 kgs per lin. meter, see on page 35.

moment assumed as $\pm \frac{30410 \times 2.50^2}{12} = \pm 15,840$ kgm

at center of span

Effective depth req'd as a rectangular beam, $d = 0.362\sqrt{\frac{15840 \times 100}{160}} = 36.0$ cm

For top beam 96.5 cm effective depth with an insulation of 7.5 cm or 104 cm in total.

steel area required $= \frac{15840 \times 100}{1200 \times 7/8 \times 96.5} = 15.7\ cm^2$

use $6 - 19^{mm\phi}$ bars $= 6 \text{ c } 2.835 = 17.0\ cm^2$

For this case neutral axis in the flange, design as a rectangular beam.

$p = \frac{17.0}{160 \times 96.5} = 0.00110$, $k = 0.166$, $j = 0.945$

$f_s = \frac{15840 \times 100}{17.0 \times .945 \times 96.5} = 1020\ kg/cm^2$

$f_c = \frac{1020 \times .166}{15(1 - 0.166)} = 13.6$ 〃

For negative moment at support

Effective depth required $= 0.362\sqrt{\frac{15840 \times 100}{40}} = 72.0$ cm

use effective depth of 131.5 cm

steel area req'd $= \frac{15840 \times 100}{1200 \times 7/8 \times 131.5} = 11.5\ cm^2$

use $6 - 19^{mm\phi}$ bars $= 6 \text{ c } 2.835 = 17.00\ cm^2$

$P = \frac{17.00}{40 \times 131.5} = 0.00323$, $k = 0.266$, $j = 0.912$

$f_s = \frac{15840 \times 100}{17.00 \times 0.912 \times 131.5} = 778\ kg/cm^2$

$f_c = \frac{778 \times 0.266}{15(1 - 0.266)} = 18.8$ 〃

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CALCULATIONS FOR
鐵筋混凝土イ型ノ大隧道

Shear at end of haunch = 30,410 × 0.6 = 18,250 kgs
" " face of column = 30,410 × 0.95 = 28,900 "

unit stress
at end of haunch
unit shear $v = \frac{18250}{40 \times 7/8 \times 96.5} = 5.41$ kg/cm²

use 12ϕ U-stirrups. As = 2 × 1.13 = 2.26 cm²
spacing $= \frac{3}{2} \times \frac{2.26 \times 1200 \times 7/8 \times 96.5}{18,250} = 18.8$ cm c. to c.

unit bond $u = \frac{18250}{4 \times 5.97 \times 7/8 \times 96.5} = 9.1$ kg/cm² use bent up bars

at face of column
unit shear $v = \frac{28900}{40 \times 7/8 \times 131.5} = 6.8$ kg/cm²

spacings of 12ϕ U-stirrups $= \frac{3}{2} \times \frac{2.26 \times 1200 \times 7/8 \times 131.5}{28900} = 16.2$ cm c. to c.

unit bond $u = \frac{28900}{4 \times 5.97 \times 7/8 \times 131.5} = 10.5$ kg/cm² use bent up bars

For bottom beam 61.5 cm effective depth with an insulation of 7.5 cm or 69 cm in total.
steel area required $= \frac{15840 \times 100}{1200 \times 7/8 \times 61.5} = 24.6$ cm²

use 10-19mmϕ bars = 10 × 2.835 = 28.35 cm²

we shall be design as a rectangular beam
P = 0.00418, K = 0.298, J = 0.901

$f_s = \frac{15840 \times 100}{28.35 \times 0.901 \times 61.5} = 1,010$ kg/cm²

$f_c = \frac{1010 \times 0.298}{15(1-0.298)} = 28.6$ "

For negative moment at support
Effective depth required $= 0.362 \sqrt{\frac{15840 \times 100}{110}} = 43.4$ cm

Use effective depth = 96.5 cm

steel area required $= \frac{15840 \times 100}{1200 \times 7/8 \times 96.5} = 15.7$ cm²

use 10-19mmϕ bars = 10 × 2.835 = 28.35 cm²

P = 0.0073, k = 0.371, j = 0.876

$f_s = \frac{15840 \times 100}{28.35 \times .876 \times 96.5} = 661$ kg/cm²

$f_c = \frac{661 \times 0.371}{15(1-0.371)} = 26.1$ "

Shear at end of haunch = = 18,250 kgs
" " face of column = = 28,900 "

unit stress
at end of haunch
unit shear $v = \frac{18,250}{110 \times 7/8 \times 61.5} = 3.08$ kg/cm²

unit bond $u = \frac{18250}{8 \times 5.97 \times 7/8 \times 61.5} = 7.1$ " use bent up bars

Stresses in side wall due to seismic positive moment

$M_s = 5{,}700$ kgm, axial compression $N_{BA} = 17{,}570$ kgs

Allowable stress being taken as $f_s = 1{,}200 \times 1.8 = 2{,}160$ kg/cm², $f_c = 47 \times 1.8 = 85$ kg/cm²

$C_1 = 0.269$

Effective depth required for moment $= 0.269\sqrt{\frac{5700 \times 100}{100}} = 20.3$ cm

Use 31 cm effective depth with an insulation of 5 cm.

Steel area required for moment $= \frac{5{,}700 \times 100}{2{,}160 \times 7/8 \times 31} = 9.7$ cm²

use 10-16mmφ bars = 20.11 cm²

$p = 0.0065$, $k = 0.355$, $j = 0.882$

$$f_s = \frac{5{,}700 \times 100}{20.11 \times 0.882 \times 31} = 1{,}038 \text{ kg/cm}^2$$

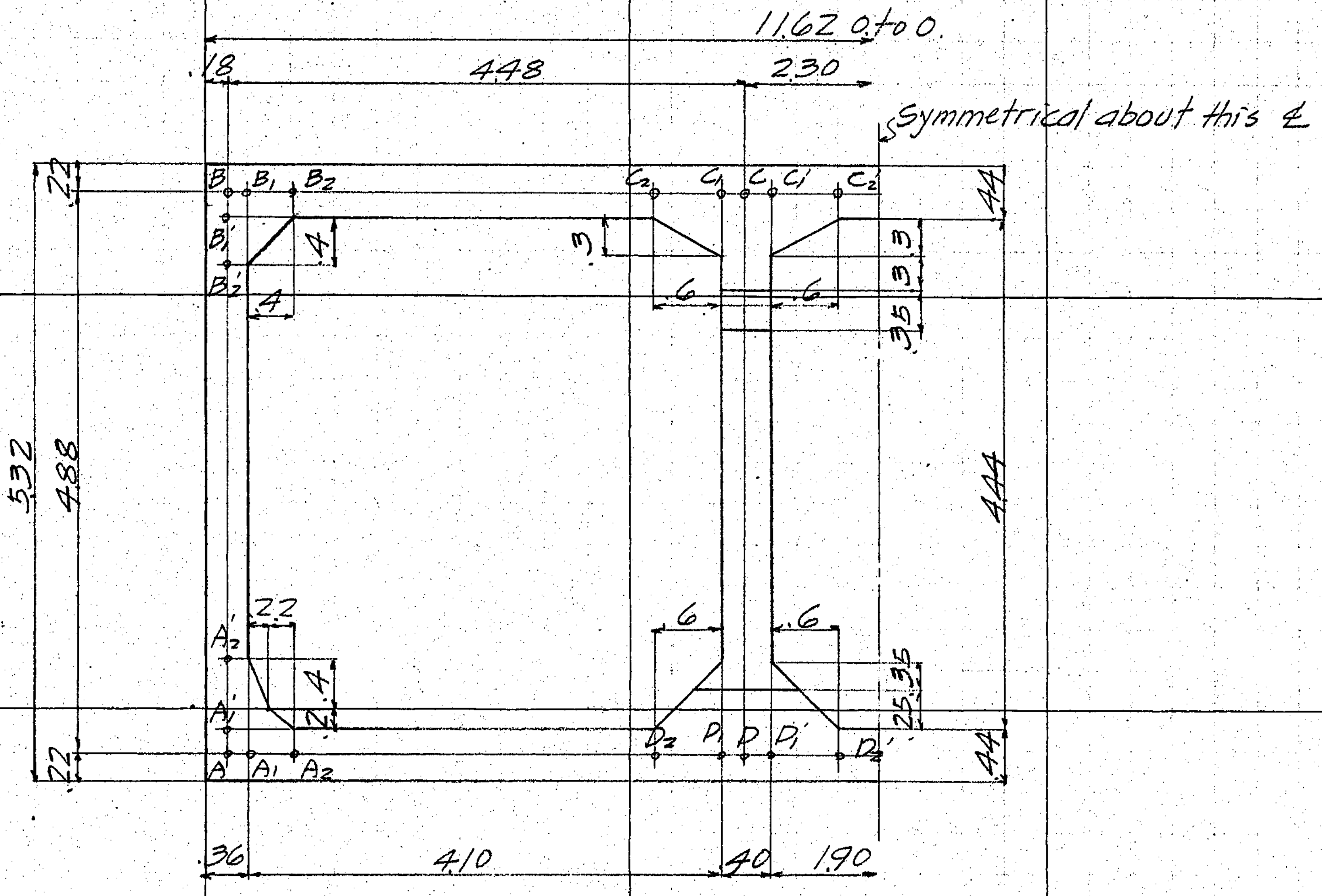
$$f_c = \frac{1{,}038 \times 0.355}{15(1 - 0.355)} = 38.1 \text{ 〃}$$

$$\text{direct stress} = \frac{17{,}570}{100 \times 36} = \frac{4.9}{43.0 \text{ kg/cm}^2}$$

All assumed sections are ample for seismic stresses.

CALCULATIONS FOR
鐵筋混凝土イ型ノ三隧道

Unit stress calculation
Assumed cross section of the tonnel



Scale 1:60

Top and bottom slab.
~~Max. positive moment $M_{U1} = 10,500$ kgm, axial compression $N_{BC} = 8,700$ kgs~~ see moment
" " " $M_{L1} = 10,300$ ", " $N_{AD} = 11,620$ " diagram on page 49.

For slab BC,
Effective depth required for bending moment $= 0.362\sqrt{\frac{10500\times100}{100}} = 37.1$ cm

use 39 cm effective depth with an insulation of 5 cm, total depth 44 cm

steel area required $= \frac{10,500\times100}{1200\times 7/8\times39} = 25.6\ \text{cm}^2$ per meter strip of slab

~~use 10-19mmφ bars $= 28.35\ \text{cm}^2$ per meter strip of slab~~

steel ratio $p = 0.00727$, $k = 0.371$, $j = 0.876$

steel stress $f_s = \frac{10,500\times100}{28.35\times0.876\times39} = 1,085\ \text{kg/cm}^2$

Concrete stress $f_c = \frac{1085\times0.371}{15(1-0.371)} = 42.7$ "

direct stress $= \frac{8700}{100\times44} = 2.0$ "

$44.7\ \text{kg/cm}^2$

use same arrangement for both top and bottom slab.

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CALCULATIONS FOR

鐵筋混凝土イ型ノ三隧道

Max. negative moment M_C = 10,500 kgm axial compression N_{BC} = 8700 kgs
" M_D = 10,300 " " N_{AD} = 11620 "

For Top slab.

Effective depth required $= 0.362\sqrt{\frac{10500\times100}{100}} = 37.1$ cm

use 69 cm effective depth

steel area required for bending $= \frac{10500\times100}{1200\times7/8\times69} = 14.5$ cm²

use 19mmφ bars spacing 10cm c. to c. $10\times2.835 = 28.35$ cm²

steel ratio $p = 0.00411$, $k = 0.295$, $j \doteq 0.902$

steel stress $f_s = \frac{10500\times100}{28.35\times0.902\times69} = 596$ kg/cm²

concrete stress $f_c = \frac{596\times0.295}{15(1-0.295)} = 16.6$ "

direct stress $= \frac{8700}{100\times74} = 1.2$ "

17.8 kg/cm²

For bottom slab.

use 64cm effective depth

$A_s = \frac{10300\times100}{1200\times7/8\times64} = 15.3$ cm²

$p = 0.0044$, $k = .303$

$j = .899$

$f_s = \frac{10300\times100}{28.35\times.899\times64} = 632$ kg/cm²

$f_c = \frac{632\times.303}{15(1-.303)} = 18.3$ "

direct c $= \frac{11620}{100\times69} = 1.7$ "

20.0 "

moment at the haunch C_2', $M_{C_2'} = -5600$ kgm (measured in the moment diagram)
axial compression $N_{CC'}$ = 8,700 kgs

use 39 cm effective depth

steel area required for bending $= \frac{5600\times100}{1200\times7/8\times39} = 13.7$ cm²

use 19mmφ bars spacing 13.3 cm c. to c. $7.5\times2.835 = 21.22$ cm²

steel ratio $= \frac{21.22}{100\times39} = 0.00545$, $k = 0.332$, $j = 0.889$

steel stress $f_s = \frac{5600\times100}{21.22\times0.889\times39} = 761$ kg/cm²

concrete stress $f_c = \frac{761\times0.332}{15(1-0.332)} = 25.2$ "

direct stress $= \frac{8700}{100\times44} = 2.0$ "

27.2 kg/cm²

use same arrangement for both top and bottom slab.

Shearing and bond stress in top and bottom slab.

shearing at point	A_1 =	16,900 kgs	= V
"	A_2 =	13,600 "	"
"	B_1 =	16,700 "	"
"	B_2 =	13,400 "	"
"	C_1 =	16,900 "	"
"	C_2 =	12,000 "	"
"	D_1 =	16,700 "	"
"	D_2 =	11,800 "	"
"	C_1', D_1' =	7800 "	"
"	C_2', D_2' =	2,900 "	"

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CALCULATIONS FOR

鐵筋混凝土イ型ノ三隧道

unit shear

at B_1 $v = \frac{16700}{100 \times 7/8 \times 79} = 2.42$ kg/cm²

at A_2 $v = \frac{13600}{100 \times 7/8 \times 39} = 3.99$ "

at C_1 $v = \frac{16900}{100 \times .902 \times 69} = 2.72$ "

at C_2 $v = \frac{12000}{100 \times .889 \times 39} = 3.46$ "

unit bond

at C_1 $u = \frac{16900}{10 \times 5.96 \times .902 \times 69} = 4.55$ kg/cm²

at C_2 $u = \frac{12000}{7.5 \times 5.96 \times 7/8 \times 39} = 7.87$ " use bent up bars

Stirrups required

using 3-U-stirrups of 9mmφ for which 6 × 0.636 = 3.81 cm² per meter strip.

Stirrups spacing required at point C_1.

$$S_1 = \frac{3}{2} \times \frac{3.81 \times 1200 \times 7/8 \times 69}{16900} = 24.5 \text{ cm. c. to c.}$$

Stirrups spacing required at point C_2,

$$S_2 = \frac{3}{2} \times \frac{3.81 \times 1200 \times 7/8 \times 39}{12000} = 19.5 \text{ cm c. to c.}$$

Detail design of side wall.

negative moment at bottom $M_A = -10380$ kgm, axial compression $N_{BA} = 18220$ kgs

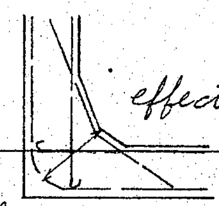
" top $M_B = -9690$ ", " "

at point A.

Effective depth required $= 0.362\sqrt{\frac{10380 \times 100}{100}} = 36.9$ cm use 68 cm

steel area required $= \frac{10380 \times 100}{1200 \times 7/8 \times 68} = 14.54$ cm² for one meter strip of wall.

use 10-16mmφ bars = 20.11 cm²



effective depth taken as 68 cm

P = 0.00296, k = 0.258, j = 0.914

$$f_s = \frac{10380 \times 100}{20.11 \times 0.914 \times 68} = 830 \text{ kg/cm}^2$$

$$f_c = \frac{830 \times 0.258}{15(1-0.258)} = 19.3 \text{ "}$$

direct stress $= \frac{18220}{100 \times 68} = 2.7$ "

22.0 kg/cm²

unit shear $v = \frac{11620}{100 \times .914 \times 68} = 1.87$ "

unit bond $u = \frac{11620}{5.027 \times .914 \times 68} = 3.72$ "

at end of haunch $A_2' = -2800$ kgm, axial compression $N_{BA} = 18220$ kgs

$B_2' = -4900$ ", " "

Effective depth required $= 0.362\sqrt{\frac{4900 \times 100}{100}} = 25.4$ cm use 31 cm

Steel area required = $\frac{4900 \times 100}{1200 \times 7/8 \times 31}$ = 15.1 cm² for one meter strip of wall.

Use 10-16 mmφ bars = 20.11 cm²

P = 0.00649 , k = 0.355 , j = 0.882

$f_s = \frac{4900 \times 100}{20.11 \times 0.882 \times 31} = 891$ kg/cm²

$f_c = \frac{891 \times 0.355}{15(1-0.355)} = 32.7$ "

direct stress = $\frac{18220}{100 \times 36}$ = 5.1 "
37.8 kg/cm²

Reinforcement for positive moment will be governed by seismic moment.

Shear at A_2' = 7,200 kgs
B_2' = 7,000 "

unit shear $v = \frac{7200}{100 \times .882 \times 31} = 2.6$ kg/cm²

unit bond $u = \frac{7200}{50.27 \times .882 \times 31} = 5.2$ "

unit bond at B_2
$u = \frac{13400}{50.27 \times 7/8 \times 39} = 7.8$ " use bent up bars

Design of center columns
axial compression on one column = 70000 kgs
Try a column section of 40×60 cm with 16-16φ reinforcements
Transformed area of section
Concrete 40 × 60 = 2400
steel 16 @ 2.011 × 14 = 450
2850 cm²
unit compressive stress $f_c = \frac{70000}{2850} = 24.6$ kg/cm²
" $f_s = 15 \times 24.6 = 369$ "

use 9 mmφ hoops, spacing to be less than 12 × 16 = 19 cm c. to c.
use 10 cm spacings for top and bottom few spaces

Design of longitudinal beams on top and bottom of column.
Span length 2.50 meters

Load on beam 28,020 kgs per lin. meter, see on page 49.
moment assumed as $\pm \frac{28020 \times 2.50^2}{12} = \pm 14,600$ kgm

at center of span
Effective depth required as a rectangular beam = $0.362\sqrt{\frac{14600 \times 100}{160}} = 34.6$ cm

For top beam 96.5 cm effective depth with an insulation of 7.5 cm or 104 cm in total.

steel area required = $\frac{14600 \times 100}{1200 \times 7/8 \times 96.5} = 14.4$ cm²

use 6 - 19 mmφ bars = 6 × 2.835 = 17.0 cm²

For this case neutral axis in the flange, design as a rectangular beam.

$P = 0.00110$, $k = 0.166$, $j = 0.945$

$$f_s = \frac{14600 \times 100}{17.0 \times 0.945 \times 96.5} = 942 \text{ kg/cm}^2$$

$$f_c = \frac{942 \times 0.166}{15(1-0.166)} = 12.5 \text{ "}$$

For negative moment at support

Effective depth required $= 0.362\sqrt{\frac{14600 \times 100}{40}} = 69.2 \text{ cm}$

use effective depth of 131.5 cm

steel area required $= \frac{14600 \times 100}{1200 \times 7/8 \times 131.5} = 10.6 \text{ cm}^2$

use 6-19 mmφ bars $= 6 \text{ c } 2.835 = 17.00 \text{ cm}^2$

$P = 0.0032$, $k = 0.266$, $j = 0.912$

$$f_s = \frac{14600 \times 100}{17.00 \times 0.912 \times 131.5} = 71.6 \text{ kg/cm}^2$$

$$f_c = \frac{71.6 \times 0.266}{15(1-0.266)} = 1.73 \text{ "}$$

Shear at end of haunch $= 28,020 \times 0.6 = 16,800$ kgs

" face of column $= 28,020 \times 0.95 = 26,600$ "

unit stress

at end of haunch

unit shear $v = \frac{16800}{40 \times 7/8 \times 96.5} = 5.0 \text{ kg/cm}^2$

use 12 mmφ U-stirrups $A_s = 2 \times 1.13 = 2.26 \text{ cm}^2$

spacings $= \frac{3}{2} \times \frac{2.26 \times 1200 \times 7/8 \times 96.5}{16800} = 20.4 \text{ cm c. to c.}$

unit bond $u = \frac{16800}{4 \times 5.97 \times 7/8 \times 96.5} = 8.3 \text{ kg/cm}^2$ use bent up bars

at face of column

unit shear $v = \frac{26600}{40 \times 7/8 \times 131.5} = 5.79 \text{ kg/cm}^2$

spacing of 12 mmφ U-stirrup $= \frac{3}{2} \times \frac{2.26 \times 1200 \times 7/8 \times 131.5}{26600} = 17.6 \text{ cm c. to c.}$

unit bond $u = \frac{26600}{4 \times 5.97 \times 7/8 \times 131.5} = 9.7 \text{ kg/cm}^2$ use bent up bars

For bottom beam 61.5 cm effective depth with an insulation of 7.5 cm or 69 cm in total.

steel area required $= \frac{14600 \times 100}{1200 \times 7/8 \times 61.5} = 22.6 \text{ cm}^2$

use 10-19 mmφ bars $= 10 \text{ c } 2.835 = 28.35 \text{ cm}^2$

We shall be design as a rectangular beam

$P = 0.00336$, $k = 0.272$, $j = 0.909$

$$f_s = \frac{14600 \times 100}{22.7 \times .909 \times 61.5} = 1150 \text{ kg/cm}^2$$

$$f_c = \frac{1150 \times 0.272}{15(1-0.272)} = 28.7 \text{ "}$$

For negative moment at support

Effective depth required $= 0.362\sqrt{\frac{14600\times100}{110}} = 41.2\,cm^2$

use effective depth $= 96.5\,cm$

steel area required $= \frac{14600\times100}{1200\times7/8\times96.5} = 14.4\ cm^2$

use 8-19mmφ bars $= 8 \times 2.835 = 22.70\ cm^2$

$P=0.0059$, $k=0.341$, $j=0.886$

$f_s = \frac{14600\times100}{22.70\times0.886\times96.5} = 752\ kg/cm^2$

$f_c = \frac{752\times0.341}{15(1-0.341)} = 25.9$ "

Shear at end of haunch $= 16,800\ kgs$

" face of column $= 26,600$ "

unit stress

at end of haunch

unit shear $v = \frac{16800}{110\times7/8\times61.5} = 2.84\ kg/cm^2$

unit bond $u = \frac{16800}{6\times5.97\times7/8\times61.5} = 8.22$ " use bent up bars

at face of column

unit shear $v = \frac{26600}{110\times.886\times96.5} = 2.83\ kg/cm^2$

unit bond $u = \frac{26600}{6\times5.97\times.886\times96.5} = 8.70$ "

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CALCULATIONS FOR

鐵筋混凝土イ型ノ三隧道

Stresses in side wall due to seismic positive moment

$M_s = +5{,}600$ kgm, axial compression $N_{BA} = 17{,}640$ kgs

Allowable stress being taken as $f_s = 1200 \times 1.8 = 2{,}160$ kg/cm², $f_c = 47 \times 1.8 = 85$ kg/cm²

$C_1 = 0.269$

Effective depth required for moment $= 0.269\sqrt{\frac{5600 \times 100}{100}} = 20.1$ cm

Use 31 cm effective depth with an insulation of 5 cm.

Steel area required for moment $= \frac{5600 \times 100}{2{,}160 \times 7/8 \times 31} = 9.6$ cm²

Use 10-16mmφ bars = 20.11 cm²

$P = 0.0065$, $k = 0.355$, $j = 0.882$

$f_s = \frac{5600 \times 100}{20.11 \times 0.882 \times 31} = 1{,}018$ kg/cm²

$f_c = \frac{1018 \times 0.355}{15(1 - 0.355)} = 37.3$ "

direct stress $= \frac{17{,}640}{100 \times 36} = \underline{4.9}$ "

42.2 kg/cm²

All assumed sections are ample for seismic stresses.

新宿停車場昇降口階段

Detail design of top slab (use same arrangement for bottom slab)

max. positive moment $M_U = +4037$ kgm axial compression $N_{AD} = 3208$ kgs

Effective depth required $d = \sqrt{\frac{M}{b}}\, c_1$ where $b = 100$ cm $c_1 = 0.362$ where $f_s = 1200$ kg/cm², $f_c = 47$ "

$d = \sqrt{\frac{4037 \times 100}{100}} \times 0.362 = 23.0$ cm

use 24 cm effective depth with an insulation of 4 cm, total depth 28 cm,

Steel area required $= \frac{4037 \times 100}{1200 \times 7/8 \times 24} = 16.0$ cm²

use 19mmφ 15 cm c. to c. $6.66 \times 2.835 = 18.9$ cm²

steel ratio $p = \frac{18.9}{100 \times 24} = 0.0079$, $k = .381$, $j = .873$

steel stress $f_s = \frac{4037 \times 100}{18.9 \times .873 \times 24} = 1020$ kg/cm²

concrete stress $f_c = \frac{1020 \times .381}{15(1-.381)} = 41.9$ "

direct stress $= \frac{3208}{100 \times 28} = 1.1$ "

43.0 "

Shearing and bond stresses

shear at point A′ $S_{A'} = 6{,}000$ kgs

unit shear $v = \frac{6000}{100 \times .873 \times 24} = 2.87$ kg/cm²

unit bond $u = \frac{6000}{5.96 \times 6.66 \times .873 \times 24} = 7.2$ kg/cm² use bent up bars

Stirrup spacing required

use 2-U-stirrup of 9mmφ for which $4 \times .636 = 2.54$ cm² per meter strip

Stirrup spacing $S = \frac{3}{2} \times \frac{2.54 \times 1200 \times .873 \times 24}{6{,}000} = 16.0$ cm c. to c.

Detail design of side wall

negative moment at A $M_A - 2993$ kgm, axial compression $N_{AB} = 7{,}280$ kgs

" B $M_B - 3039$ " " $N_{AB} =$ " "

Effective depth required $d = 0.362\sqrt{\frac{3039 \times 100}{100}} = 20.0$ cm

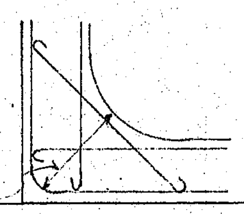
use 42 cm effective depth

Steel area required $= \frac{3039 \times 100}{1200 \times 7/8 \times 42} = 6.9$ cm²

use 16mmφ bars 15 cm c. to c. $6.66 \times 2.011 = 13.4$ cm²

steel ratio $P = \frac{13.4}{100 \times 42} = 0.0032$, $k = 0.266$, $j = 0.912$

steel stress $f_s = \frac{3039 \times 100}{13.4 \times 0.912 \times 42} = 592$ kg/cm²



concrete stress $f_c = \frac{592 \times 0.266}{15(1-.266)} = 14.3$ "

effective depth taken as 42cm

direct compression $\frac{7280}{100 \times 42} = 1.7$ "

16.0 "

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CALCULATIONS FOR

新宿停車場昇降口階段

steel ratio $P = \frac{134}{100 \times 42} = 0.0032$, $K = 0.266$, $j = 0.912$

steel stress $f_s = \frac{4190 \times 100}{134 \times .912 \times 42} = 816\ kg/cm^2$

Concrete stress $f_c = \frac{816 \times .266}{15(1-.266)} = 19.7$ "

at point B'

Effective depth required $d = 0.362\sqrt{\frac{2800 \times 100}{100}} = 19.2\,cm$

use 22 cm effective depth with an insulation of 4 cm, total depth 26 cm

Steel area required $= \frac{2800 \times 100}{1200 \times 7/8 \times 22} = 12.1\,cm^2$

use $16^{mm\phi}$ bars 15 cm c. to c. $= 13.4\,cm^2$

steel ratio $P = \frac{134}{100 \times 22} = 0.0061$, $K = .346$, $j = .885$

steel stress $f_s = \frac{2800 \times 100}{13.4 \times .885 \times 22} = 1073\ kg/cm^2$

Concrete stress $f_c = \frac{1073 \times .346}{15(1-.346)} = 37.8$ "

Shearing and bond stress

Shear at point B $S_B = 3645\ kgs$

" B' $S_{B'} = 2900$ "

unit shear at B $v = \frac{3645}{100 \times .912 \times 42} = 0.95\ kg/cm^2$

at B' $v = \frac{2900}{100 \times .885 \times 22} = 1.49$ "

unit bond at B $u = \frac{3645}{5.02 \times 6.66 \times .912 \times 42} = 2.85$ "

at B' $u = \frac{2900}{5.02 \times 6.66 \times .885 \times 22} = 4.5$ "

Stirrups required

use 2-U-stirrup of $9^{mm\phi}$ for which $4 \times .636 = 2.54\,cm^2$ per meter strip

Stirrup spacing required at point B

$S_1 = \frac{3}{2} \times \frac{A_s f_s jd}{V} = \frac{3}{2} \times \frac{2.54 \times 1200 \times .912 \times 42}{3645} = 48\,cm$ c. to c.

Stirrup spacing required at point B'

$S_2 = \frac{3}{2} \times \frac{2.54 \times 1200 \times .885 \times 22}{2900} = 30.7\,cm$ c. to c.

Detail design of bottom slab

max. negative moment $M = -4190\ kgm$

axial compression $N_{BC} = 3645\ kgs$

Effective depth required $= 0.362 \times \sqrt{\frac{4190 \times 100}{100}} = 23.4\,cm$

use 24 cm effective depth with an insulation of 4 cm, total depth 28 cm.

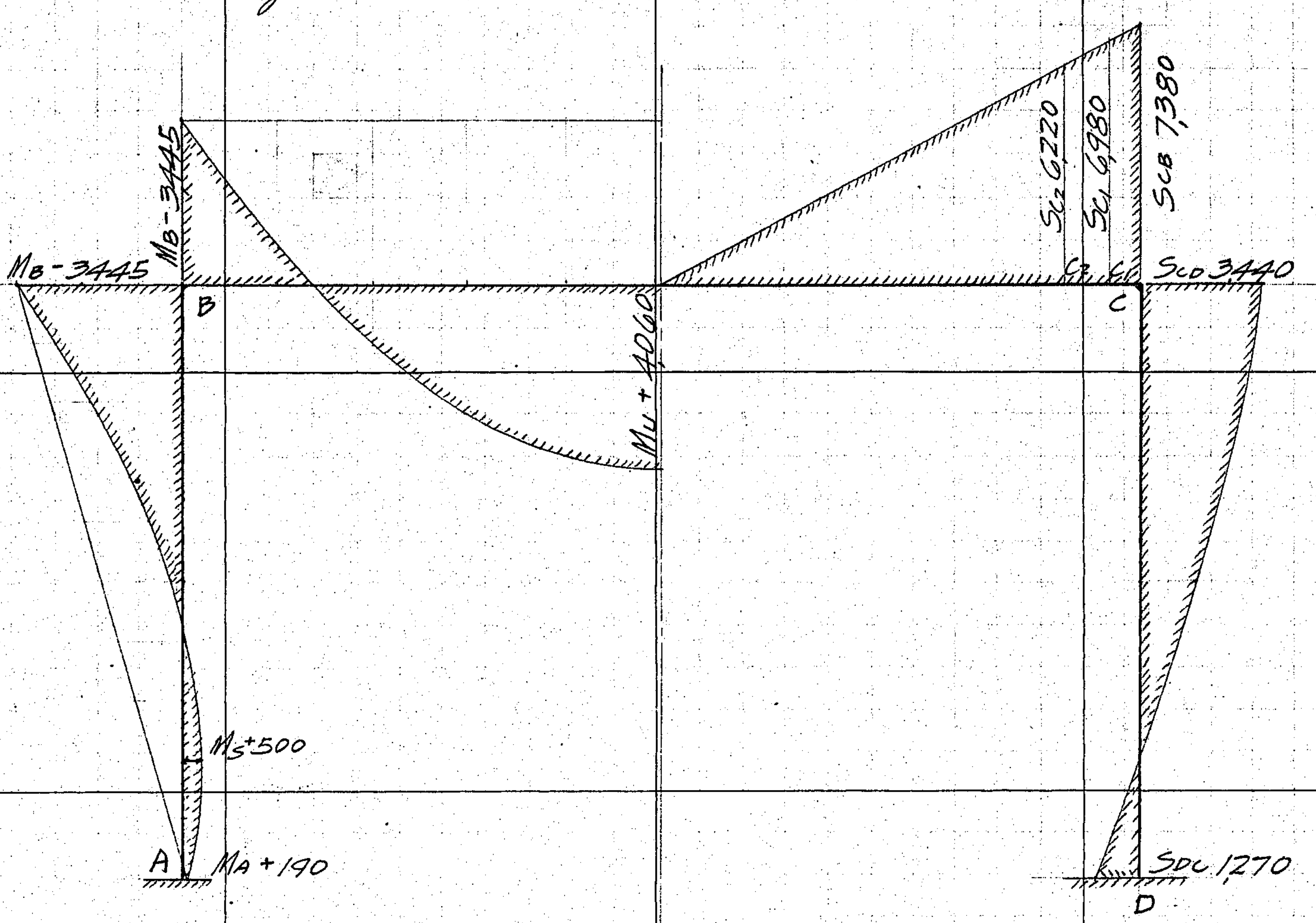
Steel area required $= \frac{4190 \times 100}{1200 \times 7/8 \times 24} = 16.6\,cm^2$

use $19^{mm\phi}$ 15 cm c. to c. $6.66 \times 2.835 = 18.9\,cm^2$

steel ratio $P = \frac{189}{100 \times 24} = 0.0079$, $K = .381$, $j = .873$

三號鐵筋混凝土框

Moment and shear diagram



Scale of space 1:30
Scale of moment $1/150^m$ = 1,000 kgm
Scale of shear $1/200^m$ = 1,000 kgs

Detail design of top slab

Max. Positive moment M_L = 4060 kgm, axial compression N_{BC} = 3440 kgs

Effective depth required for bending moment $d = C_1\sqrt{\frac{M}{b}}$, where $b = 100$ cm
$C_1 = 0.362$ for $f_s = 1200$ kg/cm²
$f_c = 47$ "

$$d = 0.362\sqrt{\frac{4060\times100}{100}} = 23.1\text{ cm}$$

use 25 cm effective depth with an insulation 5 cm, total depth 30 cm

$$\text{Steel area required} = \frac{4060\times100}{1200\times7/8\times25} = 15.5\text{ cm}^2$$

use 10-16mmφ bars = 10 @ 2.011 = 20.11 cm² per meter strip of slab

Steel ratio $P = \frac{20.11}{100\times25} = 0.0080$, $k = 0.384$, $j = 0.872$

$$\text{Steel stress } f_s = \frac{4060\times100}{20.11\times0.872\times25} = 926\text{ kg/cm}^2$$

$$\text{Concrete stress } f_c = \frac{926\times0.384}{15(1-0.384)} = 38.5\text{ "}$$

$$\text{direct stress} = \frac{3440}{100\times30} = 1.1\text{ "}$$

39.6 "

Shearing and bond stresses in top and bottom slab

Shear at point $C_1 = B_1 = 6980$ kgs
$C_2 = B_2 = 6220$ "

unit shear
at B_1 $v = \frac{6980}{100\times7/8\times45} = 1.8$ kg/cm²

at B_2 $v = \frac{6220}{100 \times 0.872 \times 25} = 29$ kg/cm²

unit bond
at B_1 $u = \frac{6980}{10 \times 5.02 \times 7/8 \times 45} = 35$ kg/cm²

at B_2 $u = \frac{6220}{10 \times 5.02 \times .872 \times 25} = 5.7$ " use bent up bars

Stirrup spacing
use U-stirrups of 9mmφ for which $5 \times 0.636 = 3.18$ cm² per meter strip

Stirrup spacing required at point B_2,

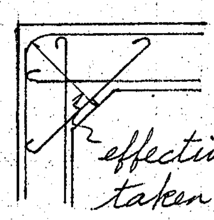
$S_1 = \frac{3}{2} \times \frac{3.18 \times 1200 \times .872 \times 25}{6220} = 20.0$ cm c. to c.

Detail design of side wall
Negative moment $M_B = 3445$ kgm, axial compression $N_{BA} = 7380$ kgs

Effective depth required $= 0.362\sqrt{\frac{3445 \times 100}{100}} = 21.3$ cm use 38 cm

Steel area required $= \frac{3445 \times 100}{1200 \times 7/8 \times 38} = 8.6$ cm²

use 16mmφ 10 cm c. to c. $= 10 \times 2.011 = 20.11$ cm²



effective depth taken as 38cm

steel ratio $p = \frac{20.11}{100 \times 38} = 0.0053$, $k = 0.327$, $j = 0.891$

steel stress $f_s = \frac{3445 \times 100}{20.11 \times .891 \times 38} = 506$ kg/cm²

Concrete stress $f_c = \frac{506 \times 0.327}{15(1-0.327)} = 16.4$ "

direct stress $= \frac{7380}{100 \times 38} = 1.9$ "

18.3 "

at end of haunch $M_{B'} = 2300$ kgm, axial compression $N_{BA} = 7380$ kgs

Effective depth required $= 0.362\sqrt{\frac{2300 \times 100}{100}} = 17.4$ cm use 19 cm

Steel area required $= \frac{2300 \times 100}{1200 \times 7/8 \times 19} = 11.6$ cm²

use 16mmφ 10 cm c. to c. $= 10 \times 2.011 = 20.11$ cm²

Steel ratio $p = \frac{20.11}{100 \times 19} = 0.0106$, $k = 0.427$, $j = 0.858$

steel stress $f_s = \frac{2300 \times 100}{20.11 \times .858 \times 19} = 701$ kg/cm²

concrete stress $f_c = \frac{701 \times 0.427}{15(1-0.427)} = 34.8$ "

direct stress $= \frac{7380}{100 \times 19} = 3.9$ "

38.7 "

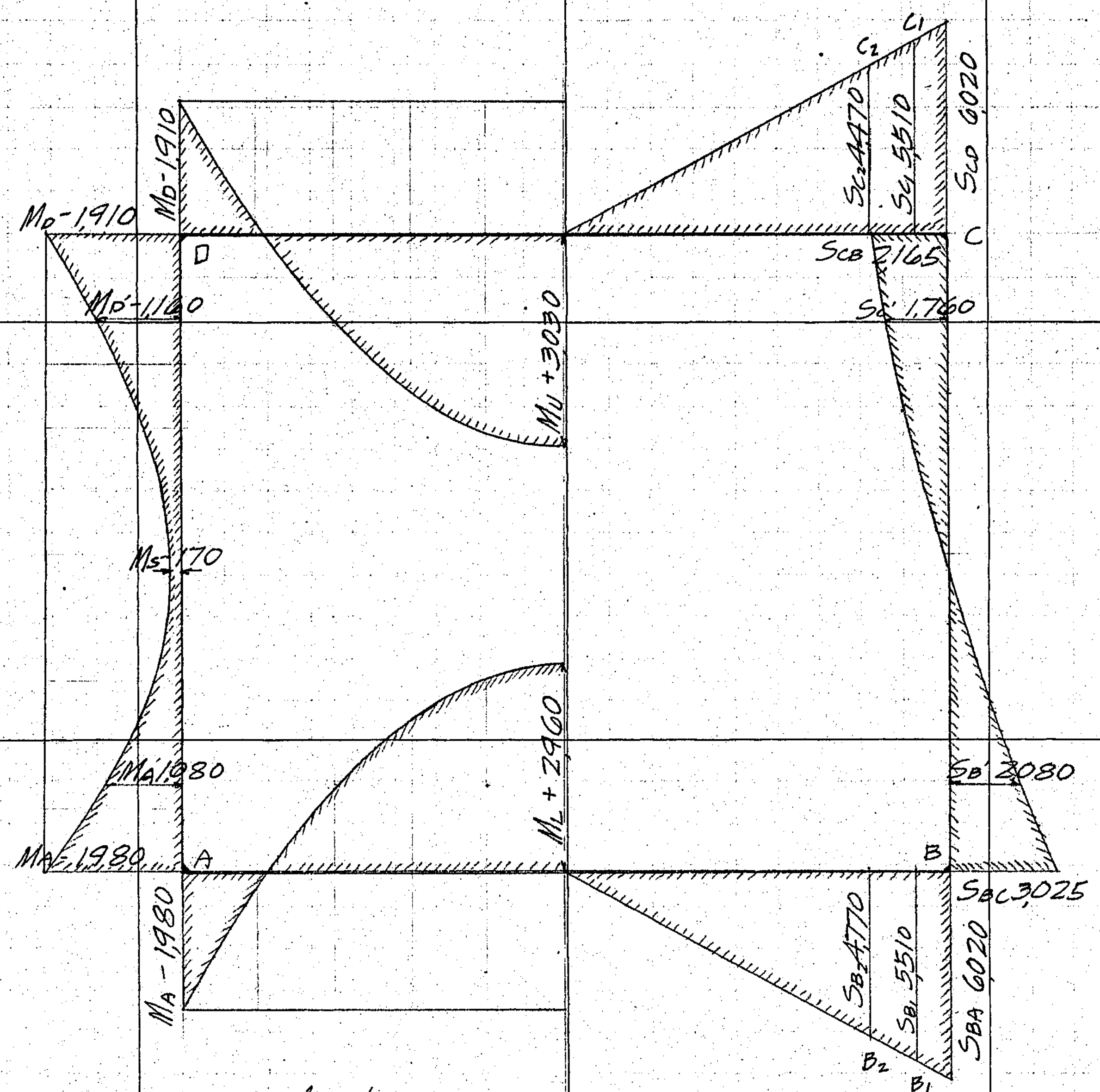
Shearing and bond stress
shear at point B' & C' $S_{B'} = 3300$ kgs

unit shear $v = \frac{3300}{100 \times .858 \times 19} = 2.0$ kg/cm²

unit bond $u = \frac{3300}{10 \times 5.02 \times .858 \times 19} = 4.0$ "

CALCULATIONS FOR
四號鐵筋混凝土框

Moment and shear diagram



Scale of space 1:30
Scale of moment $\frac{1}{100}$ m = 1,000 kgm
Scale of shear $\frac{1}{200}$ m = 1,000 kg

Top and bottom slab.

max. positive moment M_U = 3,030 kgm, axial compression N_{CD} = 2165 kg
M_L = 2,960 " , N_{AB} = 3,025 "

For top slab,

Effective depth required for bending moment $d = C_1\sqrt{\frac{M}{b}}$ where b = 100 cm
$C_1 = 0.362$ for $f_s = 1200$ kg/cm²
$f_c = 47$ "

$d = 0.362\sqrt{\frac{3030\times100}{100}} = 19.9$ cm

use 29 cm effective depth with an insulation of 5 cm, total depth = 34 cm.

Steel area required $= \frac{3030\times100}{1200\times7/8\times29} = 9.95$ cm²

use 10-16mmφ bars = 10 × 2.011 = 20.11 cm² per meter strip of slab.

steel ratio $p = \frac{20.11}{100\times29} = 0.0069$, $k = 0.363$, $j = 0.897$

Steel stress $f_s = \frac{3030\times100}{20.11\times.897\times29} = 552$ kg/cm²

Concrete stress $f_c = \frac{552\times.363}{15(1-0.363)} = 21$ "

direct stress $= \frac{2165}{100\times34} = 0.6$ "
21.6 kg/cm²

use same arrangement for both top and bottom slab.

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CALCULATIONS FOR
四號鐵筋混凝土框

Shearing and bond stresses in top and bottom slab

shear at point $A_1 = B_1 = C_1 = D_1 = 5{,}510$ kgs
$A_2 = B_2 = C_2 = D_2 = 4{,}770$ "

unit shear
at A_1 $v = \frac{5510}{100 \times 7/8 \times 49} = 1.3$ kg/cm²
at A_2 $v = \frac{4770}{100 \times .897 \times 29} = 1.8$ "

unit bond
at A_1 $u = \frac{5510}{10 @ 5.02 \times 7/8 \times 49} = 2.6$ "
at A_2 $u = \frac{4770}{10 @ 5.02 \times .897 \times 29} = 3.4$ "

Detail design of side wall
negative moment $M_A = 1{,}980$ kgm, axial compression $N_{AD} = 6{,}020$ kgs
$M_D = 1{,}910$ " " "

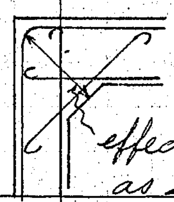
at point A_1

Effective depth required $= 0.362\sqrt{\frac{1980 \times 100}{100}} = 16.1$ cm, use 42 cm

Steel area required $= \frac{1980 \times 100}{1200 \times 7/8 \times 42} = 4.5$ cm² for one meter strip

use 16 mmφ 10 cm c. to c. $= 10 @ 2.011 = 20.11$ cm²

steel ratio $p = \frac{20.11}{100 \times 42} = 0.0048$, $k = 0.314$, $j = 0.895$



effective depth taken as 42 cm

Steel stress $f_s = \frac{1980 \times 100}{20.11 \times .895 \times 42} = 262$ kg/cm²

concrete stress $f_c = \frac{262 \times 0.314}{15(1-0.314)} = 8.0$ "

direct stress $= \frac{6020}{100 \times 42} = 1.4$ "
9.4 "

at end of haunch $M_A' = 1{,}080$ kgm, axial compression $N_{AD} = 6{,}020$ kgs
$M_D' = 1{,}160$ " , " "

Effective depth required $= 0.362\sqrt{\frac{1080 \times 100}{100}} = 11.9$ cm, use 23 cm

Steel area required $= \frac{1080 \times 100}{1200 \times 7/8 \times 23} = 4.5$ cm²

use 16 mmφ 10 cm c to c $= 10 @ 2.011 = 20.11$ cm²

steel ratio $p = 0.0088$, $k = 0.399$, $j = 0.867$

steel stress $f_s = \frac{1080 \times 100}{20.11 \times .867 \times 23} = 169$ kg/cm²

Concrete stress $f_c = \frac{169 \times .399}{15(1-.399)} = 7.5$ "

direct stress $= \frac{6020}{100 \times 28} = 2.2$ "
9.7 "

CALCULATIONS FOR

七號鐵筋混凝土框

Top and bottom slab.

max. positive moment $M_U = 6000$ kgm, axial compression $N_{DC} = 5660$ kgs
" " $M_L = 5900$ " , " $N_{AB} = 6535$ "

For top slab,

Effective depth required for bending moment $d = C_1\sqrt{\frac{M}{b}}$ where $b = 100$ cm
$C_1 = 0.362$ for $f_s = 1200$ kg/cm², $f_c = 47$ "

$d = 0.362 \times \sqrt{\frac{6000 \times 100}{100}} = 28.0$ cm

use 29 cm effective depth with an insulation of 5 cm, total depth = 34 cm

Steel area required $= \frac{6000 \times 100}{1200 \times 7/8 \times 29} = 19.7$ cm²

use 10-16mmφ bars = 10 × 2.011 = 20.11 cm² per meter strip of slab.

steel ratio $p = \frac{20.11}{100 \times 29} = 0.0069$, $k = 0.363$, $j = 0.879$

steel stress $f_s = \frac{6000 \times 100}{20.11 \times 0.879 \times 29} = 1170$ kg/cm²

concrete stress $f_c = \frac{1170 \times 0.363}{15(1-0.363)} = 44.4$ kg/cm²

direct stress $= \frac{5660}{100 \times 34} = \frac{1.7}{46.1}$ " kg/cm²

Max. negative moment $M_A = 11515$ kgm, axial compression $N_{AB} = 6535$ kgs
$M_D = 11470$ " , " $N_{DC} = 5660$ "

For bottom slab,

Effective depth required $d = 0.362 \times \sqrt{\frac{11515 \times 100}{100}} = 38.9$ cm

use 59 cm effective depth with an insulation of 5 cm, total depth 64 cm,

steel area required $= \frac{11515 \times 100}{1200 \times 7/8 \times 59} = 18.6$ cm²

use 10-16mmφ bars = 10 × 20.11 = 20.11 cm² per meter strip of slab.

steel ratio $p = \frac{20.11}{100 \times 59} = 0.0034$, $k = 0.272$, $j = 0.909$

steel stress $f_s = \frac{11515 \times 100}{20.11 \times 0.909 \times 59} = 1067$ kg/cm²

concrete stress $f_c = \frac{1067 \times 0.272}{15(1-0.272)} = 26.6$ "

direct stress $= \frac{6535}{100 \times 64} = \frac{1.0}{27.6}$ "

use same arrangement for both top and bottom slab.

shearing and bond stresses in top and bottom slab

shear at point A = D = 19650 kgs
$A_1 = D_1 = 13000$ "
$B_1 = C_1 = 13500$ "
$B_2 = C_2 = 12400$ "

$b = 100$, $h = 54$, $d' = 5$, $d = 49$
$A_s = 20.1$
$A_s' = 10.1$
$p_0 = \frac{20.1}{100 \times 54} = 0.00372$
$p_0' = 0.00187$
$\frac{d}{h} = 0.908$
$\frac{d'}{h} = 0.0926$
$\frac{u}{h} = 0.509$
$u = 27.5$
$d - u = 21.5$
$\frac{M}{N} = 176.0$
21.5
$197.5 = e$, $e' = 153.5$
$\frac{e'}{e} = 0.777$, $\frac{d'}{d} = 0.102$
$p = \frac{20.1}{100 \times 49} = 0.0041$
$p' = 0.0021$
$k = 0.31$, $\frac{Ne}{bd^2 f_c} = 0.16$

$f_c = \frac{6535 \times 197.5}{0.16 \times 100 \times 49^2} = 33.6$

$f_s = 15 \times 33.6 \times \frac{0.69}{0.31} = 1121$

unit shear

at A + D $v = \frac{19650}{100 \times 0.909 \times 59} = 3.66$ kg/cm²

at A₁ + D₁ $v = \frac{13000}{100 \times 0.879 \times 29} = 5.1$ 〃 use stirrups

at B₁ + C₁ $v = \frac{13500}{100 \times 7/8 \times 49} = 3.15$ 〃

at B₂ + C₂ $v = \frac{12400}{100 \times 0.879 \times 29} = 4.87$ 〃 〃

unit bond

at A + D $u = \frac{19650}{10 \cdot 5.02 \times .909 \times 59} = 7.3$ kg/cm² use bend up bars

at A₁ + D₁ $u = \frac{13000}{10 \cdot 5.02 \times .879 \times 29} = 10.16$ 〃 〃

at B₁ + C₁ $u = \frac{13500}{10 \cdot 5.02 \times 7/8 \times 49} = 6.27$ 〃 〃

at B₂ + C₂ $u = \frac{12400}{10 \cdot 5.02 \times .879 \times 29} = 9.69$ 〃 〃

Stirrup spacing

use U-stirrup of 9mmφ for which 5c 0.636 = 3.18 cm² per meter strip

Stirrup spacing required at point A

$S_1 = \frac{3}{2} \frac{A_s f_s jd}{V} = \frac{3}{2} \times \frac{3.18 \times 1200 \times .909 \times 59}{19650} = 15.6$ cm c. to c. (.832 29; 13,020)

Stirrup spacing required at point A₁

$S_2 = \frac{3}{2} \times \frac{3.18 \times 1200 \times 0.879 \times 29}{13000} = 11.2$ cm c. to c.

Stirrup spacing required at point B₁

$S_3 = \frac{3}{2} \times \frac{3.18 \times 1200 \times 7/8 \times 49}{13500} = 18.2$ cm 〃

Stirrup spacing required at point B₂

$S_4 = \frac{3}{2} \times \frac{3.18 \times 1200 \times .879 \times 29}{12400} = 11.8$ cm 〃

Detail design of side wall

negative moment $M_B = 4315$ kgm, axial compression $N_{CB} = 15050$ kgs
$M_C = 4270$ 〃, 〃 〃

at point B₁

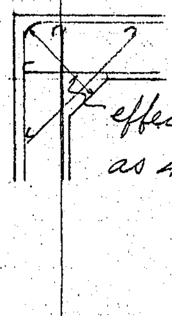
Effective depth required $= 0.362\sqrt{\frac{4315 \times 100}{100}} = 23.8$ cm use 42 cm

Steel area required $= \frac{4315 \times 100}{1200 \times 7/8 \times 42} = 9.78$ cm² for one meter strip

use 16mmφ 10cm c. to c. = 10 c 2.011 = 20.11 cm²

steel ratio $p = \frac{20.11}{100 \times 42} = 0.0048$, $k = 0.314$, $j = 0.895$

steel stress $f_s = \frac{4315 \times 100}{20.11 \times .895 \times 42} = 557$ kg/cm²



effective depth taken as 42 cm

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CALCULATIONS FOR

七號鐵筋混凝土框

concrete stress $f_c = \frac{557 \times 0.314}{15(1-0.314)} = 17.0$ kg/cm²

direct stress $= \frac{15050}{100 \times 42} = \underline{3.6}$ "

20.6 "

at end of haunch $M_{C_1} = -2550$ kgm, axial compression $N_{CB} = 15050$ kgs

$M_{B_1} = -2250$ " "

Effective depth required $= 0.362\sqrt{\frac{2550 \times 100}{100}} = 18.3$ cm . use 23 cm

steel area required $= \frac{2550 \times 100}{1200 \times 7/8 \times 23} = 10.6$ cm² for one meter strip

use 16mmφ 10cm c to c. $= 10 \times 2.011 = 20.11$ cm²

steel ratio $p = \frac{20.11}{100 \times 23} = 0.0088$, $k = 0.399$, $j = 0.867$

steel stress $f_s = \frac{2550 \times 100}{20.11 \times .867 \times 23} = 635$ kg/cm²

concrete stress $f_c = \frac{635 \times .399}{15(1-.399)} = 28.1$ "

direct stress $= \frac{15050}{100 \times 28} = \underline{5.4}$ "

33.5 "

Shearing and bond stress

Shear at point $C_1 = 4,350$ kgs

$B_1 = 4,850$ "

unit shear at B_1

$v = \frac{4850}{100 \times .867 \times 23} = 2.4$ kgs/cm²

unit bond at B_1

$u = \frac{4850}{10 \times 5.02 \times .867 \times 23} = 4.85$ "

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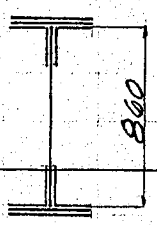
Top and bottom beam

max. positive moment M_1 = +111,500 kgm, axial compression N_{BC} = 44,780 kgs

" " " M_3 = +104,400 " " " N_{AD} = 59,920 "

For beam BC



Beam height 86.0 cm b. to b. Ls

web plate 85.0 × 1.6 = 136 cm², 1/8 web area = 17.0 cm²

Effective depth 86.0 − 2 @ 1.91 = 82.18 cm

Flange stress = 105,600 ÷ 0.8218 = 128,500 kgs.

Bottom flange area required = 128500 / 1200 = 107.1

1/8 web area = 17.0

90.1 cm² net

2 Pls 340×10 = 68.0 × 1.0 = − 68.0

2 Ls 150×150×15 = 85.5 × 4.22 = 361.0

153.5 × 1.91 293.0

use 2 Flg Ls 150×150×15 = 85.5 − 4 @ 3.75 = 70.5

2 Cov Pls 340 × 10 = 68.0 − 4 @ 2.50 = 58.0

153.5 cm² gr. 128.5 cm² net

Compression flange

Bending stress = 105,600×100×45.0 / 605,750 = 784 kg/cm²

Direct compression 44,780 / 443.0 = 101 "

889 "

For beam AD

Tension flange ample by above section

Compression flange

Bending stress = 104400×100×45.0 / 605,750 = 775 kg/cm²

Direct compression 59,920 / 443.0 = 135 "

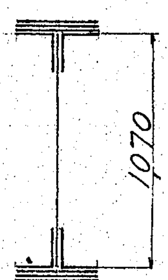
910 "

Max. negative moment M_C = −211,000 kgm, axial compression N_{BC} = 44,780 kgs

" " " M_D = −208,500 " " " N_{AD} = 59,920 "

max. end shear S_{CB} = 158,200 kgs, S_{DA} = 157,200 kgs

For beam at C



Beam height 107.0 cm b. to b. Ls

web plate 107.0 × 1.6 = 171.2 cm², 1/8 web area = 21.4 cm²

Effective depth 107.0 − 2 @ 1.50 = 104.0 cm

Flange stress 211,000 ÷ 1.04 = 202,800 kgs

Bottom flange area required = 202,800 / 1200 = 169.0 cm²

1/8 web area = 21.4

147.6 cm² net

3 Pls 340 × 10 = 102.0 × 1.5 = − 153.0

2 Ls 150×150×19 = 106.8 × 4.36 = 465.5

208.8 × 1.50 312.5

use 2 Flg Ls 150×150×19 = 106.8 − 4 @ 4.75 = 87.8

3 Cov Pls 340 × 10 = 102.0 − 6 @ 2.50 = 87.0

208.8 cm² gr. 174.8 cm² net

Compression flange
moment of inertia

4 Flg. Ls	150×150×19 =	213.52	× 49.2² + 4c 1098 =	521,390
6 cov P/s	340 × 10 =	204.0	× 55.0² =	617,000
1 Web P/	1060 × 16 =	169.6	1.6 × 106.0³ / 12 =	158,700
2 side P/s	760 × 19 =	289.0	2c 1.9 × 76.0³ / 12 =	139,000
		876.12 cm²		1426,090 cm⁴

Bending stress = 211,000 × 100 × 56.5 / 1426,090 = 835

Direct compression 44780 / 876.12 = 51
886 kg/cm²

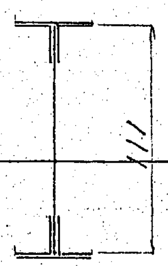
unit shear on web
158200 / 171.2 = 924 kg/cm²

For beam at D.
Tension flange ample by above section
Compression flange
Bending stress = 208500 × 100 × 56.5 / 1426,090 = 826

Direct compression 59920 / 876.12 = 68
894 kg/cm²

unit shear on web
157200 / 171.20 = 918 kg/cm²

Detail design of side column
negative moment at top M_B = −59,800 kgm, axial compression N_{BA} = 115800 kgs
" " bottom M_A = −64,800 " " N_{BC} = 44780 "
N_{AD} = 59,920 "
max. end shear S_{BA} = 44,780 kgs, S_{AB} = 59,920 kgs
at point B



Beam height assumed 111.0 cm b. to b Ls
web plate 1100 × 1.6 = 176.0 cm², 1/8 web area = 22.0 cm²
Effective depth 110.0 − 2c 1.32 = 107.36 cm
Flange stress = 59800 ÷ 1.074 = 55,700 kgs
Bottom area required = 55700 ÷ 1200 = 46.4
1/8 web area 22.0
24.4 cm²

1 P/ 340 × 10 = 34.0 × 0.5 = 17.0
2 Ls 150 × 100 × 12 = 57.12 × 2.4 = 137.0
91.12 × 1.32 120.0

use 2 Flg. Ls 150 × 100 × 12 = 57.12 − 4c 3.0 = 45.12
1 cov P/ 340 × 10 = 34.0 − 2c 2.5 = 29.0
91.12 cm² gr. 74.12 cm² net

Compression flange
flange area 91.12
1/8 web area 22.0
113.12 cm²

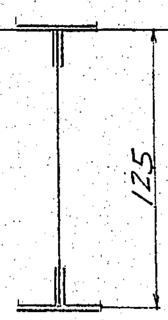
sectional area
flange area 91.12
" 91.12
web area 176.0
358.24 cm²

N_{BC} = 44780
N_{BA} = 115800
160580 × sin 45°
160580 × 0.707
= 113600 kgs

Bending stress = 55700 / 113.12 = 493
Direct compression 115800 / 358.24 = 323
816 kg/cm²

unit shear on web
44780 / 176.0 = 255 kg/cm²

at point A



Beam height assumed 125.0 cm b. to b.
web plate 1240 × 16.0 = 198.3 cm², 1/8 web area = 24.8 cm²
Effective depth 125.0 − 2c 1.32 = 122.36 cm
Flange stress = 64800 ÷ 1.224 = 53,000 kgs
Tension flange area required 53,000 ÷ 1200 = 44.2 cm²
1/8 web area = 24.8
19.4 cm net

Use same flange section for point A & B.
For positive moment will governed by seismic moment.

N

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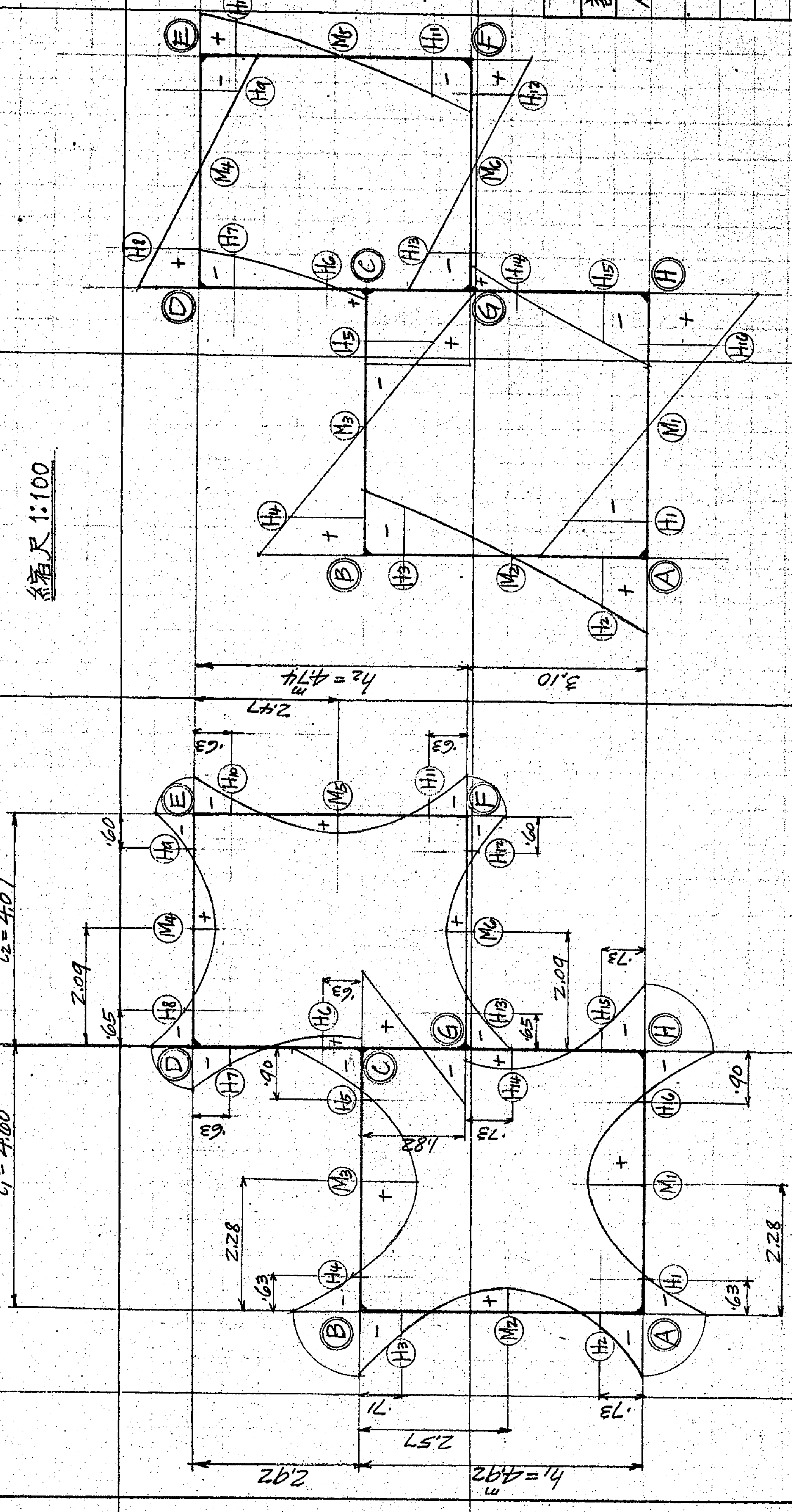
CALCULATIONS FOR
上下二段式函型隧道断面Ac路 土被4.5米

不用

鉄筋混凝土上下二段式函型隧道断面Ac路 土被四五米 其ノ一

部材	部材厚サcm
AB	46
BC	62
CD	50
DE	46
EF	40
FG	46
GC	50
GH	50
HA	66

VOID



土圧
E点 $q_1 = 4,635$ kg/m²
F,G点 $q_2 = 9,280$ kg/m²
H点 $q_3 = 12,318$ kg/m²

荷重状態

土被		4.50 m
地下水位	地表面下	1.50 m
土ノ安息角		20°00'
上床荷重	DE	$w_1 = 10,100$ kg/m
〃	BC	$w_2 = 16,170$ kg/m
下床荷重	GF	$w_1 = 10,100$ kg/m
〃	AH	$w_2 = 16,170$ kg/m