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CALCULATIONS FOR

MADE BY ____ DATE ____ FILE NO ____
CHECKED BY ____ DATE ____ PAGE NO ____

昭和六年一月

福島縣若松高田線

高田橋設計々算書

及材料調書

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MADE BY J. Masuda DATE 5-12-22 FILE NO

CHECKED BY M. Iida DATE 5-12-24 PAGE NO 1

CALCULATIONS FOR

Takata Bashi for Fukushima-Ken

This bridge shall be built across Akagawa on Wakamatsu and Takata line in Fukushima-Ken and be located 13.5 meters upstream of the present wooden beam bridge which is unable to carry up to date heavy traffic which will pass on bridge. Total length of bridge is 514.6 meters between faces of parapet walls and 515.4 meters between edges of boundary stones on parapets of both abutments. Intermediate spans consist of 25 - 19.2 meters in length and End spans 2 - 17.0 meters. The spans are figured as Combination type of one span Rahmen with overhanging arms and 3 span Rahmen, side spans being rest on said overhanging arm. All spans are built by reinforced concrete adding structural shapes as part of reinforcement.

The clear roadway is 5.5 meters between curb lines, paved with Granolithic pavement to insure water tight-ness for concrete structure.

Handrails will be Granolithic finish of posts and top rails, structural steel grates being encased.

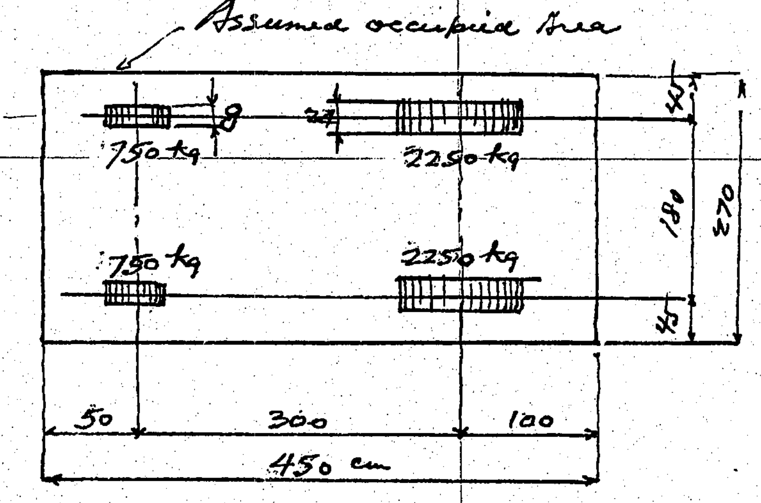
All piers are open well type and the abutments will be abutment piers to insure the scoring of ground during flood.

Assumed Loadings

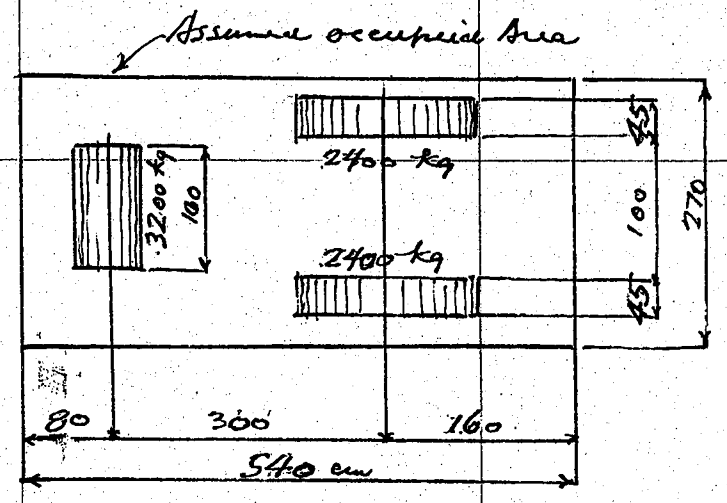
Uniform load on Roadway $w = \frac{100.000}{170 + l} \leq 500$ kg/m²

where w = Uniform load in kg per square meter
l = span length in meters

6 ton motor truck loading



8 ton Road Roller Loading.



2 rows of motor traffic on roadway with occupied width of 270 cm each; unoccupied space front and rear of motor truck shall be filled with above uniform live load. One road roller on one span.

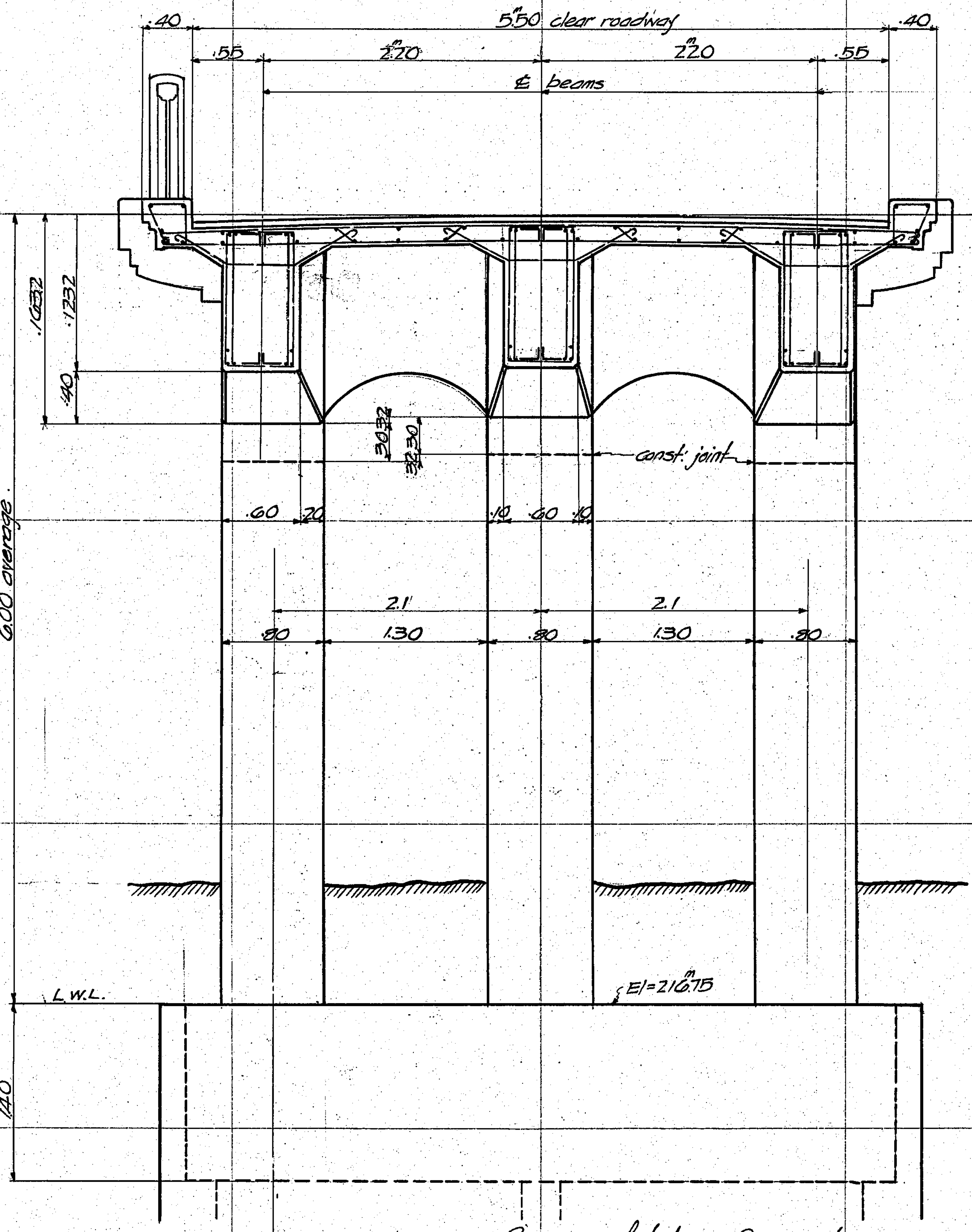
Equivalent uniform load assumed in figuring stresses of Rahmen for convenience' sake.

Impact for motor truck loading Coef = $\frac{20}{60+l}$ where l = loaded length in meters
max impact 30%

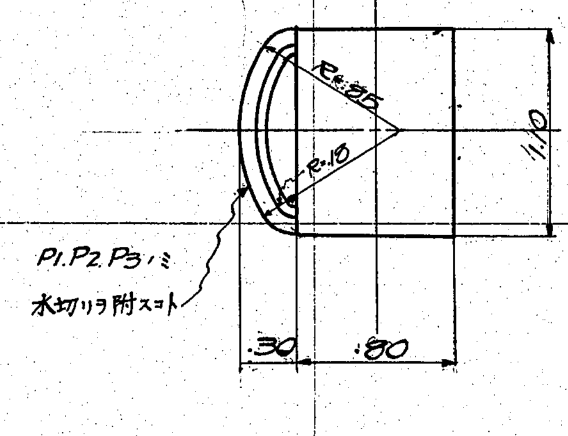
no impact for roadroller and uniform live loads.

allowable working strength and other miscellaneous data by specification issued by Engineering Department of Naimusho.

Design of Takada Bashi for Fukushima ken.
Cross section of Bridge assumed as shown on sketch below.



General sketch of Cross section of Bridge. scale 1:40.



Design of Takada Bashi for Fukushima Ken.

Design of Floor slab. Span length assumed 1.60 meters.

Dead Load

5 cm Granolithic pavement @ 2200 =	110	
18 cm Concrete slab @ 2400 =	432	
miscellaneous concrete say	8	
	550	kg per sq. meter.

Dead Load moment = 1/10 × 550 × 1.60² = 141 kgm.
Dead Load shear = 1/2 × 550 × 1.60 = 440 kg.

Live Load motor truck rear wheel concentration = 2250
30 % impact = 675
2925 kg

Front wheel concentration with impact say 1/3 × 2925 = 975 kg.

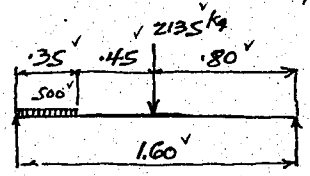
Distribution of wheel concentration on floor slab. thickness of pavement = 5.0 cm

Longitudinal distribution a. Contact between wheel and pavement = 20 cm
distribution 2 @ 5.0 = 10
a = 30 cm

Transverse distribution b. 24 + 2 @ 5 = 34 cm b = 34 cm

Effective width of slab. E = 2/3 · l + a = 2/3 × 1.60 + .30 = 1.37 meters.

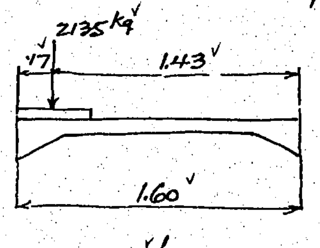
Load per meter of slab = 2925 ÷ 1.37 = 2135 kg
moment per meter strip uniform live load assumed 500 kg/sq. meter.



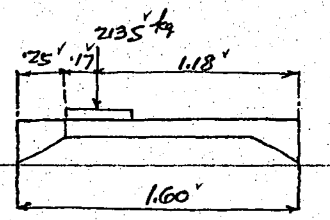
Reaction
$\frac{500 \times .35^2}{2 \times 1.60}$ = 19
2135 ÷ 2 = 1068
1087 kg

moment = 1087 × 1.60 ÷ 2 = 870 kgm.
For continuity of slab moment = 870 × 0.8 = 694 kgm.

End shear per meter strip.



max. shear at face of beam web.
2135 × $\frac{1.43}{1.60}$ = 1,908 kg.



max. shear at end of fillet.
2135 × $\frac{1.18}{1.60}$ = 1,575 kg.

Summary of moments and shears.

	moment	Shear at face of beam	Shear at end of fillet
Dead Load	141	440	550 × 1.10/2 = 303
Live Load	694	1908	1575
	835 kgm	2348 kg	1878 kg

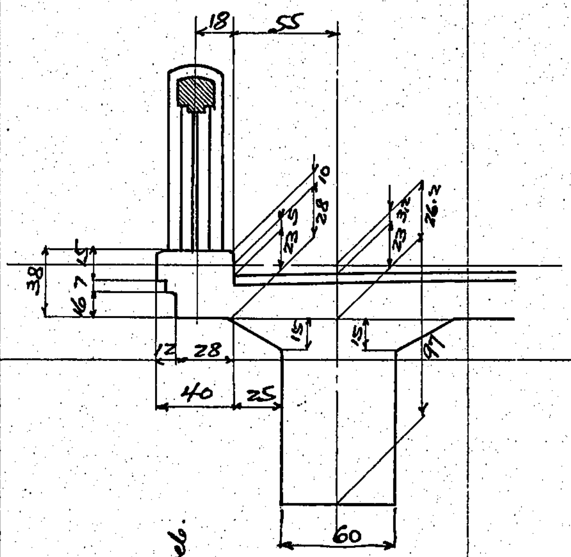
Effective depth required = $\sqrt{\frac{835 \times 100}{100 \times 7.18}}$ = 10.8 cm use 15 cm effective depth with 3 cm insulation.
Steel area required = $\frac{835 \times 100}{1200 \times \frac{7}{8} \times 15}$ = 5.30 cm² per meter strip.
Use 12 mm φ bars at 15 cm c to c = 7.54 cm² " "

At end of fillet
unit shear = $\frac{1878}{100 \times \frac{7}{8} \times 15}$ = 1.43 kg/cm² ok
unit bond = $\frac{1878}{3.77 \times 6.67 \times \frac{7}{8} \times 15}$ = 5.70 " ok.

At face of beam web.
unit shear = $\frac{2348}{100 \times \frac{7}{8} \times 30}$ = 0.90 kg/cm² ok
unit bond = $\frac{2348}{3.77 \times 6.67 \times \frac{7}{8} \times 30}$ = 3.55 " ok

Design of Takada Bashi for Fukushima Ken.

Design of Overhanging Slab beyond main beam.



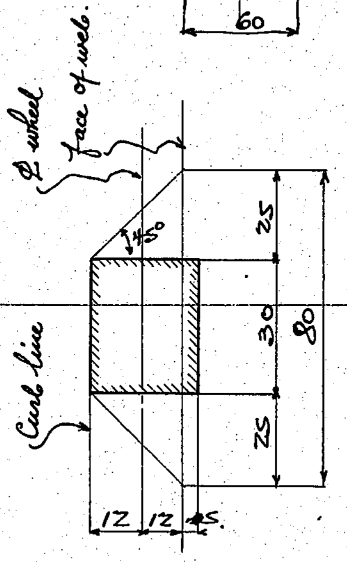
Dead Load

Floor slab and pavement	.25 @ 550 =	138 × .125 =	17.
Coping	.34 × .38 = .129 @ 2400 =	310 @ .42 =	130
Handrail say		170 × .43 =	73
miscellaneous say		12 × .35 =	4
		630 kg. .36 m	224 kgm.

Dead Load moment = 224 kgm.
Dead Load shear = 630 kg.

Live Load.

motor truck rear wheel concentration with impact = 2925 kg.
Rear wheel of motor truck in contact to curb line and its distribution on slab as following sketch assumed.
Effective width of slab = 30 + 2 × 25 = 80 cm.
load per meter strip = 2925 ÷ 0.8 = 3660 kg.



moment 3660 × .12 = 439 kgm.
Shear say $3660 \times \frac{29}{34}$ = 3120 kg.

Summary of moments and shears.

	moment	End shear.
Dead Load	224	630
Live Load	439	3120
	663 kgm	3750 kg

Effective depth required $= \sqrt{\frac{663 \times 100}{100 \times 7.18}} = 9.60$ cm.

Use 30 cm effective depth with 3 cm insulation.

Steel area required $= \frac{663 \times 100}{1200 \times \frac{7}{8} \times 30} = 2.11$ cm² per meter strip of slab.

Use 12 mm ϕ bars at 15 cm c to c = 7.54 cm²

Unit shear $= \frac{3750}{100 \times \frac{7}{8} \times 30} = 1.43$ kg/cm² ok.

Unit bond $= \frac{3750}{3.77 \times 6.67 \times \frac{7}{8} \times 30} = 5.68$ " ok.

Design of Main Beams and Pier Columns as a Rahmen.

Dead Load

	On Outside beam.			On Inside beam	
Floor slab and pavement	550 × 1.40	=	770	550 × 2.20 =	1,210
Overhanging slab, coping + handrail		=	630		—
web of beam	.97 × .60 @ 2400 =	=	1397		1,397
fillets	.15 × .25 @ 2400 =	=	90		90
extra concrete of beam near support. say		=	63		63
			2950 kg per lin m.		2,760 kg per lin m.

Design of Takada Bashi for Fukushima Ken.

Live load:-

Uniform live load $w = \frac{100000}{170+l} = \frac{100000}{170+19.2} = 529.$ use 500 kg per square meter.

6 ton motor truck loading.

For convenience sake, let us use a proper equivalent uniform load for extra weight of motor truck.

Impact for loaded length of one span = 19.2 m coef. $= \frac{20}{60+19.2} =$ 25.2 %

" " " " 2 spans = 19.2+17.0 = 36.2

coef. $= \frac{20}{60+36.2} =$ 20.8 %

46.0 %

Average coefficient = 46.0 ÷ 2 = 23.0 %

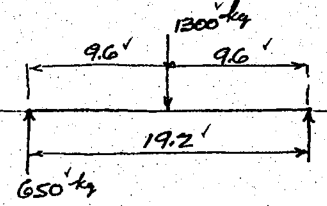
motor truck wheel load for one truck = 6000 × 1.23 = 7,400 kg

uniform load for occupied space of one truck = 500 × 4.5 × 2.7 = 6,100

Extra load of one truck = 1,300 kg

Equivalent uniform load as a simple span for this extra load of 1300 kg as a concentration.

For 19.2 meter span.



moment = 650 × 9.6 = 6240 kgm

$\frac{wl^2}{8} = 6240$, or $w = \frac{6240 \times 8}{l^2} = \frac{6240 \times 8}{19.2^2} = 135$ kg/lin m.

Equivalent uniform load = 135 ÷ 2.70 = 50 kg per square meter.

For 17.0 meter span

moment = 650 × 8.5 = 5520 kgm

$w = \frac{5520 \times 8}{17.0^2} = 153$ kg/lin m.

Equivalent uniform load = 153 ÷ 2.70 = 57 kg per square meter.

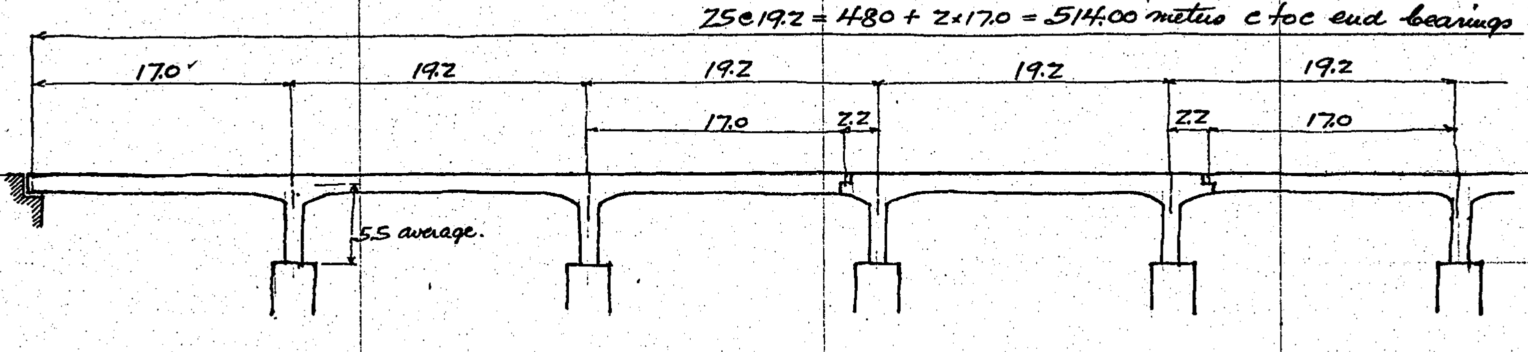
Use 60 kg/m² as an equivalent uniform load for extra load of truck.

Total uniform live load = 500 + 60 = 560 kg per sq. meter.

Live load for outside main beam 1.65 m @ 560 = 920 kg per lin meter of span.

Live load for inside main beam 2.20 @ 560 = 1,230 kg per lin meter of span.

Span length of the bridge are as follows:



A-Rahmen
7 sets required

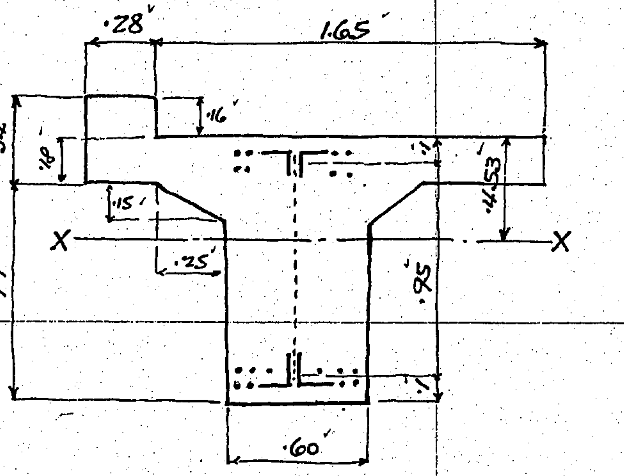
B-Rahmen.
6 sets required.

Formulas used in the following calculations of A-Rahmen are deduced by the author and those for B-Rahmen, referred to Kleinlogel's Rahmen Formeln, but somewhat modified.

Design of Takada Bashi For Fukushima Ken.

Moments of Inertia of Beams.

Outside Beams.



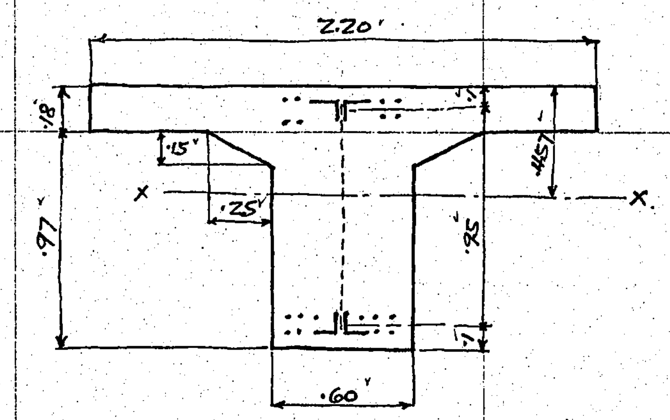
moment about top of slab.

Coping	.34 × .28 =	.095	×	.01 =	.0010
slab	1.65 × .18 =	.297	×	.09 =	.0267
fillets	.15 × .25 =	.038	×	.23 =	.0087
web	.60 × .97 =	.581	×	.665 =	.3862
Steel	$200^{cm^2} \times 14 \div 10{,}000$ =	.280	×	.575 =	.1620
		1.291^{m^2}		$.453^m$	.5846

moment of inertia about X–X line.

Coping	$\frac{.28 \times .34^3}{12} + .095 \times .443^2 =$	.01952
Slab	$\frac{1.65 \times .18^3}{12} + .297 \times .363^2 =$	.03995
fillets	$.038 \times .223^2 =$	.00189
web	$\frac{.60 \times .97^3}{12} + .581 \times .212^2 =$	.07165
Steel area	$.280 \times .122^2 =$	.00416
		$.13720^{m^4}$

Inside Beam



moment about top of Slab.

Slab	2.20 × .180 =	.396	×	.09 =	.0357
fillet	.15 × .25 =	.038	×	.23 =	.0087
web	.60 × .97 =	.581	×	.665 =	.3862
Steel	$210^{cm^2} \times 14 \div 10000$ =	.290	×	.575 =	.1670
		1.305^{m^2}		$.457^m$	.5976

moment of inertia about X–X line.

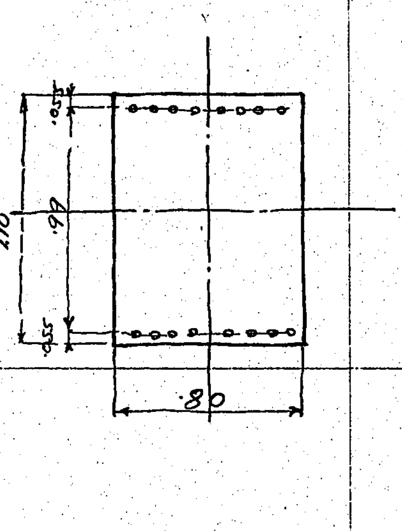
Slab	$\frac{2.20 \times .18^3}{12} + .396 \times .367^2 =$	.05457
Fillet	$.038 \times .227^2 =$	.00196
web	$\frac{.60 \times .97^3}{12} + .581 \times .208^2 =$	.07085
Steel	$.290 \times .118^2 =$	.00404
		$.13142^{m^4}$

Transformed sectional areas and moments of inertia of both beams are nearly equal.
Let us use average sectional area and moment of inertia of both beams in the following calculations.

Average moment of inertia and sectional area.

	moment of inertia	transformed sectional area
Outside Beam.	0.13720	1.291
Inside Beam.	0.13142	1.305
	0.26862	2.596
average	$I_1 = I_2 = 0.13431^{m^4}$	average 1.298^{m^2}

moment of inertia of Column.



Area of transformed section

Concrete	.80 × 1.10	= .880
steel	$80^{cm^2} \times 14 \div 10{,}000$	= .112
		$.992^{m^2}$

moment of inertia

Concrete	$\frac{.80 \times 1.10^3}{12}$	= .0888
steel	$.112 \times .495^2 =$	.0275
I_h =		.1163

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CALCULATIONS FOR

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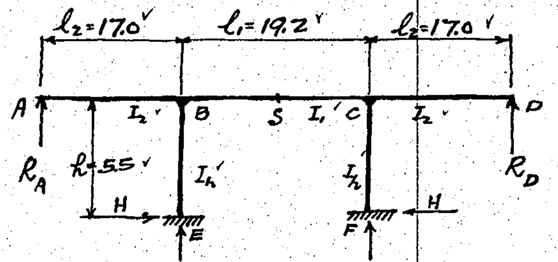
Design of Takada Bashi for Fukushima Ken.

Design of A-Rahmen.



average height of rahmen assumed $h = 5.50^m$

Constants used in the following calculation.

$v_1 = \frac{I_1 \cdot h}{I_h \cdot l_1} = \frac{0.13431 \times 5.50}{0.1163 \times 19.20} = .331$

$v_2 = \frac{I_2 \cdot h}{I_h \cdot l_2} = \frac{0.13431 \times 5.50}{0.1163 \times 17.00} = .374$

$k_1 = 4 + 6v_1 + 3v_2 = 4 + 1.986 + 1.122 = 7.108$

$k_2 = 4 + 2v_1 + 3v_2 = 4 + .662 + 1.122 = 5.784$

$k_3 = 2 + v_1 + 2v_2 = 2 + .331 + .748 = 3.079$

Dead Load stresses of Outside Rahmen.

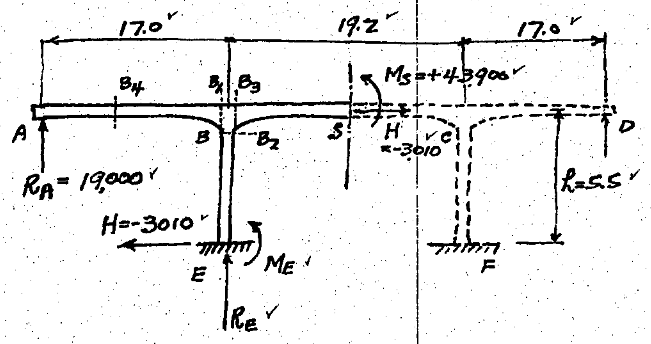
Dead Load $q_1 = q_2 = 2950$ kg per lin meter. (full load.)

Redundancies

$M_S = \frac{q_1 l_1^2 k_1 - 6q_2 l_2^2 v_1}{24 k_2} = \frac{q \times 19.2^2 \times 7.108 - 6q \times 17.0^2 \times .331}{24 \times 5.784} = 14.88\,q = 14.88 \times 2950 = +43,900$ kgm

$H = \frac{2q_1 l_1^2 - 3q_2 l_2^2}{4h k_2} = \frac{q \times 2 \times 19.2^2 - 3 \times q \times 17.0^2}{4 \times 5.5 \times 5.784} = -1.021\,q = -1.021 \times 2950 = -3010$ kg

$R_A = \frac{3q_2 l_2^2 k_3 - q_1 l_1^2 v_2}{4 l_2 k_2} = \frac{q \times 3 \times 17.0^2 \times 3.079 - q \times 19.2^2 \times .374}{4 \times 17.0 \times 5.784} = 6.440\,q = 6.440 \times 2950 = +19,000$ kg



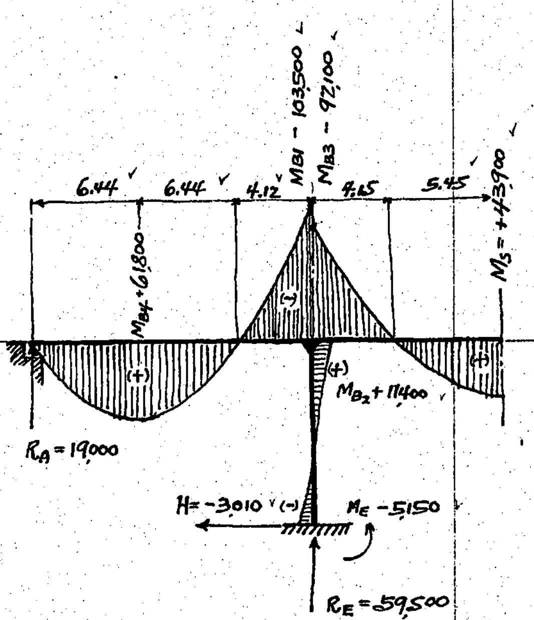
moments at support B.

M_{B1} for beam, left side of support.

$19,000 \times 17.00$	=	+	323,000
$-\frac{1}{2} \times 2950 \times 17.00^2$	=	−	426,500
		−	103,500 kgm. $= M_{B1}$

M_E for column bottom

$R_A l_2$	19000×17.00	=	−	323,000
M_S		=	+	43,900
$\frac{q l_2^2}{2}$	$\frac{1}{2} \times 2950 \times 17.00^2$	=	+	426,500
$\frac{q l_1^2}{8}$	$\frac{1}{8} \times 2950 \times 19.20^2$	=	−	136,000
Hh	$3,010 \times 5.50$	=	−	16,550
			−	5,150 kgm $= M_E$



M_{B2} for Top of column.

Hh	3010×5.50	=	+	16,550
M_E			−	5,150
			+	11,400 kgm $= M_{B2}$

M_{B3} for beam right side of support.

M_S		=	+	43,900
$\frac{q l^2}{8}$	$\frac{1}{8} \times 2950 \times 19.20^2$	=	−	136,000
			−	92,100 kgm $= M_{B3}$

M_{B4} max. moment in side span.

$R_A x - \frac{q x^2}{2} = M_{B4}$ $\frac{dM_{B4}}{dx} = R_A - qx = 0$

$x = \frac{R_A}{q} = \frac{19000}{2950} = 6.44^m$ from left support A.

19000×6.44	=	123,000
$2950 \times \frac{6.44^2}{2}$	=	− 61,200
		+ 61,800 kgm $= M_{B4}$

Points of 0 moment.

Side span $R_A x - \frac{q x^2}{2} = 0$ $x\left(x - \frac{2R_A}{q}\right) = 0$

$x = 0$ or $\frac{2R_A}{q} = \frac{2 \times 19000}{2950} = 12.88^m$ from end supp.

Center span. $M_S - \frac{q x^2}{2} = 0$ $x^2 = \frac{2M_S}{q}$

$x = \sqrt{\frac{2M_S}{q}} = \sqrt{\frac{2 \times 43900}{2950}} = 5.45^m$ from center.

R_E $2950 \times 26.60^m = 78,500$
−19,000
+ 59,500 kg $= R_E$

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CALCULATIONS FOR

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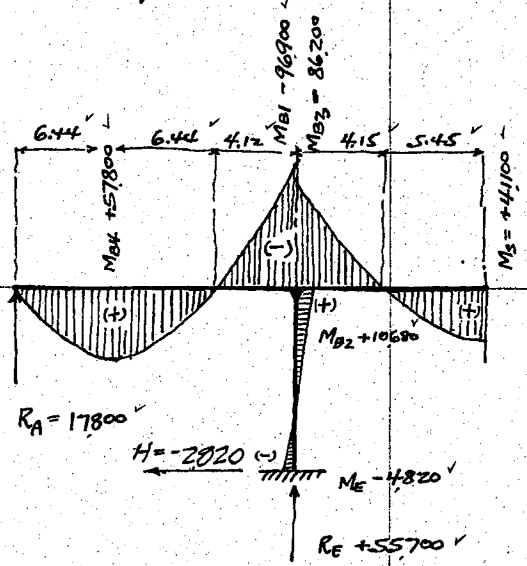
Design of Takada Bashi for Fukushima ken.

Dead Load stresses of Inside Rahmen

Dead Load = 2760 kg per lin meter of span. (See on page 4)

Let us figure the stresses by proportion of dead loads of outside & inside beams. $\frac{2760}{2950} = 0.936$



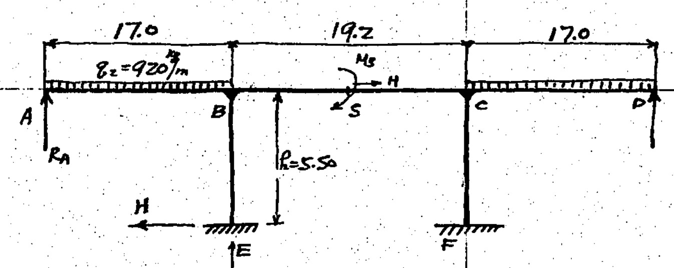
M_{B1}	$-103{,}500 \times .936$	=	−	96,900 kgm.
M_E	$-5150 \times$ "	=	−	4,820 "
M_{B2}	$+11{,}400 \times$ "	=	+	10,680 "
M_{B3}	$-92{,}100 \times$ "	=	−	86,200 "
M_{B4}	$+61{,}800 \times$ "	=	+	57,800 "
M_S	$+43900 \times$ "	=	+	41,100 "
H	$-3010 \times$ "	=	−	2,820 kg
R_A	$+19000 \times$ "	=	+	17,800 "
R_E	$+59500 \times$ "	=	+	55700 "

Live Load stresses of Outside Rahmen.

Equivalent uniform live load = 920 kg per lin meter of span.

(Case 1) Max. Positive moment in side span and negative moment in center span.

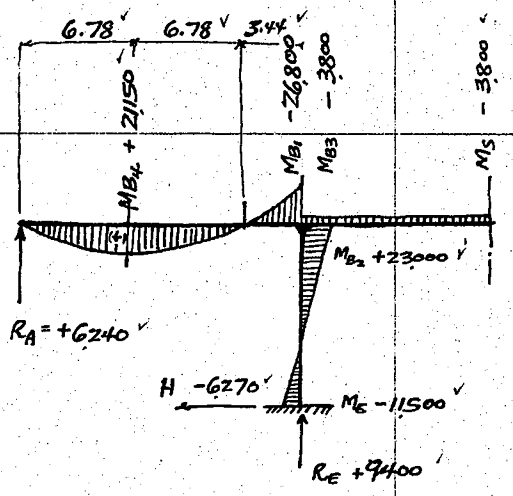
Put $g_1 = 0$ in the fundamental formulas.



$$M_S = -\frac{6 g_2 l_2^2 v_1}{24 k_2} = \frac{-920 \times 17.0^2 \times .331}{4 \times 5.784} = -3{,}800 \text{ kgm.}$$

$$H = -\frac{3 g_2 l_2^2}{4 h k_2} = -\frac{3 \times 920 \times 17.0^2}{4 \times 5.5 \times 5.784} = -6270 \text{ kg}$$

$$R_A = \frac{3 g_2 l_2^2 k_3}{4 l_2 k_2} = \frac{3 g_2 l_2 k_3}{4 k_2} = \frac{3 \times 920 \times 17.0 \times 3.079}{4 \times 5.784} = +6240 \text{ kg.}$$



$$R_E = 920 \times 17.0 - 6240 = +9400 \text{ kg}$$

M_{B4} $x = \frac{R_A}{q} = \frac{6240}{920} = 6.78^m$ from end support A.

6240×6.78	=	+ 42,300
$\frac{1}{2} \times 920 \times 6.78^2$	=	− 21,150
		+ 21,150 kgm

M_E

6240×17.0	=	− 106,000
$\frac{1}{2} \times 920 \times 17.0^2$	=	+ 132,800
6270×5.5	=	− 34,500
		− 3800
		− 11,500 kgm.

for m = 0

$$x = \frac{2 R_A}{q} = \frac{2 \times 6240}{920} = 13.56^m$$

M_{B2}

6270×5.5	=	+ 34,500
		− 11,500
		+ 23000 kgm.

Design of Takada Bashi for Fukushima ken.

M_{B1} 6240 × 17.0 = + 106,000
      ½ × 920 × 17.0² = − 132,800
      − 26800 kgm

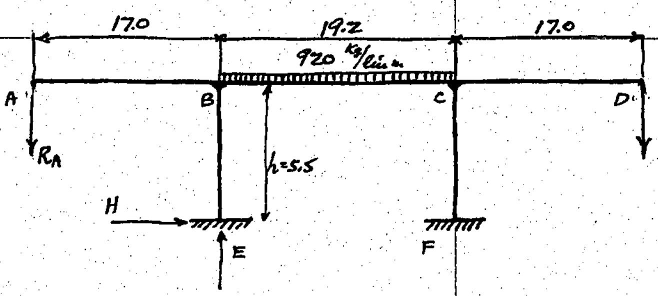
M_{B3} = M_S = − 3800 "

Live Load stresses of Inside Rahmen.

(Case 1) Equivalent uniform live load = 1230 kg per lin meter of span. $\frac{1230}{920}$ = 1.336

M_{B1}	− 26,800 × 1.336	=	− 35,700	kgm
M_E	− 11,500 "	=	− 15,370	"
M_{B2}	+ 23,000 "	=	+ 30,740	"
M_{B3}	− 3,800 "	=	− 5,080	"
M_S	− 3,800 "	=	− 5,080	"
M_{B4}	+ 21,150 "	=	+ 28,250	"
H	− 6,270 "	=	− 8,380	kg
R_A	+ 6,240 "	=	+ 8,340	"
R_E	+ 9,400 "	=	+ 12,560	"

(Case 2) max. positive moment in center span and negative moment in side span.
Outside Rahmen.

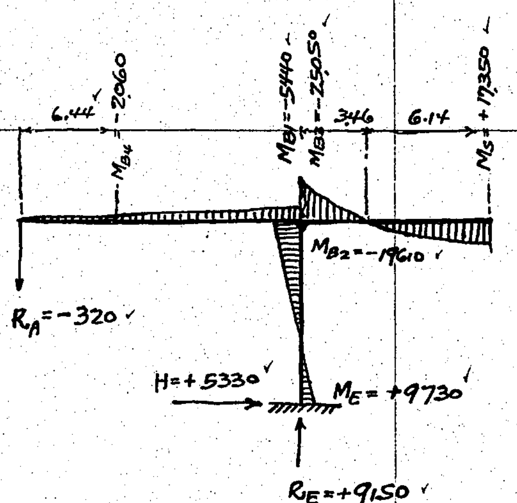


Substitute $q_2 = 0$ into the fundamental formulas.

$$M_S = \frac{q_1 l_1^2 k_1}{24\, k_2} = \frac{920 \times 19.2^2 \times 7.108}{24 \times 5.784} = +17,350 \text{ kgm}$$

$$H = \frac{q_1 l_1^2}{2h\, k_2} = \frac{920 \times 19.2^2}{2 \times 5.5 \times 5.784} = +5,330 \text{ kg}$$

$$R_A = -\frac{q_1 l_1^2 \nu_2}{4 l_2\, k_2} = -\frac{920 \times 19.2^2 \times .374}{4 \times 17.0 \times 5.784} = -320 \text{ kg}$$



End Reaction R_A is negative, but the total sum of DL+LL Reactions is positive, so we should treat this reaction as an uplifting force inspite of giving no device of anchoring.

R_E = 920 × $\frac{19.2}{2}$ + 320 = + 9,150 kg

M_{B1} = − 320 × 17.0 = − 5,440 kgm

M_{B3} = − 920 × $\frac{19.2^2}{8}$ = − 42,400
      + 17,350
      − 25,050 kgm

M_E + 320 × 17.0 = + 5,440
      − 920 × $\frac{19.2^2}{8}$ = − 42,400
      + 5330 × 5.50 = + 29,340
      + 17,350
      + 9,730 kgm

M_{B2} − 5330 × 5.50 = − 29,340
      + 9,730
      − 19,610 kgm

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CALCULATIONS FOR

Design of Takada Bashi for Fukushima Ken.

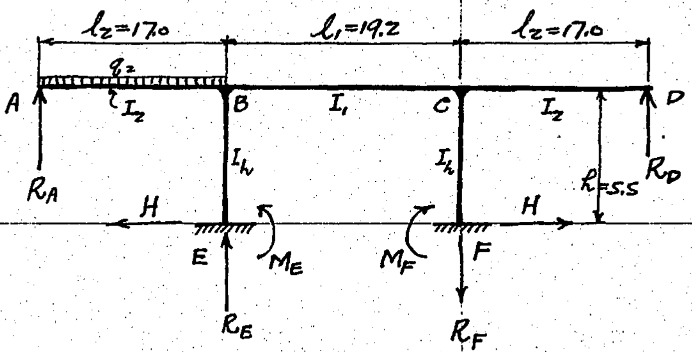
(Case 2) Inside Rahmen

M_S	+	17,350	×	1.336	=	+	23,180 kgm
H	+	5,330	×	〃	=	+	7,120 kg
R_A	−	320	×	〃	=	−	430 〃
R_E	+	9,150	×	〃	=	+	12,230 〃
M_{B1}	−	5440	×	〃	=	−	7,270 kgm
M_{B3}	−	25,050	×	〃	=	−	33,450 〃
M_E	+	9,730	×	〃	=	+	13,000 〃
M_{B2}	−	19,610	×	〃	=	−	26,200 〃
M_{B4}	−	2,060	×	〃	=	−	2,750 〃 at x=6.44

(Case 3) Max. negative moment at support B.

In the following calculations, the stresses are devided into 2 parts, one due to load on side span only and the other due to center span only. The latter is the same as for case 2 in above calculation.

Outside Rahmen. Equivalent uniform live load = 920 kg per lin meter of side span



This structure will have 5 redundanceis. Let us select R_A, H, R_E, M_E and M_F as above redundanceis.

After an elaborate diductions, we have following equations of redundanceis.

$$17{,}450\,R_A + 7{,}130\,R_E + 2{,}807\,H + 510.5\,M_E = -1638\,R_F + 205{,}300\,q$$
$$7{,}130\,R_A + 4{,}000\,R_E + 1{,}012\,H + 184.5\,M_E = -1638\,R_F + 94{,}850\,q$$
$$20{,}910\,R_A + 7{,}535\,R_E + 4{,}919\,H + 917.0\,M_E = 241{,}800\,q$$
$$3{,}802\,R_A + 1{,}370\,R_E + 916.7\,H + 190.3\,M_E = 43{,}940\,q$$
$$151.3\,H + 5.5\,M_F = 0$$

Solving these simultaneous equations, we have as follows.

$$R_A = +0.112\,R_F + 6.716\,q$$
$$R_E = -0.800\,R_F + 10.670\,q$$
$$H = +0.908\,R_F + 5.373\,q$$
$$M_E = -0.862\,R_F - 5.905\,q$$
$$M_F = -2.500\,R_F - 14.780\,q$$

In these formulas R_F will be eliminated by following 2 simultaneous equations.

$$R_D = q l_2 - R_A - R_E - R_F$$
$$R_D = \frac{R_A l_2 - \frac{q l_2^2}{2} + M_E - R_F l_1 - M_F}{l_1 + l_2}$$

from these

$$R_F = -1.702\,q$$
$$R_D = +0.145\,q$$

finally

for q = 920 kg/lin meter

R_A = +6.525 q	R_A	=	+	6,000 kg
R_E = +12.031 q	R_E	=	+	11,070 〃
H = +3.828 q	H	=	+	3,520 〃
M_E = −4.438 q	M_E	=	−	4,080 kgm
M_F = −10.525 q	M_F	=	−	9,680 〃
	R_F	=	−	1,570 kg
	R_D	=	+	130 〃

注意 ←------ Hノ符号ハ D.L.及L.L.ノCase 1+2ノ場合ト反対ニ取リタルヲ以テ注意スベシ 即チ此値ハD.L.ノ(−)ニ相当ス

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CALCULATIONS FOR

Design of Takada Bashi for Fukushima ken.

Max. positive moment in side span.

moment $= R_A x - \frac{q x^2}{2}$

$\frac{dM}{dx} = R_A - qx = 0$ or $x = \frac{R_A}{q} = \frac{6000}{920} = 6.52^m$

moment $+M_{max.} = 6000 \times 6.52 - \frac{920 \times 6.52^2}{2} = 39150 - 19550 = +19600$ kgm. $= M_{B4}$

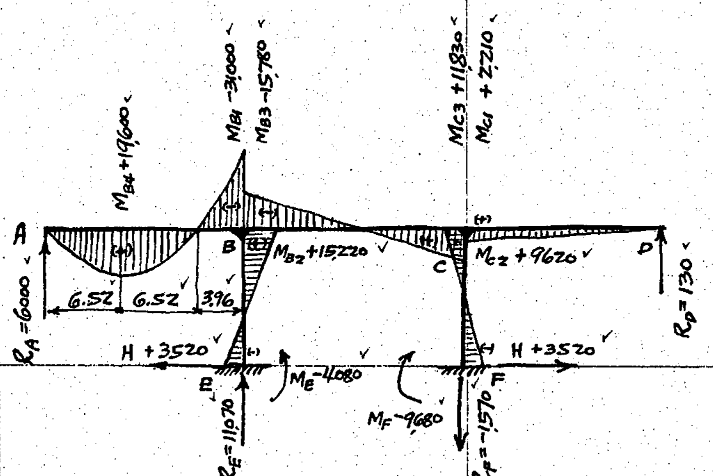
Neg. moment in beam leftside of B. M_{B1}.

$6000 \times 17.0 = +\ 102000$

$\frac{1}{2} \cdot 920 \times 17.0^2 = -\ 133000$

$-\ 31000$ kgm. $= M_{B1}$.

Top of column



M_{B2}

$3520 \times 5.50 = +\ 19300$

$M_E = -\ 4080$

$+\ 15220$ kgm $= M_{B2}$

M_{B3} $-31000 + 15220 = -\ 15780$ kgm. $= M_{B3}$

M_{C1} $130 \times 17.0 = +\ 2210$ kgm. $= M_{C1}$

M_{C2} $3520 \times 5.50 = +\ 19300$

$M_F = -\ 9680$

$+\ 9620$ kgm $= M_{C2}$

M_{C3} $2210 + 9620 = +\ 11830$ kgm $= M_{C3}$

Case 3. Inside Rahmen. $q = 1230$ kg per lin m. Ratio. $= \frac{1230}{920} = 1.336$

M_{B1}	$-$ 31000	$\times$ 1.336 =	$-$ 41450	kgm
M_{B3}	$-$ 15780	"	$-$ 21100	"
M_{B2}	+ 15220	"	+ 20350	"
M_{B4}	+ 19600	"	+ 26200	"
M_E	$-$ 4080	"	$-$ 5450	"
M_F	$-$ 9680	"	$-$ 12930	"
H	+ 3520	"	+ 4710	kg
R_A	+ 6000	"	+ 8020	"
R_E	+ 11070	"	+ 14780	"
R_F	$-$ 1570	"	$-$ 2100	"
R_D	+ 130	"	+ 170	"
M_{C3}	+ 11830	"	+ 15800	kgm
M_{C1}	+ 2210	"	+ 2950	"
M_{C2}	+ 9620	"	+ 12850	"

Design of Takada Bashi for Fukushima Ken.

Shears at several points in A - Rahmen.

Dead Load Shears.

Outside Rahmen. $q = 2950$ kg/lin meter.

at point A. S_A End Shear $= R_A$ $= +19{,}000$ kg

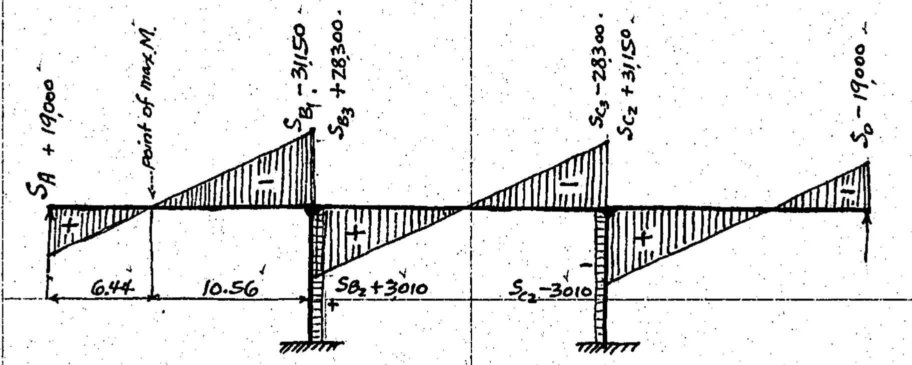
left side of B, S_{B1} $+19{,}000$
$-2950 \times 17.0 = -50150$
$-31{,}150$ kg

right side of B S_{B3}
$1/2 \times 2950 \times 19.20 =$ $+28300$ kg

Shear in column $S_{B2} = H$ $= +3{,}010$ kg

Inside Rahmen $q = 2760$ kg/m. ratio $= \frac{2760}{2950} = 0.936$

S_A	$+19{,}000$	$\times 0.936 =$	$+17{,}800$ kg
S_{B1}	$-31{,}150$	" $=$	$-29{,}150$ kg
S_{B3}	$+28300$	" $=$	$+26{,}500$ kg
Column S_{B2}	$+3{,}010$	" $=$	$+2820$ kg



Live Load shears.

Outside Rahmen.

S_A shear at support A. Case 1, max.
$S_A = +6{,}240$ kg
($S_{D1} = 6490$)

S_{B1} left side of support B. Case 2+3 combined, max.
Case 2 $R_A = -320$
Case 3 " $= +6{,}000$
" $8l_2 = 920 \times 17 = -15640$
$S_{B1} = -9960$ kg
($S_A = 5680$)

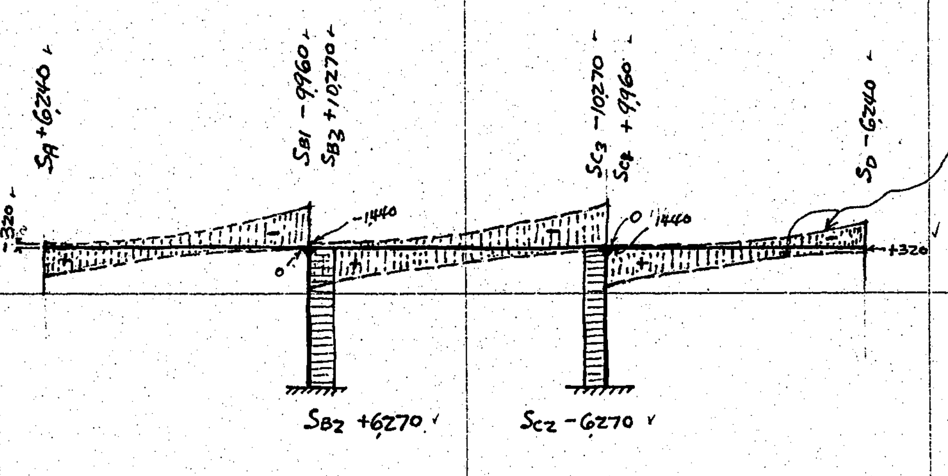
S_{B3} right side of support B Case 2+3 combined, max.

Case 2. $920 \times 19.2 \div 2 = +8830$
Case 3 $R_F = -(-1570) = +1570$
" $R_D = -(+130) = -130$
$S_{B3} = +10270$ kg
($S_{C3} = 7400$)

S_{B2} Shear in column Case 1 max.
$S_{B2} = -H = +6{,}270$ kg

Inside Rahmen. ratio 1.336

S_A	$=$	$+8{,}340$ kg
S_{B1}	$=$	$-13{,}310$ kg
S_{B3}	$=$	$+13{,}740$ kg
S_{B2}	$=$	$+8{,}380$ kg



max shears at various points due to moving uniform live load assumed to vary parabolically.

Design of Takada Bashi for Fukushima ken.

Stresses during Earthquake. Acceleration of Earthquake assumed 2000 mm/sec² or k = 0.200

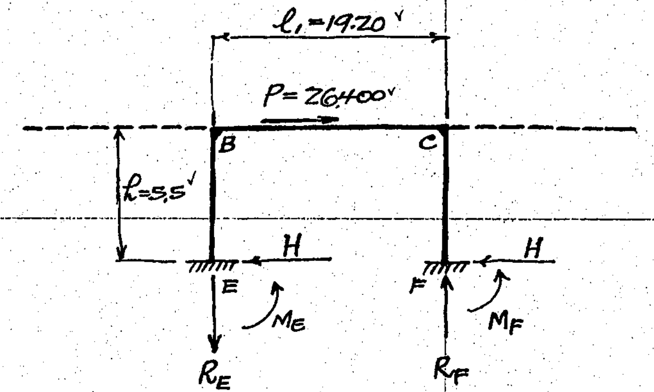
Outside Rahmen.

Dead Load of super structure = 53.20 m @ 2950 = 157,000
weight of column .80×1.1×5.5×2÷2 = 4.85 @ 2400 = 11,600
Strut and miscellaneous concrete say 1400
170,000 kg.

Seismic force P_0 = 0.200 × 170,000 = 34,000 kg.

Dead Load end reaction = 19,000 kg.
frictional resistance say 0.20 × 19000 = 3,800
for both ends 2 @ 3800 = 7,600
Net Seismic force P = 26,400 kg.

For this case, end reaction $R_A + R_D$ caused by the seismic force will be very small. For simplicity sake, these end reactions neglected in the following calculations.



$v = v_1 = 0.331$ (see page 7), $3v+1 = 1.993$, $6v+1 = 2.986$

$H = \frac{P}{2} = \frac{26400}{2} = -13,200$ kg.

$R_E = -\frac{3Phv}{l_1(6v+1)} = -\frac{3 \times 26400 \times 5.5 \times .331}{19.2 \times 2.986} = -2,510$ kg

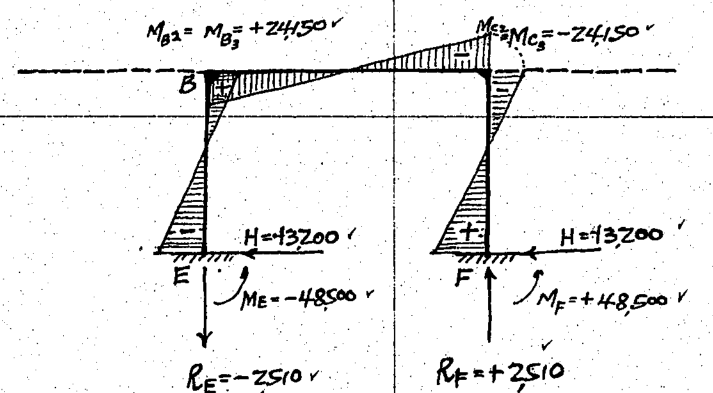
$R_F = -R_E = +2,510$ kg

$M_E = -\frac{Ph}{2} \times \frac{3v+1}{6v+1} = -\frac{26400 \times 5.5}{2} \times \frac{1.993}{2.986} = -48,500$ kgm

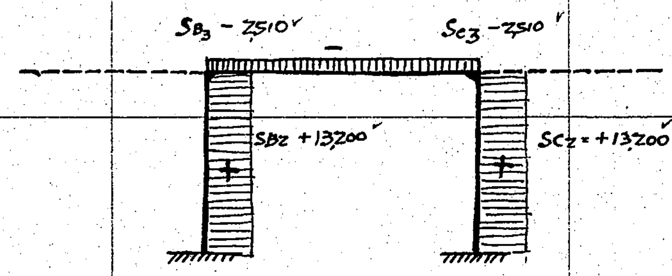
$M_F = -M_E = +48,500$ kgm.

$M_B = +\frac{Ph}{2} \times \frac{3v}{6v+1} = \frac{26400 \times 5.5}{2} \times \frac{.993}{2.986} = +24,150$ kgm.

$M_C = -M_B = -24,150$ kgm.



Moment diagram



Shear diagram.

Inside Rahmen

Dead Load
Super structure 53.20 m @ 2760 = 146,700
½ wt. of column = 11,600
Strut and misc. concrete say = 1,700
160,000 kg.

Seismic force P_0 = 0.2 × 160,000 = 32,000
frictional resistance say 0.20 × 17800 × 2 = −7100
net seismic force P = 24,900 kg.

Ratio = $\frac{24900}{26400}$ = 0.943

H	−13200	× 0.943	=	−12,450 kg
R_E	−2510	"		−2370 "
R_F	+2510	"		+2370 "
M_E	−48500	"		−45,750 kgm
M_F	+48500	"		+45,750 "
M_B	+24150	"		+22,770 "
M_C	−24150	"		−22,770 "

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CALCULATIONS FOR

Design of Takada Bashi for Fukushima ken.

Summary of moments and shears for A-Rahmen.
Outside Rahmen.

Moments.

	M_{B4}	M_{B3}	M_{B2}	M_{B1}	M_E	M_S
Dead Load	+61,800	−92,100	+11,400	−103,500	−5,150	+43,900
Live Load case1	+21,150		+23,000		−11,500	
〃 case2		−25,050		−5,440		+17,350
〃 case3		−15,780		−31,000		—
	+82,950	−132,930	+34,400	−139,940	−16,650	+61,250
Dead Load	+61,800	−92,100	+11,400	−103,500	−5,150	+43,900
Live Load case1						−3,800
〃 case2	−2,060	—	−19,610	—	+9,730	
〃 case3	—	+11,830	—	+2,210	—	
	+59,740	−80,270	−8,210	−101,290	+4,580	+40,100
Dead Load	+61,800	−92,100	+11,400	−103,500	−5,150	+43,900
Earthquake	—	±24,150	±24,150	—	±48,500	0
	+61,800	−116,250	+35,550	−103,500	−53,650	+43,900
	+61,800	−67,950	−12,750	−103,500	+43,350	+43,900

Note; —
Figures underlined are governing stresses for the corresponding sections.

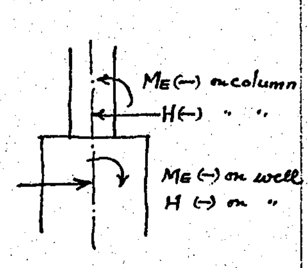
Shears.

	S_A	S_{B3}	S_{B2}	S_{B1}
Dead Load	+19,000	+28,300	+3,010	−31,150
Live Load max.	+6,240	+10,270	+6,270	−9,960
	+25,240	+38,570	+9,280	−41,110
Dead Load	+19,000	+28,300	+3,010	−31,150
Earthquake	—	∓2,510	±13,200	—
	+19,000	+30,810	+16,210	−31,150
	+19,000	+25,790	−10,190	−31,150

Reactions

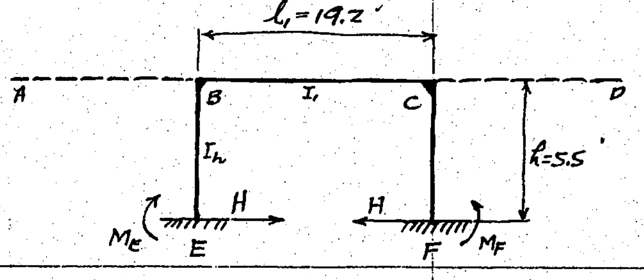
H and M_E Corresponding to R_E

	R_A	R_E	H	M_E
Dead Load.	+19,000	+59,500	−3,010	−5,150
Live Load case1	+6,240	+9,400	−6,270	−11,500
〃 case2	—	—	—	—
〃 case3.	—	—	—	—
	+25,240	+68,900	−9,280	−16,650
Dead Load	+19,000	+59,500	−3,010	−5,150
Earthquake	—	±2,510	±13,200	±48,500
←	+19,000	+62,010	+10,190	+43,350
→	+19,000	+56,990	−16,210	−53,650



Design of Takada Bashi for Fukushima Ken

Temperature Stresses in A-Rahmen.
Outside and Inside Rahmen.



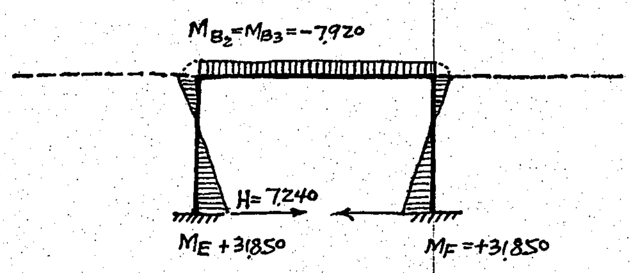
Vertical reaction caused by temperature change will be very small and for the sake of simplicity, let us neglect them.

E = modulus of elasticity of concrete = 1,400,000,000 kg/m²
ε = coefficient of expansion = 0.000012 for 1°C
t = variation of temperature = ± 15°C
I = moment of inertia of beam = 0.13431 m⁴

$$v = \frac{I_1 h}{I_h l_1} = \frac{0.13431 \times 5.5}{0.1163 \times 19.20} = 0.331$$

$$E\varepsilon t = 252{,}000 \text{ kg}$$

15° rise.



$$H = 3\varepsilon t E I_1 \frac{2v+1}{h^2 v(v+2)} = 3 \times 252{,}000 \times 0.13431 \frac{1.662}{5.5^2 \times .331 \times 2.331} = 7240 \text{ kg}$$

$$M_E = M_F = 3\varepsilon t E I \frac{v+1}{hv(v+2)} = 3 \times 252{,}000 \times 0.13431 \times \frac{1.331}{5.5 \times .331 \times 2.331} = +31{,}850 \text{ kgm}$$

$$M_B = M_C = M - Hh = 3\varepsilon t E I \frac{v}{hv(v+2)} = -3 \times 252{,}000 \times .13431 \times \frac{.331}{5.5 \times .331 \times 2.331} = -7920 \text{ kgm}$$

For 15° fall of temperature

H = −7,240 kg

$M_E = M_F$ = −31,850 kgm

$M_B = M_C$ = + 7,920 kgm

Summary for Dead, Live and Temperature stresses.
Outside Rahmen.

		M_{B2}	M_{B3}	M_E	M_S	H	R_E
Dead Load		+ 11,400	− 92,100	− 5,150	+ 43,900	− 3,010	+ 59,500
Live Load	case 1	+ 23,000		− 11,500		− 6,270	+ 9,400
"	case 2		− 25,050		+ 17,350		
"	case 3		− 15,780				
Temperature		+ 7,920	− 7,920	− 31,850	+ 7,920	− 7,240	——
		+ 42,320	− 140,850	− 48,500	+ 69,170	− 16,520	+ 68,900

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CALCULATIONS FOR

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Design of Takada Bashi for Fukushima Ken.

Summary of moments and Shears for A-Rahmen.

Inside Rahmen.

Moments.

	M_{B4}	M_{B3}	M_{B2}	M_{B1}	M_E	M_S
Dead Load	+ 57,800	− 86,200	+ 10,680	− 96,900	− 4,820	+ 41,100
Live Load case 1	+ 28,250		+ 30,740		− 15,370	
〃 case 2		− 33,450		− 7,270		+ 23,180
〃 case 3		− 21,100		− 41,450		—
	+ 86,050	− 140,750	+ 41,420	− 145,620	− 20,190	+ 64,280
Dead Load	+ 57,800	− 86,200	+ 10,680	− 96,900	− 4,820	+ 41,100
Live Load case 1						− 5,080
〃 case 2	− 2,750	—	− 26,200	—	+ 13,000	
〃 case 3	—	+ 15,800	—	+ 2,950	—	
	+ 55,050	− 70,400	− 15,520	− 93,950	+ 8,180	+ 36,020
Dead Load	+ 57,800	− 86,200	+ 10,680	− 96,900	− 4,820	+ 41,100
Earthquake	—	± 22,770	± 22,770	—	± 45,750	0
	+ 57,800	− 108,970	+ 33,450	− 96,900	− 50,570	+ 41,100
	+ 57,800	− 63,430	− 12,090	− 96,900	+ 40,930	+ 41,100

Shears

	S_A	S_{B3}	S_{B2}	S_{B1}
Dead Load	+ 17,800	+ 26,500	+ 2,820	− 29,150
Live Load max.	+ 8,340	+ 13,740	+ 8,380	− 13,310
	+ 26,140	+ 40,240	+ 11,200	− 42,460
Dead Load	+ 17,800	+ 26,500	+ 2,820	− 29,150
Earthquake	—	∓ 2,370	± 12,450	—
	+ 17,800	+ 28,870	+ 15,270	− 29,150
	+ 17,800	+ 24,130	− 9,630	− 29,150

Reactions

H and M_E corresponding to R_E.

	R_A	R_E	H	M_E
Dead Load	+ 17,800	+ 55,700	− 2,820	− 4,820
Live Load case 1	+ 8,340	+ 12,560	− 8,380	− 15,370
〃 case 2	—	—	—	—
〃 case 3	—	—	—	—
	+ 26,140	+ 68,260	− 11,200	− 20,190
Dead Load	+ 17,800	+ 55,700	− 2,820	− 4,820
Earthquake	—	± 2,370	± 12,450	± 45,750
←	+ 17,800	+ 58,070	− 15,270	− 50,570
→	+ 17,800	+ 53,330	+ 9,630	+ 40,930

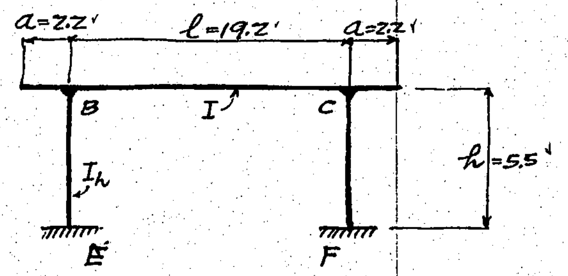
Temperature stresses combined.

	M_{B2}	M_{B3}	M_E	M_S	H	R_E
Dead Load	+ 10,680	− 86,200	− 4,820	+ 41,100	− 2,820	+ 55,700
Live Load case 1	+ 30,740		− 15,370		− 8,380	+ 12,560
〃 case 2		− 33,450		+ 23,180		
〃 case 3		− 21,100				
Temperature	+ 7,920	− 7,920	− 31,850	+ 7,920	− 7,240	—
	+ 49,340	− 148,670	− 52,040	+ 72,200	− 18,440	+ 68,260

Note: Figures underlined are governing stresses for the corresponding sections.

Design of Takada Bashi for Fukushima Ken.

Design of B-Rahmen



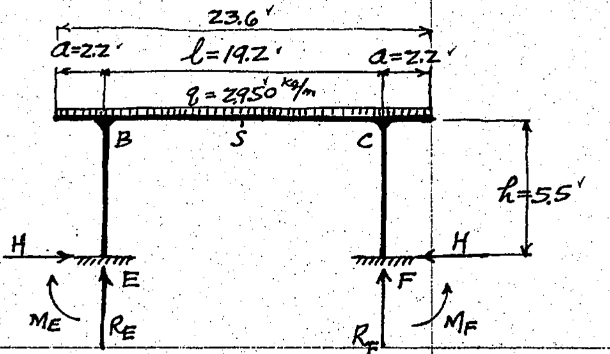
Average height of rahmen assumed $h = 5.50^m$.
Constants used in the following calculations.

$$v = \frac{I.h}{I_h.l} = \frac{0.13431 \times 5.50}{0.1163 \times 19.20} = 0.331$$

$v+2 = 2.331$, $2+3v = 2.993$, $6v+1 = 2.986$, $5v-1 = .655$

$a^2 = 2.2^2 = 4.84$, $l^2 = 19.2^2 = 368.64$, $6a^2 = 29.04$, $3a^2 = 14.52$

Dead Load Stresses:
Outside Rahmen.



Dead Load $q = 2950$ kg per lin meter

$$R_E = R_F = \frac{q(l+2a)}{2} = \frac{2950 \times 23.6}{2} = +34{,}800 \text{ kg.}$$

$$H = \frac{q(l^2-6a^2)}{4h(v+2)} = \frac{2950(368.64-29.04)}{4 \times 5.5 \times 2.331} = +19{,}500 \text{ kg}$$

(33.96)

$$M_E = M_F = \frac{q(l^2-6a^2)}{12(v+2)} = \frac{2950 \times 33.96}{12 \times 2.331} = +35{,}800 \text{ kgm}$$

$$M_{B2} = M_{C2} = \frac{q(6a^2-l^2)}{6(v+2)} = -\frac{2950 \times 33.96}{6 \times 2.331} = -71{,}600 \text{ kgm}$$

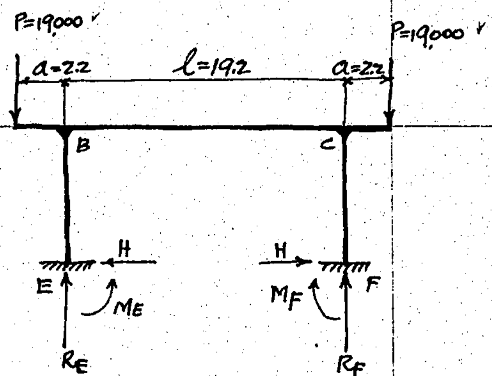
Beam inside $$M_{B3} = M_{C3} = -\frac{3qa^2v + ql^2}{6(v+2)} = -\frac{3 \times 2950 \times 4.84 \times .331 + 2950 \times 368.64}{6 \times 2.331}$$

$$= -1010 - 77750 = -78760 \text{ kgm}$$

$$M_S = \frac{ql^2(2+3v) - 12qa^2v}{24(v+2)} = \frac{2950 \times 2.993 \times 368.64 - 12 \times 2950 \times 4.84 \times .331}{24 \times 2.331}$$

$$= 58150 - 1010 = +57{,}140 \text{ kgm}$$

$$M_{B1} = -\frac{qa^2}{2} = -\frac{2950 \times 2.2^2}{2} = -7{,}140 \text{ kgm}$$



Dead Load concentration on cantilever end due to A-rahmen.
$P = 19{,}000$ on both ends.

$R_E = R_F = P = +19{,}000$ kg

$$H = -\frac{Pa}{h} \cdot \frac{3}{v+2} = -\frac{19000 \times 2.2}{5.5} \times \frac{3}{2.331} = -9770 \text{ kg}$$

$$M_E = M_F = -Pa \frac{6v+1}{(6v+1)(v+2)} = -\frac{Pa}{v+2} = -\frac{19000 \times 2.2}{2.331} = -17{,}930 \text{ kgm}$$

$$M_{B2} = +\frac{2Pa}{v+2} = +\frac{2 \times 19000 \times 2.2}{2.331} = +35{,}850 \text{ kgm}$$

$$M_{B3} = -Pa \cdot \frac{v}{v+2} = -19000 \times 2.2 \times \frac{.331}{2.331} = -5{,}930 \text{ kgm}$$

$$M_{B1} = -Pa = -19000 \times 2.2 = -41{,}800 \text{ kgm}$$

Shears.

Uniform dead load			Dead load concentration from A rahmen		
S_{B1}	$= 2950 \times 2.2$	$= -6{,}490$ kg	S_{B1}	$= -P$	$= -19{,}000$ kg
S_{B2}	$= -H$	$= -19{,}500$	S_{B2}	$= -H$	$= +9{,}770$
S_{B3}	$= q \cdot \frac{l}{2}$	$= +28{,}300$	S_{B3}	$=$	0

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CALCULATIONS FOR

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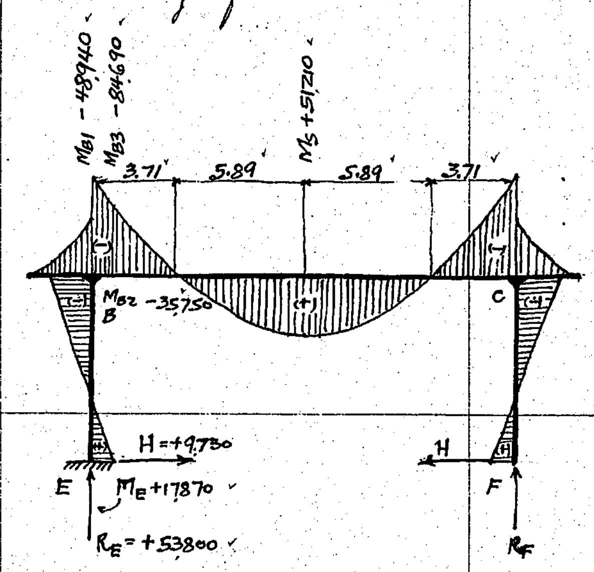
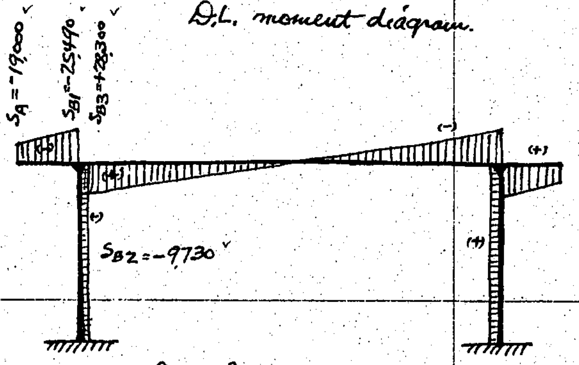
Design of Takada Bashi for Fukushima ken.

Summary of Dead Load moments, reactions, and Shears for Outside rahmen.



D.L. moment diagram.



D.L. Shear diagram.

moments	unif. load	concentration	Total
$M_E = M_F$	+ 35,800	− 17,930	+ 17,870 kgm
$M_{B2} = M_{C2}$	− 71,600	+ 35,850	− 35,750
$M_{B3} = M_{C3}$	− 78,760	− 5,930	− 84,690
M_S	+ 57,140	− 5,930	+ 51,210
$M_{B1} = M_{C1}$	− 7,140	− 41,800	− 48,940
Reaction			
$R_E = R_F$	+ 34,800	+ 19,000	+ 53,800 kg
H	+ 19,500	− 9,770	+ 9,730
Shears.			
S_{B1}	− 6,490	− 19,000	− 25,490 kg
S_{B2}	− 19,500	+ 9,770	− 9,730
S_{B3}	+ 28,300	0	+ 28,300

Point of 0 moment in center span.

$$M_S - \frac{qx^2}{2} = 0$$

$$x^2 = \frac{2M_S}{q} = \frac{2 \times 51210}{2950} = 34.74$$

$$x = 5.89^m$$

Dead Load stresses for Inside Rahmen.

$$\text{Coefficient} = \frac{2760}{2950} = 0.936$$

moments			
$M_E = M_F$	+ 17870	× 0.936 =	+ 16,720
$M_{B2} = M_{C2}$	− 35,750		− 33,450
$M_{B3} = M_{C3}$	− 84,690		− 79,250
M_S	+ 51,210		+ 47,950
$M_{B1} = M_{C1}$	− 48,940		− 45,800
Reactions			
$R_E = R_F$	+ 53,800		+ 50,350
H	+ 9,730		+ 9,110
Shears			
S_{B1}	− 25,490		− 23,850
S_{B2}	− 9,730		− 9,110
S_{B3}	+ 28,300		+ 26,500
S_A	− 19000		− 17,800

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CALCULATIONS FOR

Design of Takada Bashi for Fukushima Ken.

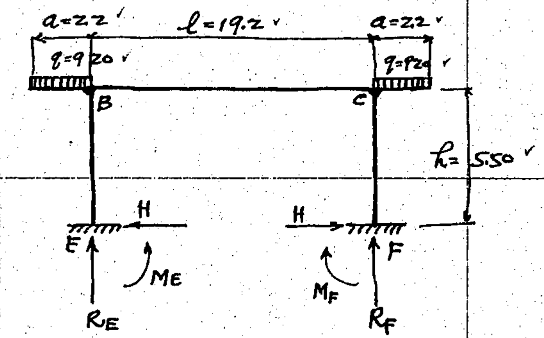
Live Load Stresses for Outside B-Rahmen.

Case 1 Both cantilever arms loaded.

Uniform load $q = 920$ kg per lin meter.

Concentration on cantilever end from A-rahmen. max. value $= P = +6{,}240$ kg. on each end. (see page 14)

Stresses due to uniform load.



$R_E = R_F = qa = +920 \times 2.2 = +2{,}020$ kg

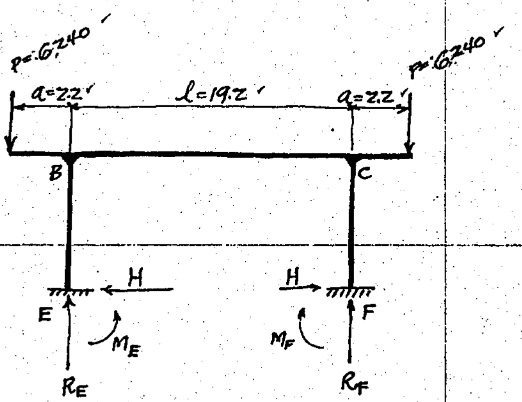
$H = -\frac{3qa^2}{2h(\nu+2)} = -\frac{920 \times 14.52}{11.0 \times 2.331} = -520$ kg

$M_E = M_F = -\frac{qa^2}{2(\nu+2)} = -\frac{920 \times 4.84}{4.662} = -960$ kgm.

$M_{B3} = M_{C3} = -\frac{qa^2\nu}{2(\nu+2)} = -\frac{920 \times 4.84 \times .331}{2 \times 2.331} = -320$ kgm

$M_{B2} = M_{C2} = +\frac{qa^2}{\nu+2} = +\frac{920 \times 4.84}{2.331} = +1{,}910$ kgm

$M_{B1} = M_{C1} = -\frac{qa^2}{2} = -\frac{920 \times 4.84}{2} = -2{,}230$ kgm



$R_E = R_F = P = +6{,}240$ kg

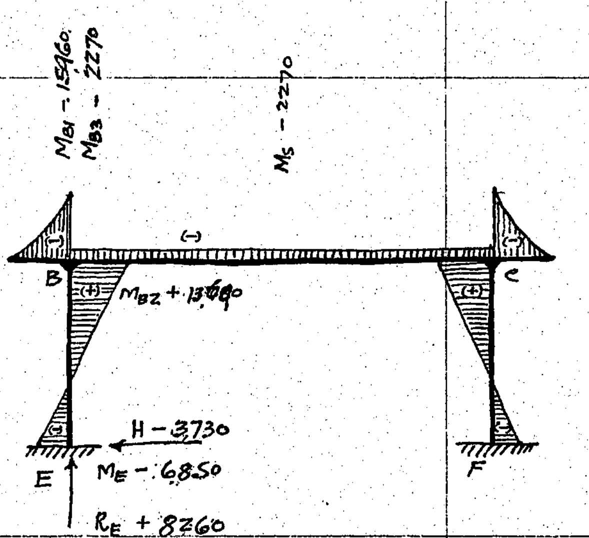
$H = -\frac{Pa}{h} \cdot \frac{3}{\nu+2} = -\frac{6240 \times 2.2}{5.5} \times \frac{3}{2.331} = -3{,}210$ kg.

$M_E = M_F = -\frac{Pa}{\nu+2} = -\frac{6240 \times 2.2}{2.331} = -5{,}890$ kgm.

$M_{B1} = -Pa = -6240 \times 2.2 = -13{,}730$ kgm

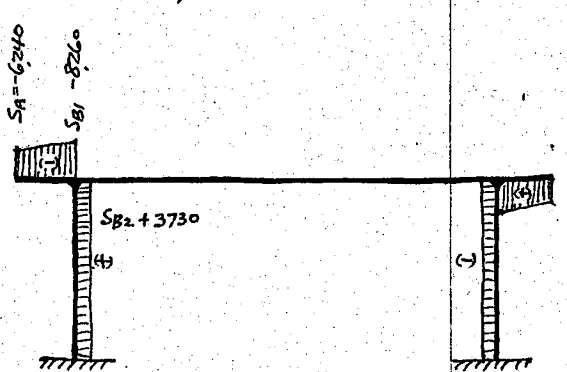
$M_{B2} = +\frac{2Pa}{\nu+2} = +\frac{2 \times 6240 \times 2.2}{2.331} = +11{,}780$ kgm

$M_{B3} = -\frac{Pa\nu}{\nu+2} = -\frac{6240 \times 2.2 \times .331}{2.331} = -1{,}950$ kgm.



Summary for case 1.

		Unif. load	Concentration.	Total.	
Moment	$M_E = M_F$	− 960	− 5,890	− 6,850	kgm
	$M_{B2} = M_{C2}$	+ 1,910	+ 11,780	+ 13,690	"
	$M_{B3} = M_{C3}$	− 320	− 1,950	− 2,270	"
	M_S	− 320	− 1,950	− 2,270	"
	$M_{B1} = M_{C1}$	− 2,230	− 13,730	− 15,960	"
Reaction	$R_E = R_F$	+ 2,020	+ 6,240	+ 8,260	kg
	H	− 520	− 3,210	− 3,730	"
Shear	S_{B1}	− 2,020	− 6,240	− 8,260	kg
	S_{B2}	+ 520	+ 3,210	+ 3,730	"
	S_{B3}	0	0		



Inside Rahmen. Coefficient $= \frac{1230}{920} = 1.336$

moment	$M_E = M_F$	− 6,850 × 1.336 =	− 9,160	kgm
	$M_{B2} = M_{C2}$	+ 13,690	+ 18,300	"
	$M_{B3} = M_{C3}$	− 2,270	− 3,030	"
	M_S	− 2,270	− 3,030	"
	$M_{B1} = M_{C1}$	− 15,960	− 21,340	"
Reaction	$R_E = R_F$	+ 8,260	+ 11,040	kg
	H	− 3,730	− 4,990	"
Shear	S_{B1}	− 8,260	− 11,040	"
	S_{B2}	+ 3,730	+ 4,990	"
	S_{B3}	0	0	

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CALCULATIONS FOR

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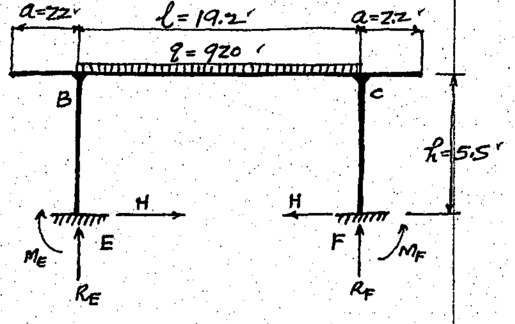
Design of Takada Bashi for Fukushima ken

Case 2. Center span loaded. Outside rahmen.



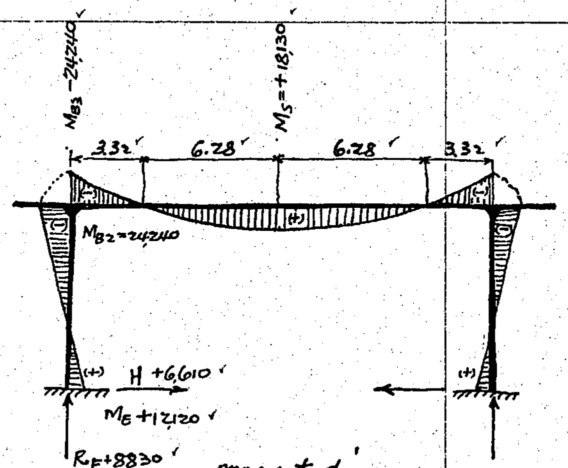
$R_E = R_F = \frac{ql}{2} = \frac{920 \cdot 19.2}{2} = +\ 8830\ kg$

$H = + \frac{ql^2}{4h(v+2)} = + \frac{920 \cdot 19.2^2}{22 \cdot 2.331} = +\ 6,610\ kg$

$M_E = M_F = + \frac{ql^2}{12(v+2)} = + \frac{920 \cdot 19.2^2}{12 \cdot 2.331} = +12,120\ kgm$

$M_B = M_C = - \frac{ql^2}{6(v+2)} = \frac{920 \cdot 19.2^2}{6 \cdot 2.331} = -24,240\ kgm$

$M_S = + \frac{ql^2}{24} \cdot \frac{2+3v}{v+2} = \frac{920 \cdot 19.2^2 \cdot 2.993}{24 \cdot 2.331} = +18,130\ kgm$



moment diagram
Outside rahmen.

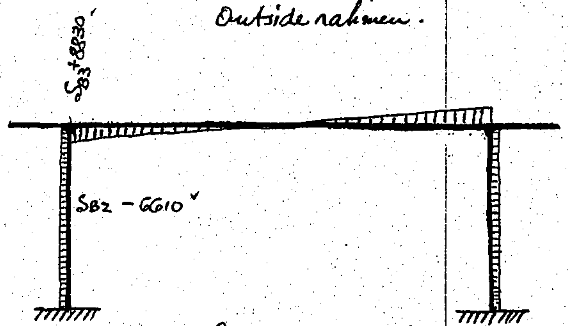
point of Zero moment

$x^2 = \frac{2M_S}{q} = \frac{2 \cdot 18130}{920} = 39.45$

$x = 6.28\ m$

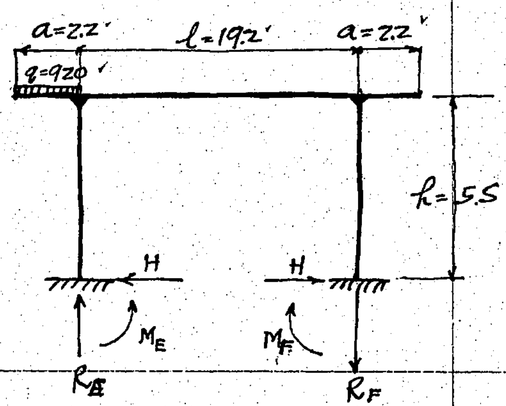
Inside rahmen. Propotion = 1.336.

$R_E = R_F$	+	8830 × 1.336	= + 11,800	kg
H	+	6,610	= + 8830	"
$M_E = M_F$	+	12,120	= + 16,180	kgm
$M_B = M_C$	−	24,240	= − 32,360	"
M_S	+	18,130	= + 24,240	"



Shear diagram of
Outside rahmen.

Case 3 One cantilever arm loaded outside rahmen.



$R_E = qa \cdot \frac{a+2l}{2l} + \frac{M_F - M_E}{l} = \frac{920 \cdot 2.2 \cdot 40.6}{38.4} + \frac{-750}{19.2} = +2,100\ kg$ $\quad R_F = -80\ kg$

$H = - \frac{qa^2}{4h} \cdot \frac{3}{v+2} = - \frac{920 \cdot 2.2^2 \cdot 3}{22 \cdot 2.331} = -\ 260\ kg$

$M_E = - \frac{qa^2}{4} \cdot \frac{(5v-1)}{(6v+1)(v+2)} = - \frac{920 \cdot 4.84 \cdot .655}{4 \cdot 2.986 \cdot 2.331} = -\ 100\ kgm$

$M_F = - \frac{qa^2}{4} \cdot \frac{7v+3}{(6v+1)(v+2)} = - \frac{920 \cdot 4.84 \cdot 5.317}{4 \cdot 2.986 \cdot 2.331} = -\ 850\ kgm$

$M_{B1} = - \frac{qa^2}{2} = - \frac{920 \cdot 4.84}{2} = -\ 2,230$ "

$M_{B2} = + \frac{qa^2}{4} \cdot \frac{13v+4}{(6v+1)(v+2)} = + \frac{920 \cdot 4.84}{4} \cdot \frac{8.303}{2.986 \cdot 2.331} = +\ 1330$ "

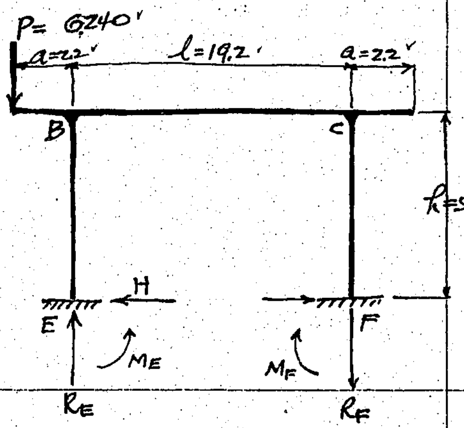
$M_{B3} = - \frac{qa^2}{4} \cdot \frac{v(12v+13)}{(6v+1)(v+2)} = - \frac{920 \cdot 4.84}{4} \cdot \frac{.331 \cdot 16.972}{2.986 \cdot 2.331} = -\ 900$ "

$M_{C3} = M_{C2} = + \frac{qa^2}{4} \cdot \frac{11v}{(6v+1)(v+2)} = + \frac{920 \cdot 4.84}{4} \cdot \frac{3.641}{2.986 \cdot 2.331} = +\ 580$ "

Design of Takada Bashi for Fukushima Ken.

Case 3 continued   Concentration on one cantilever end, outside rahmen.

max. concentration due to live load = 6,240 kg (see page 14)



$$H = \frac{Pa}{2h}\cdot\frac{3}{v+2} = -\frac{6240\times2.2\times3}{11\times2.331} = -1{,}610 \text{ kg}$$

$$M_E = -\frac{Pa}{2}\cdot\frac{5v-1}{(6v+1)(v+2)} = -\frac{6240\times2.2}{2}\cdot\frac{.655}{2.986\times2.331} = -650 \text{ kgm}$$

$$M_F = -\frac{Pa}{2}\cdot\frac{7v+3}{(6v+1)(v+2)} = -\frac{6240\times2.2}{2}\cdot\frac{5.317}{2.986\times2.331} = -5{,}240 \text{ ''}$$

$$M_{B1} = -Pa = -6240\times2.2 = -13{,}730 \text{ ''}$$

$$M_{B2} = +\frac{Pa}{2}\cdot\frac{13v+4}{(6v+1)(v+2)} = +\frac{6240\times2.2}{2}\cdot\frac{8.303}{2.986\times2.331} = +8{,}190 \text{ ''}$$

$$M_{B3} = -\frac{Pa}{2}\cdot\frac{v(12v+13)}{(6v+1)(v+2)} = -\frac{6240\times2.2}{2}\cdot\frac{.331\times16.972}{2.986\times2.331} = -5{,}530 \text{ ''}$$

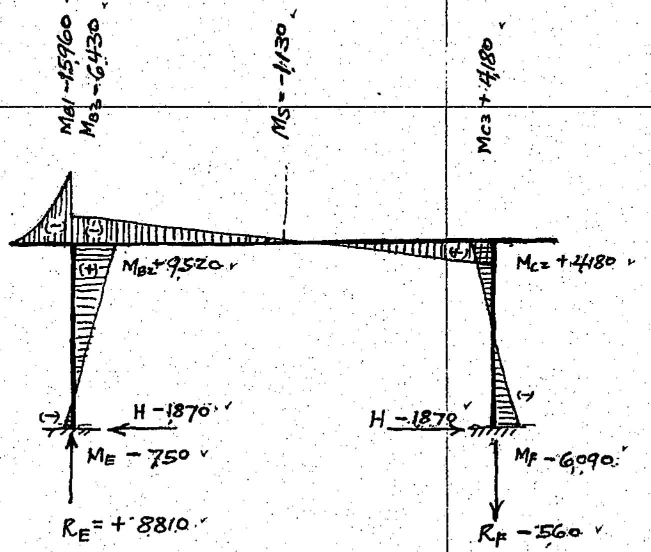
$$M_{C2}=M_{C3} = +\frac{Pa}{2}\cdot\frac{11v}{(6v+1)(v+2)} = +\frac{6240\times2.2}{2}\cdot\frac{3.641}{2.986\times2.331} = +3{,}600 \text{ ''}$$

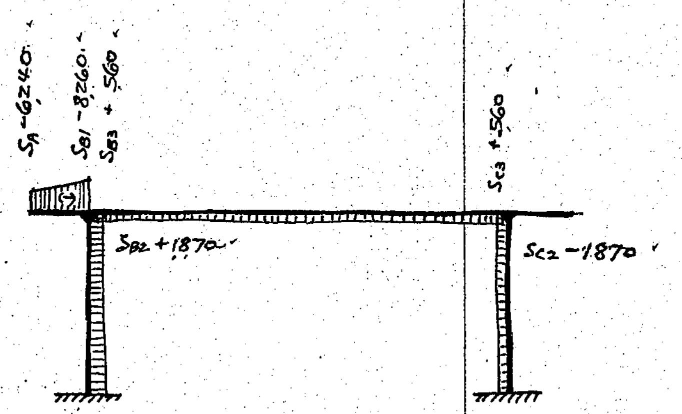
$$R_E = P\cdot\frac{a+l}{l} + \frac{M_F-M_E}{l} = +\frac{6240\times21.4}{19.2} + \frac{-4{,}590}{19.2} = +6{,}710 \text{ kg}$$
(6950, 240)

$$R_F = -P\frac{a}{l} + \frac{M_E-M_F}{l} = -\frac{6240\times2.2}{19.2} + \frac{4590}{19.2} = -480 \text{ kg}$$
(720, 240)

Summary of Stresses (case 3) for Outside Rahmen.

moments.	Uniform load.	Concentration	Total.
M_E	− 100	− 650	− 750 kgm
M_F	− 850	− 5,240	− 6,090
M_{B2}	+ 1330	+ 8190	+ 9,520
$M_{C2}=M_{C3}$	+ 580	+ 3,600	+ 4,180
M_{B3}	− 900	− 5,530	− 6,430
M_{B1}	− 2,230	− 13,730	− 15,960
Reaction			
R_E	+ 2,100	+ 6,710	+ 8,810 kg
R_F	− 80	− 480	− 560
H	− 260	− 1,610	− 1,870
Shears.			
S_{B1}	− 2,020	− 6,240	− 8,260 kg
$S_{B2}=-S_{C2}$	+ 260	+ 1,610	+ 1,870
$S_{B3}=S_{C3}$	+ 80	+ 480	+ 560
S_A	0	− 6,240	− 6,240





Design of Takada Bashi for Fukushima ken.

Summary of stresses (case 3) for Inside Rahmen. Propotion 1.336

Moments						
M_E	−	750	× 1.336 =	−	1,000	kgm
M_F	−	6,090		−	8,140	"
M_{B2}	+	9,520		+	12,710	"
$M_{C2}=M_{C3}$	+	4180		+	5,590	"
M_{B3}	−	6,430		−	8,590	"
M_{B1}	−	15,960		−	21,320	"
Reactions						
R_E	+	8,810		+	11,770	kg
R_F	−	560		−	750	"
H	−	1,870		−	2,500	"
Shears.						
S_{B1}	−	8,260		−	11,030	kg
$S_{B2}=-S_{C2}$	+	1,870		+	2,500	"
S_{B3}	+	560		+	750	"
S_A	−	6,240		−	8,340	"

Stresses during Earthquake k assumed 0.200

	Outside Rahmen		Inside rahmen	
Dead Load of superstructure	= 23.6 m @ 2950 =	69600	23.6 @ 2760 =	65,100
Weight of column (½)	4.85 m³ @ 2400 =	11,600		11,600
Strut + misc. concrete say		1,400		1,700
		82,600		78,400
frictional resistance on cantilever end from A rahmen	2×19000×2 =	7600	2×17800×2 =	7,100
		90,200 kg		85,500 kg

Seismic force = 90200 × 0.2 = 18,040 kg for Outside rahmen Coef 18040 ÷ 26400 = .683 (refering to
" = 85500 × 0.2 = 17,100 " " Inside " " 17100 ÷ 26400 = .648 Page 13)

		Outside Rahmen		Inside Rahmen
H	−13,200 × .683 =	− 9,020 kg	× .648 =	− 8,550 kg
R_E	− 2,510	− 1,710 "		− 1630 "
$R_F = -R_E$	+ 2,510	+ 1,710 "		+ 1630 "
M_E	−48,500	− 33,100 kgm		− 31,450 kgm
$M_F = -M_E$	+48,500	+ 33,100 "		+ 31,450 "
M_B	+24,150	+ 16,500 "		+ 15,650 "
$M_C = -M_B$	−24,150	− 16,500 "		− 15,650 "

Temperature stresses are same as for A Rahmen see page 15.
Outside + Inside Rahmen ---- H = ± 7,240 kg for 15°C rise or fall
$M_E=M_F$ = ± 31,850 kgm "
$M_B=M_C$ = ∓ 7920 " "

Design of Takada Bashi for Fukushima Ken.

Summary of moments and shears for B-Rahmen.
Outside Rahmen.

note:- Figures underlined are governing stresses for the corresponding section.

Moments

	M_{B3}	M_{B2}	M_{B1}	M_E	M_S
Dead Load	-84690	-35750	-48940	+17870	+51210
Live Load case 1			-15960		
〃 case 2	-24240	-24240		+12120	+18130
〃 case 3	-6430	—		—	—
	-115,360	-59990	-64900	+29990	+69340
Dead Load	-84690	-35750	-48940	+17870	+51210
Live Load case 1		+13690		-6850	-2270
〃 case 2	—	—	0		
〃 case 3	+4180	+ [illegible]	—		
	-80510	-22060	-48940	+11020	+48940
Dead Load	-84690	-35750	-48,940	+17870	+51,210
Earthquake	±16500	±16500	—	±33100	0
	-101,190	-52250	-48940	+50970	+51,210
	-68,190	-19250		-15230	
Dead Load	-84690	-35750	-48940	+17870	+51210
Live Load case 1			-15960		
〃 case 2	-24240	-24240		+12120	+18130
〃 case 3	-6,430	—			
Temperature	-7920	-7920	—	+31,850	+7920
	-123,280	-67910	-64900	+61840	+77260

Shears

	S_A	S_{B3}	S_{B2}	S_{B1}
Dead Load	-19000	+28300	-9730	-25490
Live Load max.	-6240	+8830	-6610	-8260
	-25240	+37130	-16,340	-33,750
Dead Load	-19,000	+28,300	-9,730	-25490
Earthquake	—	+1,710	-9020	—
	-19,000	+30,010	-18750	-25490
Dead Load	-19000	+28300	-9,730	-25490
Live Load max.	-6240	+8830	-6610	-8260
Temperature	—	—	-7240	—
	-25,240	+37,130	-23,580	-33,750

Reactions (H+M corresponding to R_E)

	R_E	R_F	H	M_E
Dead Load	+53800	+53800	+9730	+17870
Live Load case 1				
〃 case 2	+8830	+8830	+6610	+12120
〃 case 3				
	+62630	+62630	+16340	+29990
Dead Load	+53800	+53800	+9730	+17870
Earthquake	+1710	-1710	+9020	+33100
	+55510	+52090	+18750	+50970
Dead Load	+53800	+53800	+9730	+17870
Live Load max.	+8830	+8830	+6610	+12120
Temperature	—	—	+7240	+31850
	+62630	+62630	+23580	+61840

Design of Takada Bashi for Fukushima Ken.

Inside Rahmen.

note:– Figures underlined are governing stresses for the corresponding sections.

moments	M_{B3}	M_{B2}	M_{B1}	M_E	M_S
Dead Load	− 79250	− 33450	− 45800	+ 16720	+ 47950
Live Load case1			− 21340		
〃 Case2	− 32360	− 32360		+ 16180	+ 24240
〃 Case3	− 8590	——		——	——
	− 120200	− 65810	− 67140	+ 32900	+ 72190
Dead Load	− 79250	− 33450	− 45800	+ 16720	+ 47950
Live Load case1		+ 18300		− 9160	− 3030
〃 Case2			0		
〃 Case3	+ 5590				
	− 73660	− 15150	− 45800	+ 7560	+ 44920
Dead Load	− 79250	− 33450	− 45800	+ 16720	+ 47950
Earthquake	± 15650	± 15650	———	± 31450	0
	− 94900	− 49100	− 45800	+ 48170	+ 47950
Dead Load	− 79250	− 33450	− 45800	+ 16720	+ 47950
Live Load case1.			− 21340		
〃 Case2	− 32360	− 32360		+ 16180	+ 24240
〃 Case3	− 8590	—		——	——
Temperature	− 7920	− 7920	——	+ 31850	+ 7920
	− 128120	− 73730	− 67140	+ 64750	+ 80110

Shears	S_A	S_{B3}	S_{B2}	S_{B1}
Dead Load	− 17800	+ 26500	− 9110	− 23850
Live Load max.	− 8340	+ 11800	− 8830	− 11040
	− 26140	+ 38300	− 17940	− 34890

	S_A	S_{B3}	S_{B2}	S_{B1}
Dead Load	− 17800	+ 26500	− 9110	− 23850
Earthquake	——	+ 1630	− 8550	——
	− 17800	+ 28130	− 17660	− 23850
Dead Load	− 17800	+ 26500	− 9110	− 23850
Live Load max.	− 8340	+ 11800	− 8830	− 11040
Temperature	——	——	− 7240	——
	− 26140	+ 38300	− 25180	− 34890

H and M_E corresponding to R_E

Reactions	R_E	R_F	H	M_E
Dead Load	+ 50350	+ 50350	+ 9110	+ 16720
Live Load case1				
〃 Case2	+ 11800	+ 11800	+ 8830	+ 16180
〃 Case3				
	+ 62150	+ 62150	+ 17930	+ 32900
Dead Load	+ 50350	+ 50350	+ 9110	+ 16720
Earthquake	+ 1630	− 1630	+ 8550	+ 31450
	51980	+ 48720	+ 17660	+ 48170
Dead Load	+ 50350	+ 50350	+ 9110	+ 16720
Live Load max.	+ 11800	+ 11800	+ 8830	+ 16180
Temperature.	——	——	+ 7240	+ 31850
	+ 62150	+ 62150	+ 25180	+ 64750

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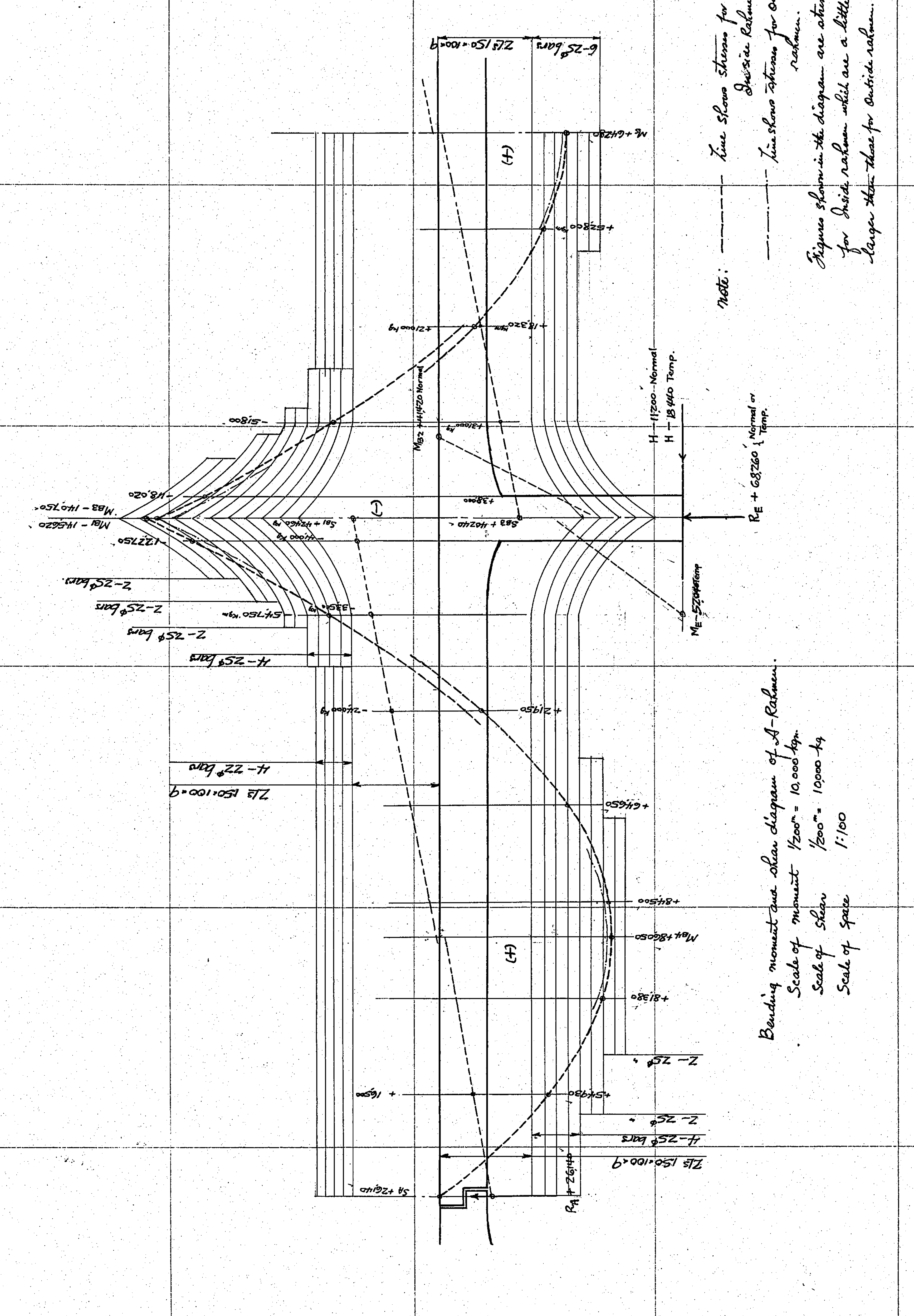
CALCULATIONS FOR

MADE BY K. Inaba DATE 6-1-4 FILE NO

CHECKED BY M. Iinda DATE 6-1-13 PAGE NO 25

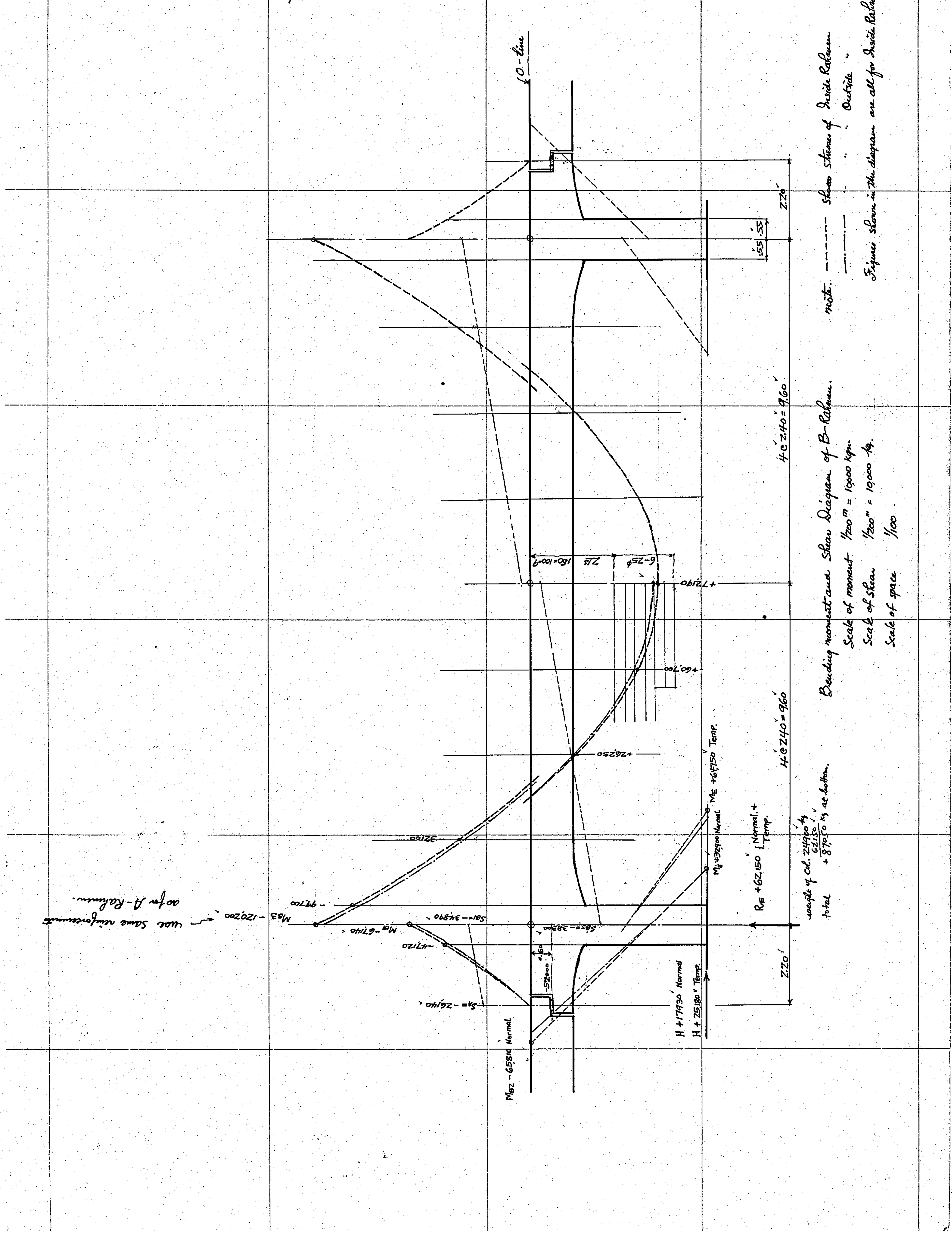
Design of Takada Bashi for Fukushima ken.

Moment and Shear Diagram of A-Rahmen.



Design of Takada Bashi for Fukushima Ken.

Moment and Shear Diagram of B-Rahmen.



Design of Takada Bashi for Fukushima Ken.

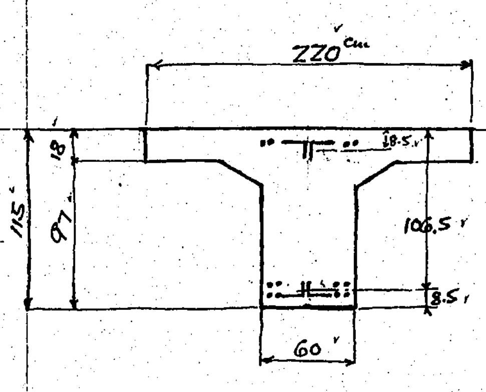
Design of Sections.

Moments and Shears for Outside and Inside Rahmen are nearly equal. Let us design the sections propotioning to the larger stresses and use the same sections for both rahmen. (Inside Rahmen governs).

Sections for A-Rahmen.

Positive moment in side span. $M_{B4} = +86{,}050$ kgm.

Assumed section



Steel area assumed as follows.

Bottom reinforcements.

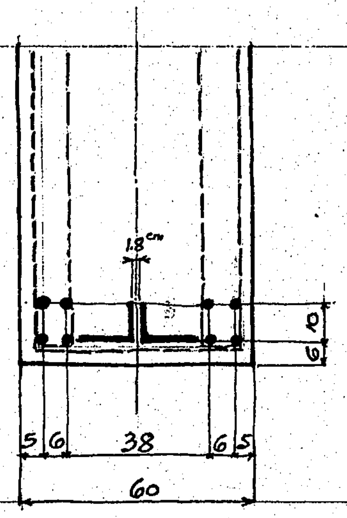
ZIS 150×100×9 = 43.38 − 4.50 = 38.88 cm^2 net.
8 − 25mmφ bars = 39.26
A_s = 78.14 cm^2 net

Top reinforcements

ZIS 150×100×9 = 43.38
4 − 22mmφ bars = 15.20
A_s' = 58.58 cm^2 gross.

Steel ratio bottom $p = \frac{78.14}{220 \times 106.5} = 0.00334$

top $p' = \frac{58.58}{220 \times 106.5} = 0.00250$ or $p' = 0.75p$.



$d'/d = 8.5/106.5 = 0.08$

From the formulas of k + j, $k = 0.262$, $j = 0.927$

$f_s = \frac{M}{A_s \cdot jd} = \frac{86050 \times 100}{78.14 \times .927 \times 106.5} = 1115$ kg/cm^2 ok

$f_c = \frac{f_s k}{n(1-k)} = \frac{1115 \times .262}{15 \times .738} = 26.4$ " ok.

$f_s' = f_s \cdot \frac{k - \frac{d'}{d}}{1-k} = 1115 \cdot \frac{.262 - .08}{.738} = 275$ " ok. (.182 noted)

Positive moment in Center span $M_s = +64{,}280$ kgm Corresponding $H = 7120 - 2820 = +4{,}300$ kg (comp.)

Steel area assumed.

Bottom reinforcements

ZIS 150×100×9 = 43.38 − 4.50 = 38.88
6 − 25mmφ bars = 29.45
A_s = 68.33 cm^2 net.

Top reinforcements

ZIS 150×100×9 = 43.38
4 − 22mmφ bars = 15.20
A_s' = 58.58 cm^2 gross.

Steel ratio $p = \frac{68.33}{220 \times 106.5} = 0.00292$

" $p' = 0.0025$ or $p' = 0.86p$. $d'/d = 0.08$

$k = .245$, $j = .928$

$f_s = \frac{64280 \times 100}{68.33 \times .928 \times 106.5} = 950$ kg/cm^2 ok (direct comp. neglected).

$f_c = \frac{950 \times .245}{15 \times .755} = 20.6$

Direct comp. $\frac{4300}{12980} = \frac{0.3}{20.9}$ kg/cm^2 ok transformed area see page 6.

Shear at 2nd Support A. $R_A = +26140$ kg.

perimeter of reinforcements for bond
ZIS @ 50 = 100
4 − 25φ bars = 31.4
131.4

unit shear = $\frac{26140}{60 \times .928 \times 106.5} = 4.41$ kg/cm^2 use proper stirrups + bent up bars.

unit bond = $\frac{26140}{131.4 \times .928 \times 106.5} = 2.01$ " ok.

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CALCULATIONS FOR

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Design of Takada Bashi for Fukushima Ken.

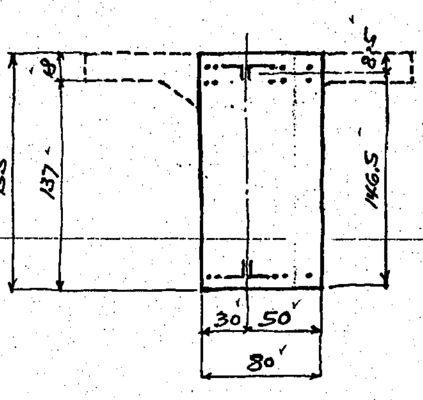
Negative moment at support B. moment at face of column

Left side − 122,750 kgm, Shear −41,000 kg

Right side − 118,020 Corresponding H = −2820 + 7120 + 4710 = +9010 ℃ (neglected)

Shear + 38,000 kg

Assumed section



Steel area assumed as follows.

Top reinforcements

Z∟s 150 × 100 × 9 = 43.38 − 4.50 = 38.88

10 − 25mmφ bars = 49.08

A_s = 87.96 cm² net.

Bottom reinforcements

Z∟s 150 × 100 × 9 = 43.38

5 − 25mmφ bars = 24.54

A_s' = 67.92 cm² gross.

Steel ratio $p = \frac{87.96}{80 \times 146.5} = 0.0075$ top.

$p' = \frac{67.92}{80 \times 146.5} = 0.0058$ bott. or $p' = 0.77\,p$.

$d'/d = 8.5/146.5 = 0.058$

From the prepared diagrams $k = .323$, $j = .907$

$f_s = \frac{M}{A_s j d} = \frac{122750 \times 100}{87.96 \times .907 \times 146.5} =$ 1050 kg/cm² ok.

$f_c = \frac{f_s k}{n(1-k)} = \frac{1050 \times .323}{15 \times .677} =$ 33.4 " ok

Perimeter of reinforcement for bond.

Z∟s @ 50 = 100.

10 − 25φ bars @ 7.85 = 78.5 / 178.5 cm

$f_s' = f_s \cdot \frac{k - \frac{d'}{d}}{1-k} = 1050 \times \frac{.323 - .058}{.677}$ (.265) = 411. " ok.

unit shear = $\frac{41000}{80 \times .907 \times 146.5}$ = 3.86 kg/cm² ok. use proper stirrups.

unit bond = $\frac{41000}{178.5 \times .907 \times 146.5}$ = 1.73 kg/cm² ok.

Negative moment at ℄ of support B.

Left side M_{B1} = − 145620 kgm H - neglected Shear −42460 kg

Right side M_{B3} = − 140750 " +40240.

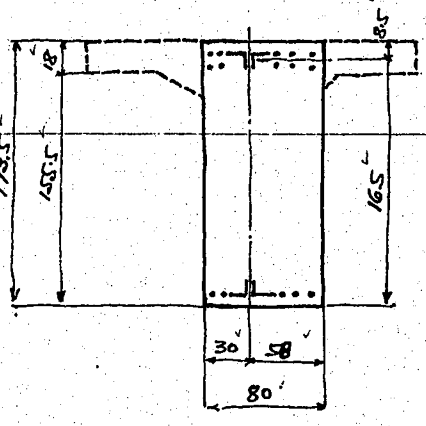
Assumed section

Steel area same as above. A_s = 87.96 cm² net $p = 0.0067$

A_s' = 67.92 " gross $p' = 0.0052$, $p' = 0.77p$.

$d'/d = 8.5/165 = 0.0515$

From the prepared diagrams $k = .312$, $j = .910$



$f_s = \frac{145620 \times 100}{87.96 \times .910 \times 165} =$ 1103 kg/cm² ok

$f_c = \frac{1103 \times .312}{15 \times .688} =$ 33.4 " ok

$f_s' = 1103 \times \frac{.312 - .0515}{.688}$ (.2605) = 417 " ok.

unit shear = $\frac{42460}{80 \times .91 \times 165}$ = 3.53 " ok use proper stirrups

unit bond = $\frac{42460}{178.5 \times .91 \times 165}$ = 1.58 " ok.

Design of Takada Bashi for Fukushima ken.

Sections of B-Rahmen.

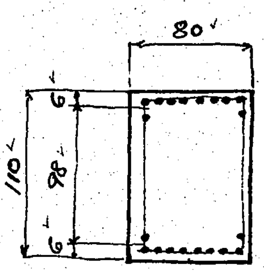
Stresses in Beams for B-Rahmen are nearly equal and a little smaller than those for A-Rahmen.
Let us use the same sections designed for A-Rahmen to the corresponding sections.

Design of Columns
Columns of B-Rahmen.

max. Stresses.	M_E moment at bottom	M_{B2} moment at top	Load on bottom	Load on top.
normal state	+ 32900 kgm	−65810 kgm	87050 kg	62150 kg
normal state with Temperature.	+64750 "	−73730 "	87050	62150 "

Probable moment M_{B2} at bottom of beam −52000 kgm about.

Section for Top of column.



Eccentricity $= \frac{52000}{62150} = .837^m$ $\quad z/h = 83.7/110 = 0.76$ $\quad d'/h = 6/110 = .0546$

Try reinforcements 10 − 25 mmφ bars on both side = 98.16 cm^2

Steel ratio $p_0 = 2p = \frac{98.16}{80 \times 110} = 0.01115$

From the prepared diagrams $k = .443$, $L = 0.154$

$f_c = \frac{M}{Lbh^2} = \frac{52000 \times 100}{0.154 \times 80 \times 110^2} = 34.8$ kg/cm² ok

$f_s = nf_c\left(\frac{d}{kh} - 1\right) = 15 \times 34.8\left(\frac{104}{.443 \times 110} - 1\right) = 592$ " ok.

max. shear at top $S_{B2} = -25180$ kg for temperature + D.L. + L.L.

unit shear $= \frac{25180}{80 \times \frac{7}{8} \times 104} = 3.45$ kg/cm² $< 4.0 \times 1.25 = 5.0$ ok

unit bond $= \frac{25180}{\frac{157}{2} \times \frac{7}{8} \times 104} = 3.52$ " $< 6.0 \times 1.25 = 7.5$ ok. use some extra joint bars.

Section for Bottom of column. Same section assumed.

Eccentricity $z = \frac{64750}{87050} = 0.744$ $\quad z/h = 74.4/110 = 0.677$ $\quad d'/h = .0546$

Reinforcements same as before for top section.

$p_0 = 0.01115$

$k = .468$, $L = .152$

$f_c = \frac{64750 \times 100}{.152 \times 80 \times 110^2} = 43.8 = 35.0 \times 1.25 = 43.8$ ok.

$f_s = 15 \times 43.8\left(\frac{104}{.468 \times 110} - 1\right) = 673$ kg/cm² ok

Shear and bond stress, same as for top section, ok. use some extra joint bars.

Columns for A-Rahmen
use the same details as for B-Rahmen.

Design of Takada Bashi for Fukushima ken.

Stresses of pier columns during transverse earthquake. k assumed 0.200.

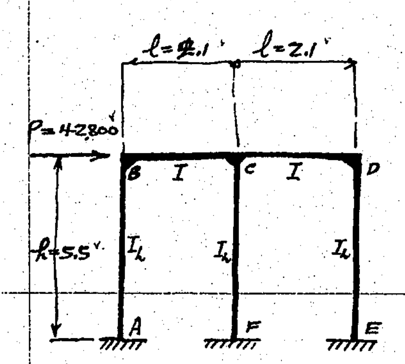
Columns for A-Rahmen.

Dead Load.

Outside Rahmen 2@ 2950 = 5900

Inside " 1@ 2760 = 2760

8,660 kg per lin meter of span.



Dead Load Reaction on column.

Outside Rahmen 2@ 59500 = 119,000

Inside " = 55700

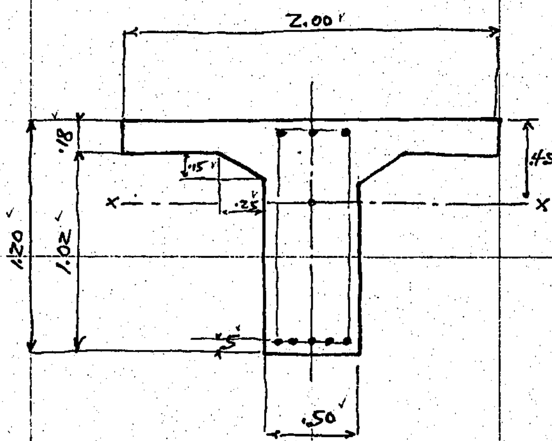
½ weight of columns. (Page 13) = 39300

214,000 kg. on one bent.

Seismic force = 214000 × 0.2 = 42800 kg.

Moments of inertia I for Top beam.

Center of gravity of the section



Slab	.18 × 2.00 =	.3600	×	.09 =	.0324
fillet	.25 × .15 =	.0375	×	.23 =	.0086
web.	.50 × 1.02 =	.5100	×	.69 =	.3540
steel top	15 cm² × 15 ÷ 10000 =	.0225	×	.05 =	.0011
" bottom	25 × 15 ÷ 10000 =	.0375	×	1.15 =	.0432
		.9675 m²		.454 m	.4393

Moment of inertia about X-X axis

Slab. $\frac{2.0 \times .18^3}{12} + .360 \times .364^2 = .00097 + .0477 = .04867$

fillets $.0375 \times .224^2 =$ .00188

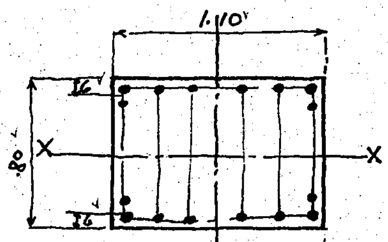
web $\frac{.50 \times 1.02^2}{12} + .510 \times .236^2 = .04337 + .02838 = .07175$

steel top $.0225 \times .404^2 =$ .00367

" bottom $.0375 \times .696^2 =$ .01817

$I =$ 0.14414 m⁴

Moment of inertia of columns. I_h



Concrete	1.10 × .80 =	.880	$\frac{1.10 \times .8^3}{12}$	=	.04691
Steel	$\frac{78.5 \times 15}{10000}$ =	.118	$.118 \times .34^2$	=	.01363
		0.998 m²		I_h =	.06054 m⁴

Constants to be used in following calculation.

$v = \frac{I \cdot h}{I_h \cdot l} = \frac{0.14414 \times 5.50}{0.06054 \times 2.10} = 6.24$

$(v+2) = 8.24$, $(v+2)v = 51.41$, $(v+1)v = 45.2$

$(6v^2+9v+1) = 233.6 + 56.2 + 1 = 290.8$ $(3v+4)v = 141.8$

$(24v^2+39v+4) = 935 + 243.5 + 4 = 1182.5$

$(3v^2+6v+1) = 116.8 + 37.5 + 1 = 155.3$

$(12v^2+15v+2) = 467.5 + 93.6 + 2 = 563.1$

Values of 6 redundancies.

$M_1 = -\frac{(v+2)v}{2(6v^2+9v+1)} Ph = -\frac{51.41 \times 42800 \times 5.5}{2 \times 290.8} = -$ 20800 kgm.

$M_2 = -M_1$ $= +$ 20800 "

$H_1 = \frac{(24v^2+39v+4)}{6(6v^2+9v+1)} P = \frac{1182.5 \times 42800}{6 \times 290.8} = +$ 29000 kg

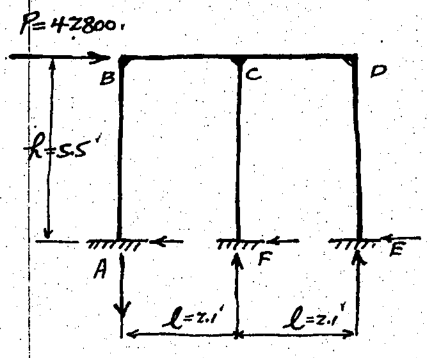
$H_2 = \frac{(12v^2+15v+2)}{6(6v^2+9v+1)} P = \frac{563.1 \times 42800}{6 \times 290.8} = +$ 13800 "

$V_1 = \frac{(3v+4)v}{2(6v^2+9v+1)} \cdot \frac{Ph}{l} = \frac{141.8 \times 42800 \times 5.5}{2 \times 290.8 \times 2.1} = +$ 27300 kg

$V_2 = -\frac{(3v+4)v}{2(6v^2+9v+1)} \cdot \frac{Ph}{l} = -$ 27300 "

Design of Takada Bashi for Fukushima ken.

Moments at several points in the structure.



$M_B = M_1 + V_1 l = -20800 + 27300 \times 2.1 = +36500$ kgm.

$M_A = M_1 + V_1 l + H_1 h - Ph = +36500 + 29000 \times 5.5 - 42800 \times 5.5 = -39500$ kgm

$M_F = M_1 - M_2 + (H_1 - H_2)h = -20800 - 20800 + 15200 \times 5.5 = +42000$ "

$M_D = M_2 + V_2 l = +20800 + (-27300 \times 2.1) = -36500$ kgm

$M_E = M_2 + V_2 l + H_2 h = -36500 + 13800 \times 5.5 = +39400$ "

Horizontal reactions on bottom of columns.

$H_A = P - H_1 = 42800 - 29000 = +13800$ kg

$H_F = H_1 - H_2 = 29000 - 13800 = +15200$ "

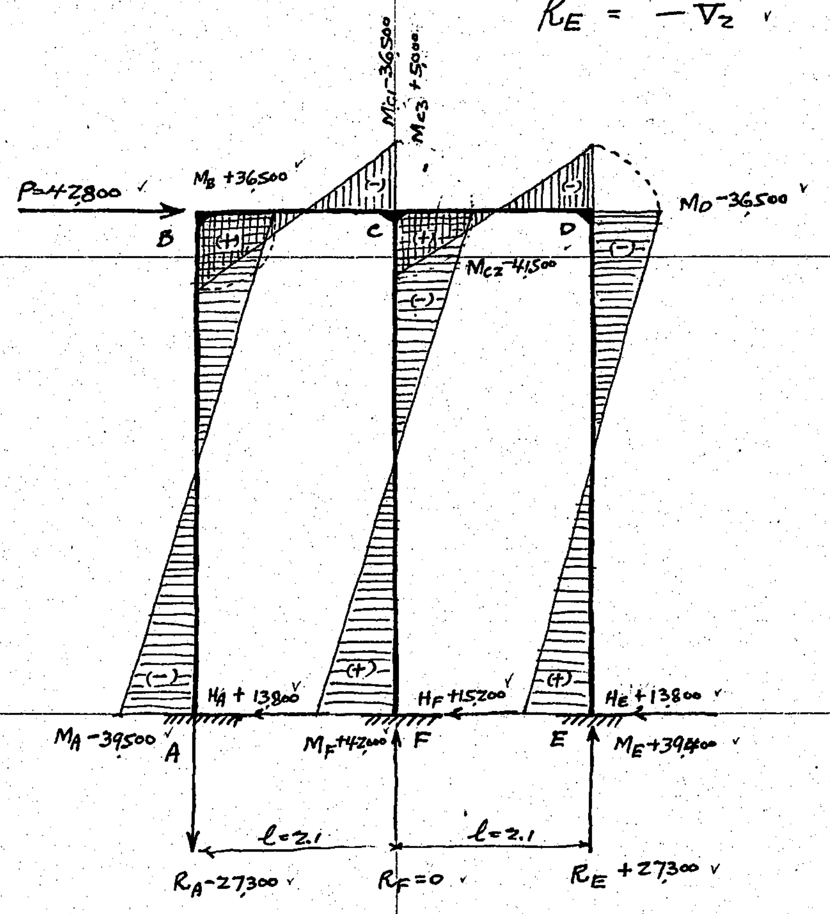
$H_E = H_2 = +13800$ "

Vertical Reactions on column

$R_A = -V_1 = -27300$ "

$R_F = V_1 + V_2 = 0$ "

$R_E = -V_2 = +27300$ "



Moments + reactions for columns of A-Rahmen.

$M_{C_2} = -H_F h + M_F = -15200 \times 5.5 + 42000 = -41500$ kgm

$M_{C_3} = 41500 - 36500 = +5000$ "

Dead Load stresses

Dead Load assumed 2500 kg/lin m.

$M_B = -\frac{ql^2}{12(1+v)} = -\frac{2500 \times 2.1^2}{12 \times 7.24} = -130$ kgm $= M_D$

$M_A = +\frac{ql^2}{24(1+v)} = +65$ " $= M_E$

$M_C = M_F = 0$

Dead Load stresses are very small and neglected.

Stresses on columns for B-Rahmen.

M_B	+36500	× 0.92 =	+ 33600 kgm
M_A	−39500		− 36300 "
M_F	+42000		+ 38600 "
M_D	−36500		− 33600 "
M_E	+39400		+ 36200 "
M_{C_2}	−41500		− 38200 "
M_{C_3}	+ 5000		+ 4600 "
H_A	+13800		+ 12700 kg
H_F	+15200		+ 14000 "
H_E	+13800		+ 12700 "
R_A	−27300		− 25100 "
R_F	0		0
R_E	+27300		+ 25100 "

Dead load on columns for B-Rahmen.

Out side columns	2 × 53800 =	107600
Inside "		50400
½ Columns wt + c say		39300
		197300

Seismic force = 197300 × .20 ≒ 39460 kg

Proportion = $\frac{39460}{42800}$ ≒ 0.92

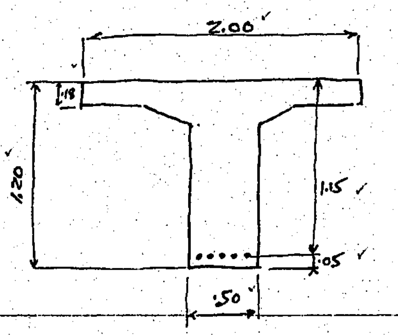
Design of Takada Bashi for Fukushima Ken.

Stresses of Pier Bent during transverse earthquake.

Sections of Top Beam. moment = ± 36,500 kgm Direct compression 29000 kg or 13800 kg

assumed section

$f_s = 1200 \times 1.6 = 1920$ $f_c = 45 \times 1.6 = 72$



Steel area required $= \frac{36500 \times 100}{1920 \times \frac{7}{8} \times 115} = 189\ cm^2$

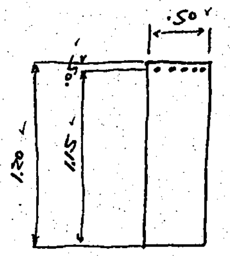
use 5 − 25 mm φ bars = 24.52 cm²

Steel ratio $p = \frac{24.52}{200 \times 115} = .0011$ $t/d = 18/115 = .157$

From the prepared diagrams $k = 0.19$; $j = .94$

$f_s = \frac{36500 \times 100}{24.52 \times .94 \times 115} = 1377\ kg/cm^2 < 1920$ ok

$f_c = \frac{1377 \times .19}{15 \times .81} = 21.5$ " < 72 ok



For negative moment.

Steel ratio $p = \frac{24.52}{50 \times 115} = 0.0043$

From the prepared tables $k = 0.300$, $j = 0.900$

$f_s = \frac{36500 \times 100}{24.52 \times .90 \times 115} = 1440\ kg/cm^2$ ok

$f_c = \frac{1440 \times .30}{15 \times .70} = 41.1$ " ok.

Direct compression on concrete $= \frac{29000}{.9675 \times 10000} = 3.0\ kg/cm^2$

Direct ~~tension~~ comp. on steel $= 3.0 \times 15 = 45.0$ "

Combined stress.

	Positive moment f_s	Positive moment f_c	Negative moment f_s	Negative moment f_c
Due to moment	1377	21.5	1440	41.1
" direct comp.	−45	+3.0	−45	+3.0
	1,332 kg/cm²	24.5 kg/cm²	1395 kg/cm²	44.1 kg/cm²

Assumed section is ample.

Sections of column.

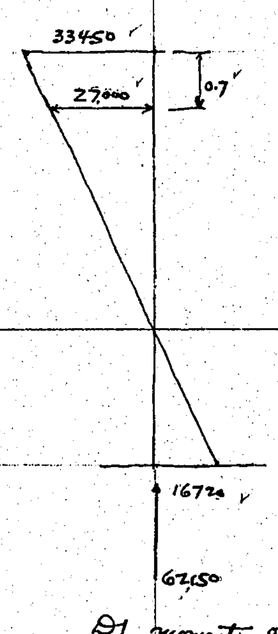
max. stress in column due to Dead Load + Earthquake will occur at top of inside column of B Rahmen

	moment	load on column
Dead Load stress of longitudinal B-Rahmen	−33450 kgm	62,150 kg + 1850 (strut+say) = 64000 kg
Transverse earthquake stress	−38200 "	0

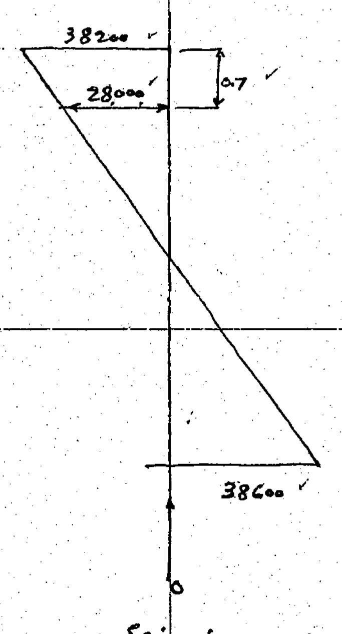
probable moment at bottom plane of beam

Dead Load m = 27,000 kgm

Seismic m = 28,000 "



D.L. moment on col.



Seismic moment on col.

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CALCULATIONS FOR

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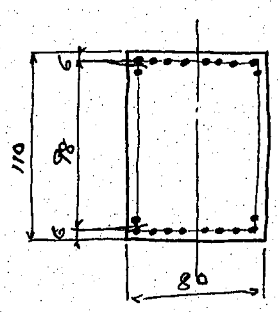
Design of Takada Bashi for Fukushima Ken.

Dead Load stresses on column. (Longitudinal direction)

Dead Load moment 27000 kgm at bottom plane of beam + strut.
Dead Load on column 64,000 kg $H = 9110$ kg



Eccentricity $z = \frac{27000}{64000} = 0.42^{m}$ $z/h = 42/110 = 0.382$

$d'/h = 6/110 = .0546$ $p_3 = 0.0115$

From the prepared diagrams $k = .666$, $L = .143$

$f_c = \frac{27000 \times 100}{.143 \times 80 \times 110^2} = 19.5$ kg/cm²

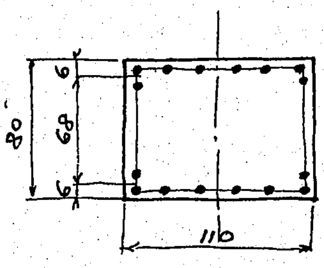
$f_s = 15 \times 19.5 \left(\frac{104}{.666 \times 110} - 1\right) = 123$ "

unit shear $= \frac{9110}{80 \times \frac{7}{8} \times 104} = 1.3$ "

unit bond $= \frac{9110}{78.5 \times \frac{7}{8} \times 104} = 1.3$ "

Seismic stresses on column (transverse direction)

Seismic moment = 28,000 kgm at bottom plane of strut.
Seismic load on center col. = 0. $H_r = 14,000$ kg on center col.



Eccentricity ∞ or for this case beam formula will be applied.

Steel area = 8-25φ bars = 39.3 cm² on both sides.

steel ratio $p = p' = \frac{39.3}{110 \times 74} = .00483$ $d'/d = 6/74 = .081$

From the prepared diagrams. $k = .276$, $j = .915$

$f_s = \frac{28000 \times 100}{39.3 \times .915 \times 74} = 1,052$ kg/cm²

$f_c = \frac{1052 \times .276}{15 \times .724} = 26.8$ "

unit shear $= \frac{14000}{110 \times .915 \times 74} = 1.9$ "

unit bond $= \frac{14000}{62.8 \times .915 \times 74} = 3.3$ "

Combined stresses at one corner of highest intensity of stress.

	f_s	f_c	Shear	Bond
Dead Load	123	19.5	1.3	1.3
Earthquake	1,052	26.8	1.9	3.3
	1,175 kg/cm²	46.3 kg/cm²		4.6 kg/cm²

Assumed section is ample for all columns of all rahmen.

Design of Takada Bashi for Fukushima Ken.

Design of Column footing.

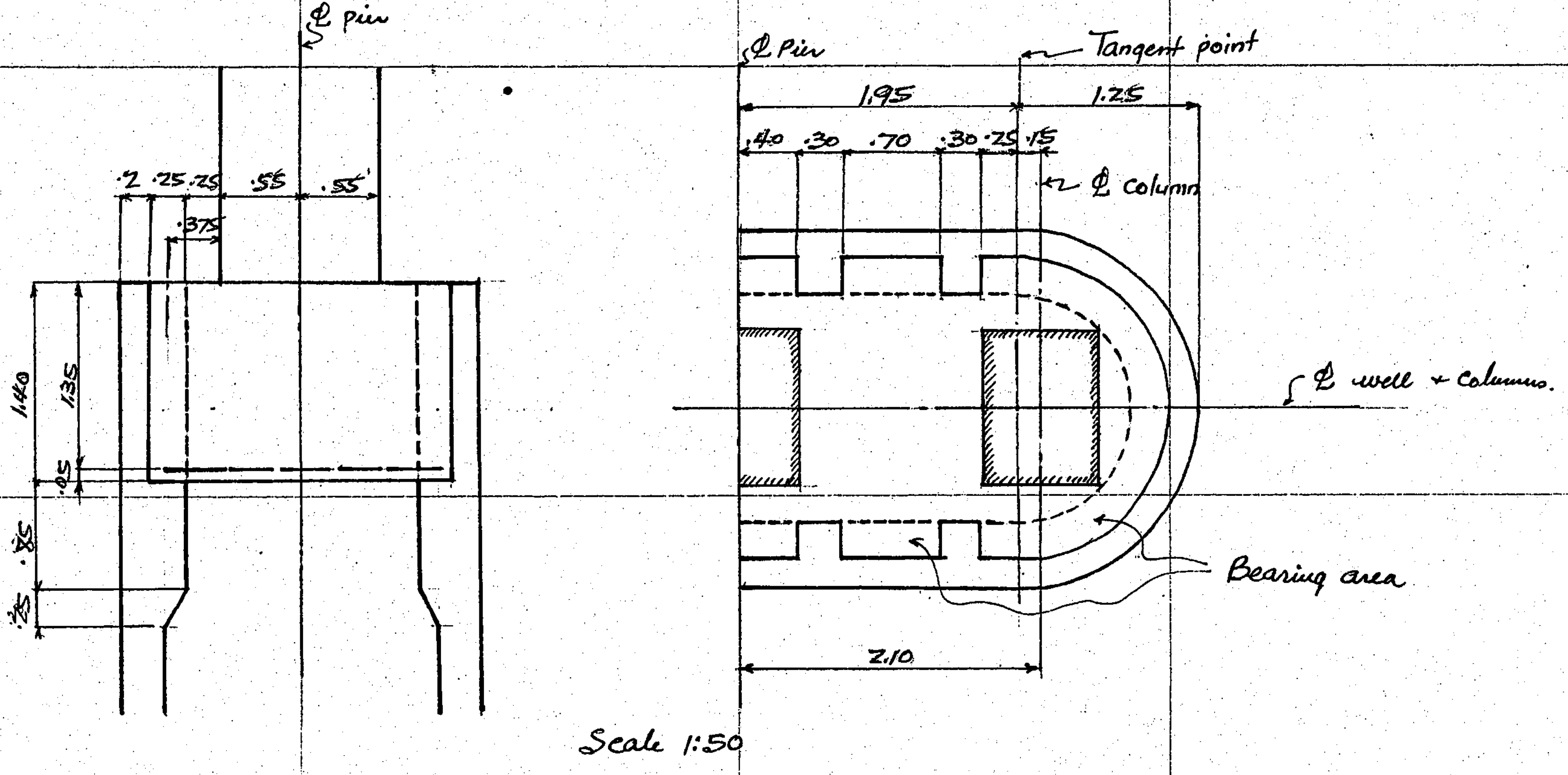
Superimposed loads and moment on column.

A-Rahmen.

	2-Outside columns			1-Inside columns.			Total.		
	R_E	H	M_E	R_E	H.	M_E	R_E	H	M_E
Dead Load	+119,000	-6020	-10,300	+55,700	-2820	-4820	+174,700	-8840	-15,120
Live Load.	+18,800	-12,540	-23,000	+12,560	-8380	-15,370	+31,360	-20,920	-38,370
	+137,800	-18,560	-33,300	+68,260	-11,200	-20,190	+206,060	-29,760	-53,490
Dead Load	+119,000	-6020	-10,300	+55,700	-2820	-4820	+174,700	-8840	-15,120
Earthquake	+5020	-26,400	-97,000	+2370	-12,450	-45,750	+7390	-38,850	-142,750
	+124,020	-32,420	-107,300	+58,070	-15,270	-50,570	+182,090	-47,690	-157,870
Dead Load	+119,000	-6020	-10,300	+55,700	-2820	-4820	+174,700	-8840	-15,120
Live Load	+18,800	-12,540	-23,000	+12,560	-8380	-15,370	+31,360	-20,920	-38,370
Temperature	—	-14,280	-63,700	—	-7240	-31,850	—	-21,520	-95,550
	+137,800	-32,840	-97,000	+68,260	-18,440	-52,040	+206,060	-51,280	-149,040

B-Rahmen.

	2-Outside Columns			1-Inside column			Total.		
	R_E	H	M_E	R_E	H	M_E	R_E	H	M_E
Dead Load	+107,600	+19,460	+35,740	+50,350	+9110	+16,720	+157,950	+28,570	+52,460
Live Load	+17,660	+13,220	+24,240	+11,800	+8830	+16,180	+29,460	+22,050	+40,420
	+125,260	+32,680	+59,980	+62,150	+17,930	+32,900	+187,410	+50,620	+92,880
Dead Load	+107,600	+19,460	+35,740	+50,350	+9110	+16,720	+157,950	+28,570	+52,460
Earthquake	+3420	+18,040	+66,200	+1630	+8550	+31,450	+5050	+26,590	+97,650
	+111,020	+37,500	+101,940	+51,980	+17,660	+48,170	+163,000	+55,160	+150,110
Dead Load	+107,600	+19,460	+35,740	+50,350	+9110	+16,720	+157,950	+28,570	+52,460
Live Load	+17,660	+13,220	+24,240	+11,800	+8830	+16,180	+29,460	+22,050	+40,420
Temperature	—	+14,480	+63,700	—	+7240	+31,850	—	+21,720	+95,550
	+125,260	+47,160	+123,680	+62,150	+25,180	+64,750	+187,410	+72,340	+188,430
wt. of columns + struts	+26,000			+13,300			+39,300		
wt. of footing							+37,100		
							+263,810		
Call these							+263,800 kg	+72,300 kg	+188,400 kg-m



Scale 1:50

Design of Takada Bashi for Fukushima ken.

Bearing area on well.

0.25 × 3.90 = 0.975
2.1φ − 1.60φ = 1.453
0.30 × 1.60 = 0.480
less 0.25 × 3 × 8 = −0.600
2.308 m^2

Weight of footing

3.90 × 2.10 = 8.18
2.10φ = 3.46
less 0.30 × .25 × 8 = −0.60
11.04 × 1.4 = 15.45 m^3

15.45 @ 2400 = 37,100 kg.

Average Bearing pressure = 263800 / 2.308 = 114,500 kg/□m

114,500 × 0.25 = 28,600 kg per lin meter of support on well.

Bearing pressure due to moment.

Lever arm say 1.85 meters, length of support say 4.30 meter.

188,400 / 1.85 = ± 101,800 kg.

101,800 ÷ 4.30 = ± 23,700 kg.

Combined bearing pressure due to, Vertical load = 28,600
moment = ± 23,700
52,300 kg C or 4,900 kg C per lin m.

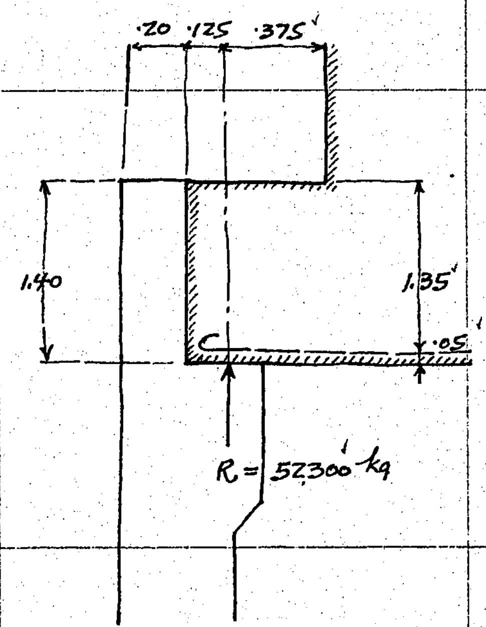
Unit compression = 52300 ÷ (25 × 100) = 20.9 kg C < 45 × 1.25 = 56.2 ok.

Reinforcements in footing.

moment on footing. 52,300 × .375 = 19,600 kg/m

Steel required = 19600 × 100 / (1500 × 7/8 × 135) = 11.05 cm^2/m strip.

use 5 − 22φ = 19.00 cm^2
use extra bond bars of 5 − 22φ = 19.00 cm^2



Steel ratio = 38.00 / (100 × 135) = 0.0028

k = 0.248, j = .917

f_s = 19600 × 100 / (38 × .917 × 135) = 416 kg/cm^2 ok.

f_c = 416 × .248 / (15 × .752) = 9.14 " "

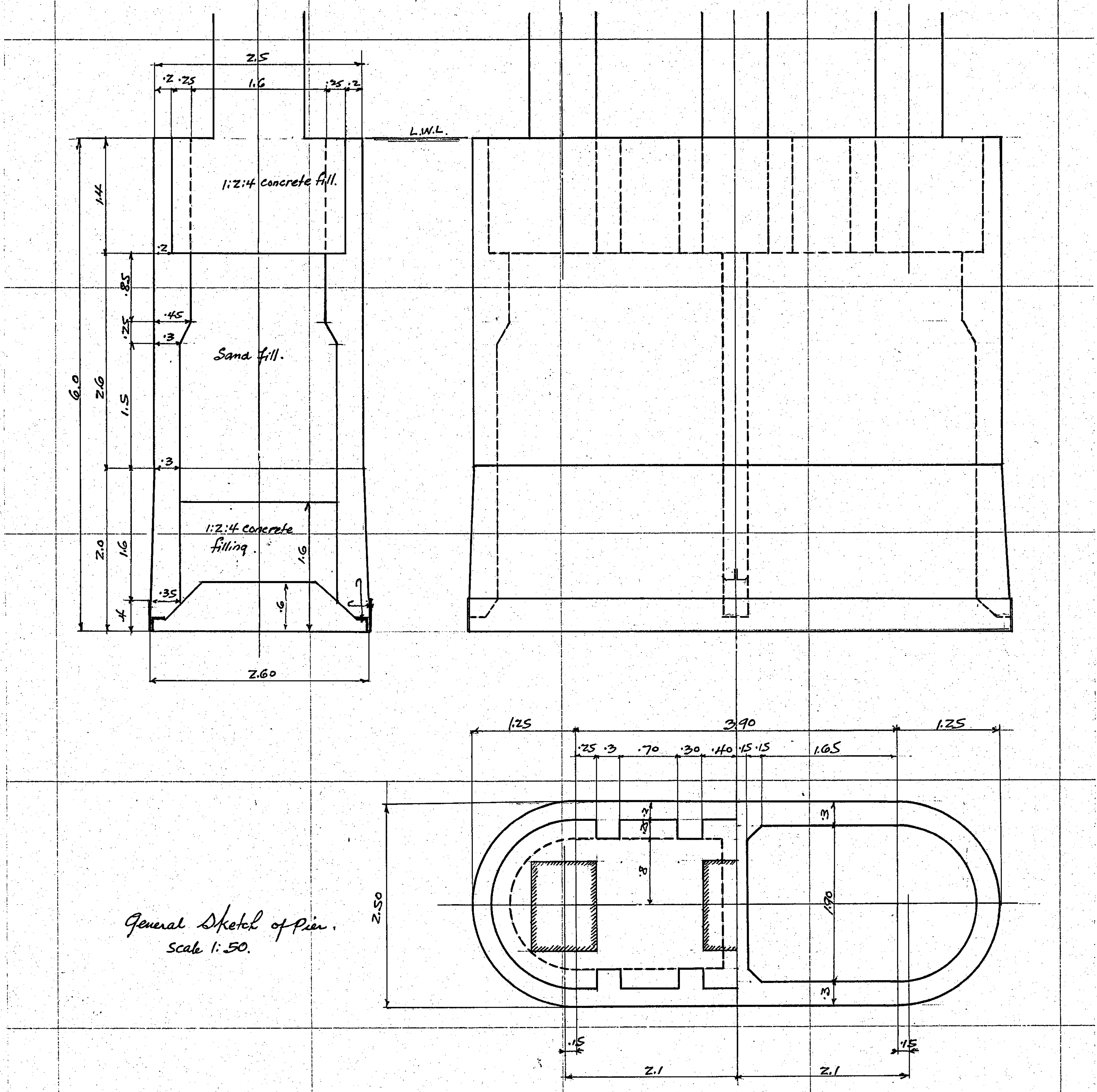
unit shear = 52300 / (100 × .917 × 135) = 4.22 " " < 4.0 × 1.25 = 5.0

unit bond = 52300 / (69.1 × .917 × 135) = 6.12 " " < 6.0 × 1.25 = 7.5

Design of Takada Bashi for Fukushima Ken.

Design of Pier well.

General dimensions and details as shown on sketch below.



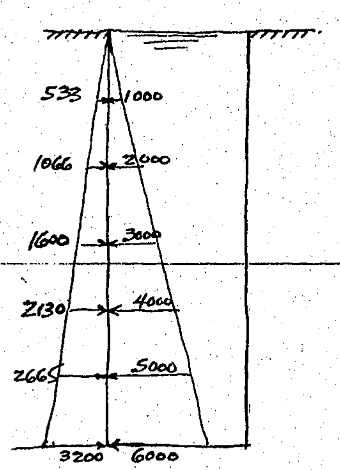
General Sketch of Pier.
Scale 1:50.

Design of Takada Bashi for Fukushima Ken

External Earth pressure on well. $\frac{1}{3} \times wh = \frac{1}{3} \times 1600 \times h = 533h$ kg/m²
Internal water pressure on well. $wh = 1000h$

External pressure +

Depth from top of well	Earth pressure	water pressure	Combined pressure
1	533 kg/m²	− 1,000 kg/m²	− 467 kg/m²
2	1,066	− 2,000	− 934
3	1,600	− 3,000	− 1,400
4	2,130	− 4,000	− 1,870
5	2,665	− 5,000	− 2,335
6	3,200	− 6000	− 2800



moment on side wall. span length assumed 2.70 meters.

Depth from top of well.	moment $\frac{1}{10} wl^2$	Shear $\frac{1}{2} wl$
1		
2	775 kg-m	1440 kg
3	1,165	2,160
4	1,550	2,875
5	1,940	3,600
6	2,330	4,320

At bottom section

Effective depth required $= \sqrt{\frac{2330 \times 100}{100 \times 7.18}} = 18.0$ cm

use 32 cm effective depth with an insulation of 3 cm, total depth = 35 cm

Steel area required $= \frac{2330 \times 100}{1200 \times \frac{7}{8} \times 32} = 6.94$ cm² per meter strip.

unit shear $= \frac{4320}{100 \times \frac{7}{8} \times 32} = 1.54$ kg/cm² ok.

Required spacings of 12 mm φ bars for bond stress.

no of bars $= \frac{4320}{6 \times 3.77 \times \frac{7}{8} \times 32} = 6.81$ spacing $= \frac{100}{6.81} = 14.7$ cm c to c.
$A_s = 7.69$ cm² ok.

At Section 5.0 m from top of well.

Steel area required $= \frac{1940 \times 100}{1200 \times \frac{7}{8} \times 29.5} = 6.27$ cm²

unit shear $= \frac{3600}{100 \times \frac{7}{8} \times 29.5} = 1.40$ kg/cm² ok.

no. of 12 mm φ bars req'd for bond $= \frac{3600}{6.0 \times 3.77 \times \frac{7}{8} \times 29.5} = 6.17$ spacing $= \frac{100}{6.17} = 16.2$ cm c to c
$A_s = 6.98$ cm² ok.

At section 4.0 m below top

Steel area required $= \frac{1550 \times 100}{1200 \times \frac{7}{8} \times 27.5} = 5.37$ cm²

unit shear $= \frac{2875}{100 \times \frac{7}{8} \times 27.5} = 1.20$ kg/cm² ok

no. of 12 mm φ bars for bond $= \frac{2875}{6.0 \times 3.77 \times \frac{7}{8} \times 27.5} = 5.29$ spacing $= \frac{100}{5.29} = 18.9$ cm c to c
$A_s = 5.98$ cm² ok

At section 3.0 m below top.

Steel area required $= \frac{1165 \times 100}{1200 \times \frac{7}{8} \times 27.5} = 4.03$ cm²

no. of 12 φ bars for bond $= \frac{2160}{6.0 \times 3.77 \times \frac{7}{8} \times 27.5} = 3.96$ spacing $= \frac{100}{3.96} = 25.3$ cm c to c.
$A_s = 4.47$ cm² ok

At section 2.0 m below top

Steel area required $= \frac{775 \times 100}{1200 \times \frac{7}{8} \times 27.5} = 2.69$ cm²

no. of 12 φ bars for bond $= \frac{1440}{6.0 \times 3.77 \times \frac{7}{8} \times 27.5} = 2.65$ spacing $= \frac{100}{2.65} = 37.7$ cm c to c
$A_s = 3.00$ cm² ok

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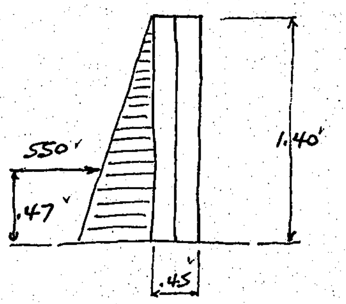
MADE BY K. Inaba DATE 6-1-18 FILE NO ______
CHECKED BY M. Iida DATE 6-1-22 PAGE NO 38

CALCULATIONS FOR

Design of Takada Bashi for Fukushima Ken.

Side wall on top.



Earth pressure on vertical wall.

$\frac{1}{6} \times 1600 \times 1.4^2 = 523$ kg / m strip.

for 1.05 m wide $523 \times 1.05 = 550$ kg

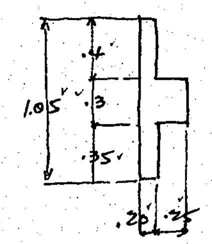
moment $= 550 \times .47 = 259$ kgm. Shear $= 550$ kg.

Steel area req'd. $= \frac{259 \times 100}{1200 \times \frac{7}{8} \times 42.5} = .58$ cm²

use 3-12 mm φ $= 3.39$ cm²

unit shear $= \frac{550}{30 \times \frac{7}{8} \times 42.5} = 0.49$ kg/cm² ok

unit bond $= \frac{550}{3 \times 3.77 \times \frac{7}{8} \times 42.5} = 1.31$ " ok



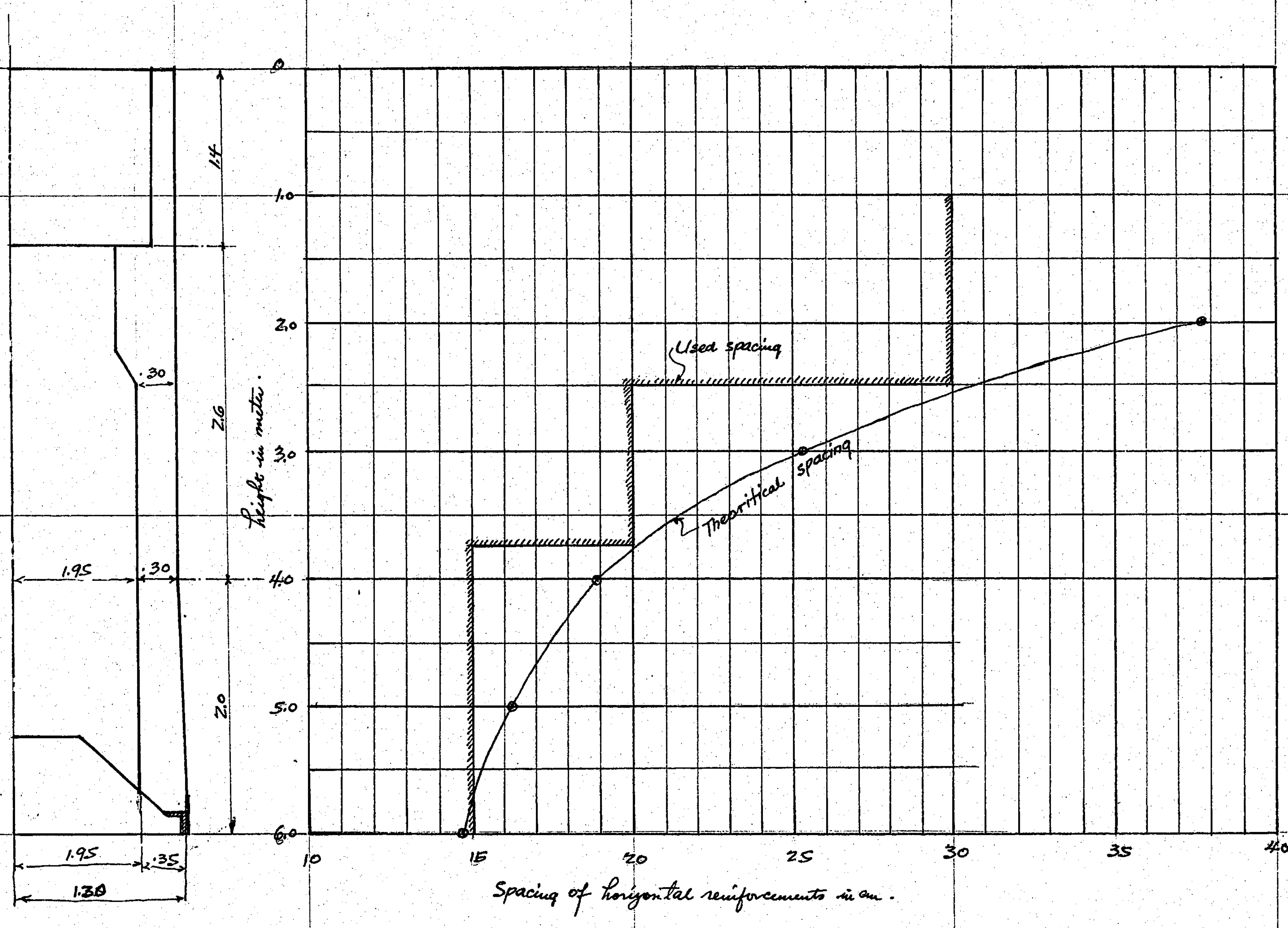
Wall without counterfort. $m = 523 \times .47 = 246$ kgm Shear $= 523$ kg.

Steel area req'd $= \frac{246 \times 100}{1200 \times \frac{7}{8} \times 17.5} = 1.34$ cm²

Eff. depth req'd. $= \sqrt{\frac{246 \times 100}{100 \times 7.18}} = 5.9$ cm. ok. 12 mm φ 40 cm c to c about.

unit shear $= \frac{523}{100 \times \frac{7}{8} \times 17.5} = 0.34$ kg/cm² ok

unit bond $= \frac{523}{3.77 \times 2.5 \times \frac{7}{8} \times 17.5} = 3.62$ " ok.



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MADE BY K. Inaba DATE 6-1-23 FILE NO

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CALCULATIONS FOR

Design of Takada Bashi for Fukushima ken.

Stability of Pier.

weight and center of gravity of well.

Top 1.40 meter

0.20 × 3.90 × 2 × 1.40 = 2.19
(2.50ϕ - 2.10ϕ) × 1.40 = 2.03
.25 × .3 × 8 × 1.40 = .84
5.06 @ 2400 = 12,150 kg

Lower 4.45 m.

Cross sectional area of wall.

.45 × .85 = .382
.375 × .25 = .094
.30 × 1.50 = .450
.325 × 1.60 = .520
.25 × .25 = .063
1.509 cm.

Length of wall.

2 × 3.90 = 7.80
2.3ϕ = 7.23
15.03 m × 1.509 = 22.6 @ 2400 = 54100 kg.

Partition wall 1.6 × .3 × 3.0 = 1.44
fillets .15 × .15 × 2 × 4.0 = .18
1.62 m3 @ 2400 = 3900 kg

Bottom fill 1.60 × 3.9 × 1.6 = 10.00
1.6ϕ × 1.6 = 3.22
13.22 m3 @ 2200 = 29,100 kg.

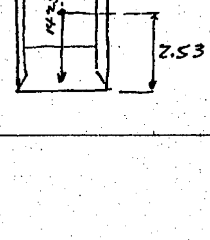
Curb shoes say 1250 kg.
100,500 kg.

Sand filling 1.6 × 3.9 × 3.0 = 18.70
1.6ϕ × 3.0 = 6.03
24.73 m3 @ 1700 = 42000

Total wt. of well. = 142,500 kg.

Center of gravity of well.

	vol. of concrete	weight	arm	moment
Top 1.40 m	5.06	12150	5.30	64400
Lower 4.45 shell	22.60	54100	2.40	129900
Partition wall	1.63	3900	3.10	12100
Bottom filling	13.22	29100	0.80	23300
Curb shoe		1250	.15	200
Sand filling		42000	3.10	130200
	42.51 m3	142,500 kg	2.53 m	360,100



Superimposed Loads. Thrust and moment transmitted from columns. see page 34

At normal state.

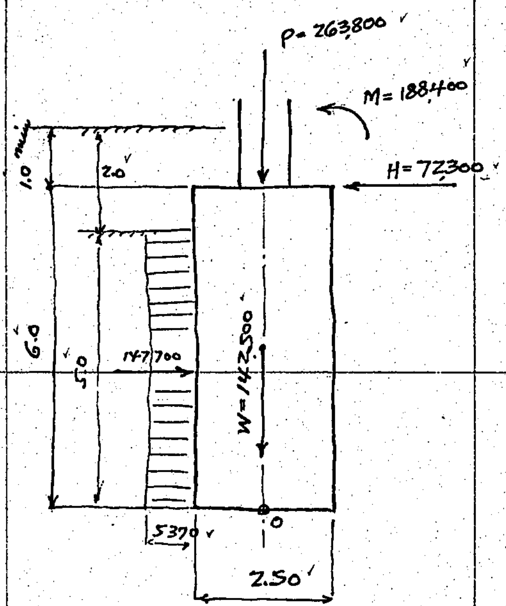
	R_E	H	M_E
Dead Load	+ 157,950	+ 28,570	+ 52,460
Live Load	+ 29,460	+ 22,050	+ 40,420
Temperature	—	+ 21,720	+ 95,550
	+ 187,410	+ 72,340	+ 188,430
Columns + struts	+ 39,300		
footing	+ 37,100		
	+ 263,810 kg		
Call these	+ 263,800 kg	+ 72,300 kg	+ 188,400 kg·m

During Earthquake and temperature

	R_E	H	M_E
Dead Load	+ 157,950	+ 28,570	+ 52,460
Temperature	—	+ 21,720	+ 95,550
Earthquake	+ 5,050	+ 26,590	+ 97,650
	+ 163,000	+ 76,880	+ 245,660
Column + struts	+ 39,300		
footing	+ 37,100		
	+ 239,400		
Call these	+ 239,400 kg	+ 76,900 kg	+ 245,700 kg

Design of Takada Bashi for Fukushima Ken

Case 1. Stability of Pier at normal state. (D.L. + L.L. + Temperature)



Taking moment about point O.

Load	Hor. forces	Vert. forces	Lever arms	Moments
P		263,800 ×	0 =	0
M		×	=	188,400
H	72,300	×	6.00 ×	433,600
W		142,500 ×	0 =	0
	72,300	406,300		622,000

Skin friction on well assumed 1,500 kg/m² — Top 2.0 m earth neglected.
average length of well say 5.5 m.
Frictional resistance on one side of the well.
5.50 × 5.0 × 1500 = 41200 kg.
Frictional couple = 41200 × 2.5 = -103,000 kgm

$\frac{188400}{2.5} = 75400$ kg.

Reactional earth pressure moment
72300 × 2.5 = -181,000
75400 × 2.5 = -188400
147,700 — -472,400 kgm
622,000
149,600 kgm

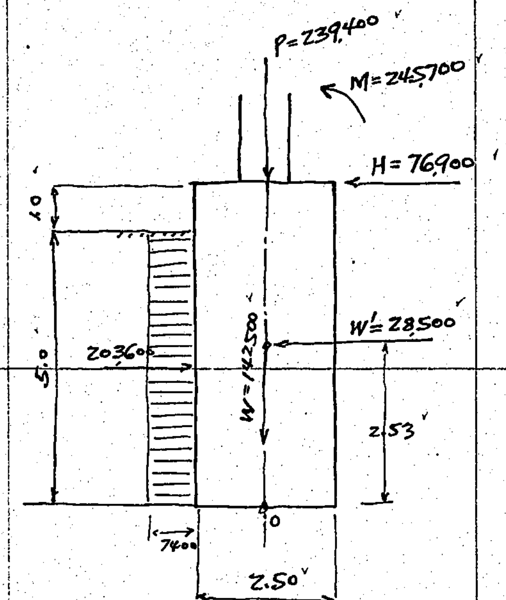
Eccentricity = $\frac{149600}{406300} = 0.38$ m Resultant force within middle third

max. toe pressure = $\frac{406300}{2.5 \times 5.5}\left(1 \pm \frac{6 \times .38}{2.5}\right) = 56400$ kg/m² (5.15 tons/□) ok.
(.91; 2660)

Reactional earth pressure = 147,700 kg
average unit pressure = $\frac{147,700}{5.0 \times 5.5} = 5,370$ kg/m²

Allowable max. pressure = 2.0 × 1600 × 3 = 9600 kg/m² ok

Case 2. Stability during Earthquake. D.L. + L.L. + Temperature.



Taking moment about point O.

Loads	Hor. forces	Vert. forces	Lever arms	moments
P.		239,400 ×	0 =	0
M		×	=	245,700
H	76900	×	6.0 =	462,000
W		142,500 ×	0 =	0
W'	28,500	×	2.53 =	72,100
	105,400 kg	381,900 kg		779,800 kgm.

Reactional earth pressure on well.
245,700 ÷ 2.5 = 98200
105,400
203,600 × 2.50 = -509,000

frictional couple = -103,000
- 612,000
779,800
167,800 kgm

Eccentricity = $\frac{167,800}{381,900} = 0.43$ m
Resultant force outside of middle third. Pressure area 1.25 - .43 = .82 × 3 = 2.46
2.46 × 5.5 = 13.53 m²

max. toe pressure = $\frac{381900 \times 2}{13.53} = 56500$ kg/m² (5.16 tons/□) ok

$\frac{203600}{5.0 \times 5.5} = 7400$ kg/m² < 9600 ok.

備考 基礎地盤ハ径15~40cmノ玉石層ニ砂利及砂ヲ混ジ空隙完全ニ填充セル極メテ良好ナル
地盤ニシテ安全荷重ハ8 tons/□以上ト認メラル (ボーリング調書参照)

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CALCULATIONS FOR

MADE BY K. Inaba DATE 6-1-21 FILE NO
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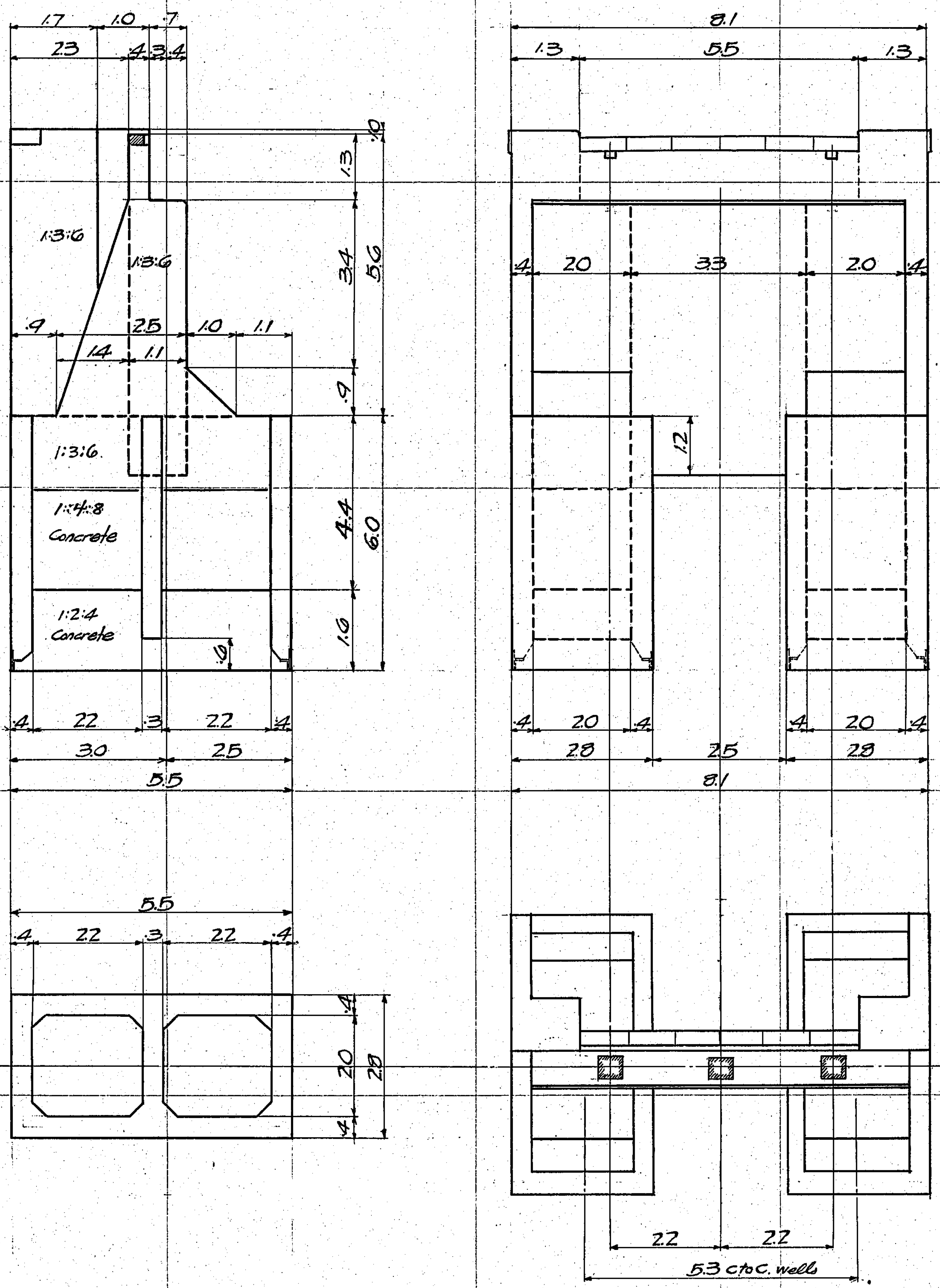
Design of Takada Bashi for Fukushima Ken.
Design of Abutment at Right approach.
General dimensions are as shown on sketch below.

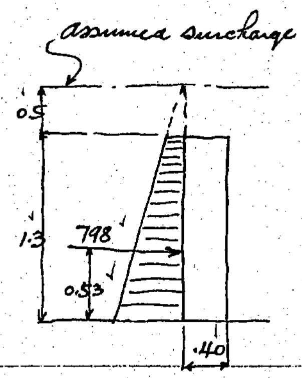


General Sketch of abutment.
Scale 1:100.

Design of Takada Bashi for Fukushima Ken.

Design of Parapet wall.

assumed surcharge for Live Load.



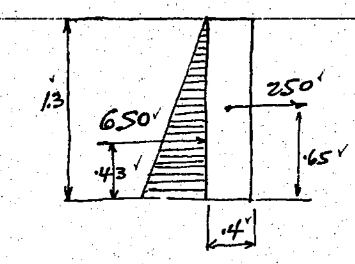
Earth pressure at normal state.
1/3 × 1600 × 0.5 = 267.
1/3 × 1600 × 1.8 = 960
1227 ÷ 2 = 614 kg/m² average.

Earth pressure on wall = 614 × 1.3 = 798 kg per lin meter of wall.
moment = 798 × .53 = 423 kgm.
Effective depth required = $\sqrt{\frac{423 \times 100}{100 \times 7.18}}$ = 7.7 cm

use 37 cm effective depth with an insulation of 3 cm.
Steel area required = $\frac{423 \times 100}{1200 \times \frac{7}{8} \times 37}$ = 1.09 cm²

use 12 cm φ bars at 30 cm c to c = 3.77 cm² per meter strip.
unit shear = $\frac{798}{100 \times \frac{7}{8} \times 37}$ = 0.25 kg/cm² ok
unit bond = $\frac{798}{12.56 \times \frac{7}{8} \times 37}$ = 1.96 " ok.

Earth pressure during Earthquake. k assumed 0.200
$\frac{0.48 \times 1600 \times 1.3^2}{2}$ = 650 kg per lin meter of wall.

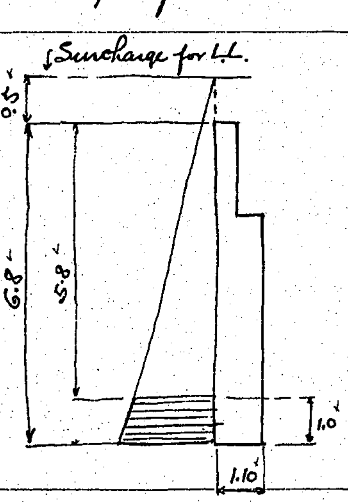


weight of wall = .40 × 1.3 = .52 @ 2400 = 1250 kg per meter strip
Seismic force = 1250 × .2 = 250 kg
moment on wall
250 × .65 = 163
650 × .43 = 280
443 kgm.

Shear = 250 + 650 = 900 kg ok.

Design of Curtain wall.

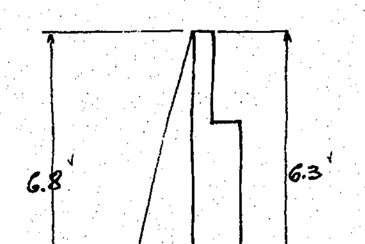
Earth pressure at normal state. Span length assumed 3.3 meters.



1/3 × 1600 × 6.8 = 3625 kg per sq.m. for bottom 1 m strip average.
moment = 1/10 × 3625 × 3.30² = 3945 kgm.
Shear = 1/2 × 3625 × 3.30 = 5980 kg.
Effective depth required = $\sqrt{\frac{3945 \times 100}{100 \times 7.18}}$ = 23.4 cm

use 105 cm effective depth with an insulation of 5 cm.
Steel area required = $\frac{3945 \times 100}{1200 \times \frac{7}{8} \times 105}$ = 3.58 cm²

use 19 mm φ bars at 30 cm c to c = 9.45 cm²
unit shear = $\frac{5980}{100 \times \frac{7}{8} \times 105}$ = 0.65 kg/cm² ok.
unit bond = $\frac{5980}{19.9 \times \frac{7}{8} \times 105}$ = 3.27 " ok.



Earth pressure during earthquake.
0.48 × 1600 × 6.3 = 4,840 kg/m²
weight of wall 1.10 @ 2400 = 2640
Seismic force = 2640 × .2 = 528 kg per lin m
4,840
5,368 "

moment on wall = 1/10 × 5,368 × 3.3² = 5,850 kgm < 3945 × 1.6 = 6,310
Shear " " = 1/2 × 5,368 × 3.3 = 8,850 kg < 5980 × 1.6 = 9,570

Assumed section is ample.

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MADE BY K. Inaba DATE 6-1-22 FILE NO

CHECKED BY M. Jinda DATE 6-1-23 PAGE NO 43

CALCULATIONS FOR

Design of Takada Bashi for Fukushima ken.

Design of wing wall.

At Bottom section

Difference of depth of earth between outside and inside fillings assumed 3.0 meters.
Surcharge for Live Load assumed 0.5 meter. $h = 3.0 + 0.5 = 3.50$ meters.

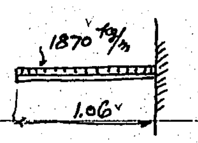
Earth pressure on Bottom 1 meter strip of wall.

$1/3 \times 1600 \times 3.5 = 1870$ kg/m²

moment on wall $= \frac{1}{2} \times 1870 \times 1.06^2 = 1050$ kgm

Shear " " $= 1870 \times 1.06 = 1980$ kg

Effective depth required $= \sqrt{\frac{1050 \times 100}{100 \times 7.18}} = 12.1$ cm



use 37 cm effective depth with an insulation of 3 cm.

Steel area required $= \frac{1050 \times 100}{1200 \times \frac{7}{8} \times 37} = 2.70$ cm²

use 16 mmφ bars at 45 cm c to c $= 4.47$ on both sides

Unit shear $= \frac{1980}{100 \times \frac{7}{8} \times 37} = 0.61$ kg/cm² ok.

Unit bond $= \frac{1980}{11.2 \times \frac{7}{8} \times 37} = 5.46$ " ok.

Earth pressure during earthquake. $h = 3.0$ meters.

$0.48 \times 1600 \times 3.0 = 2,300$ kg/m²

weight of wall $= .40 \times 2400 = 960$

Seismic force $= 960 \times .2 = 190$

Total load on wall $= 2300 + 190 = 2,490$ kg per sq.m. $< 1870 \times 1.6 = 2990$ ok.

Section at 3 meter below top.

Earth pressure same as above. Span length 1.70 meters.

moment $= \frac{1}{2} \times 1870 \times 1.7^2 = 2,700$ kgm

Shear $= 1870 \times 1.7 = 3,180$ kg

Effective depth $= \sqrt{\frac{2700 \times 100}{100 \times 7.18}} = 19.4$ cm

use 37 cm effective depth with 3 cm insulation

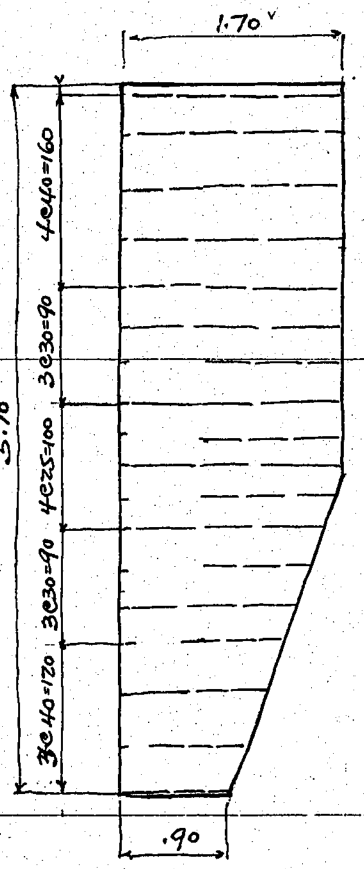
Steel area required $= \frac{2700 \times 100}{1200 \times \frac{7}{8} \times 37} = 6.95$ cm²

use 16 mmφ at 25 cm c to c $= 8.04$ cm²

Unit shear $= \frac{3180}{100 \times \frac{7}{8} \times 37} = 0.98$ kg/cm² ok.

Unit bond $= \frac{3180}{20.1 \times \frac{7}{8} \times 37} = 4.90$ " ok.

Stresses during earthquake. ok.



Design of Takada Bashi for Fukushima Ken.

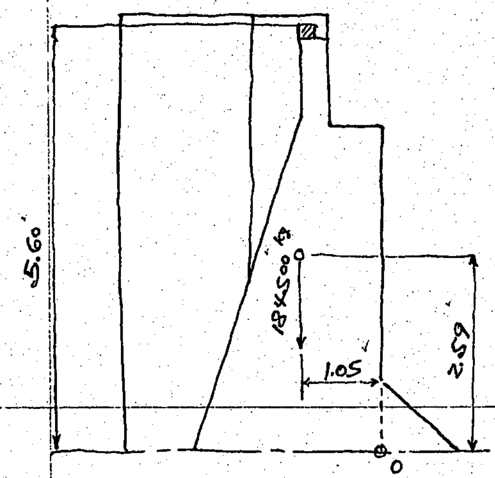
Design of Shaft.

weight and center of gravity of shaft. moment about front face of wall, at bottom o.

Description	Dimension	Volume		weight	Hor. arm	Hor. moment	Vert. arm	Vert. moment
Parapet wall.	.40 × 1.06 × 5.50 =	2.33	@ 2400 =	5,590	.90	5,030	4.83	27,000
Column under pedestals	1.00 × 1.30 × 5.70 × 2 =	14.82	"	35,550	1.20	42,650	2.85	101,400
wing wall	1.70 × 5.70 × .40 × 2 =	7.75	"	18,600	2.55	47,400	2.85	53,000
body	1.10 × 0.70 × 4.30 × 2 =	6.62	"	15,880	1.57	24,900	1.43	22,700
"	0.90 × 0.80/2 × 3.0 × 2 =	2.16	"	5,180	1.97	10,200	1.00	5,180
front wall	0.70 × 4.30 × 7.30 =	21.95	"	52,660	.35	18,450	2.15	113,200
"	0.40 × 4.30 × 5.50 =	9.46	"	22,700	.90	20,420	2.15	48,800
"	1.10 × 1.20 × 2.50 =	3.30	"	7,920	.55	4,360	−.60	− 4,750
fillet	0.90 × 1.0/2 × 2.0 × 2 =	1.80	"	4,320	−.33	− 1,425	.30	1,295
Light pedestals say	2.70 m³ × 2 =	5.40	"	12,950	1.20	15,550	7.10	92,000
Handrail on wing	.15 × .9 × 1.20 × 2 =	.32	"	770	2.30	1,770	6.15	4,730
End posts	.5 × .5 × 1.15 × 2 =	.58	"	1,390	3.15	4,380	6.28	8,730
Granite (踏掛石)	.23 × .3 × 5.5 =	.38	@ 2600 =	990	.95	940	5.49	5,430
	volume of concrete =	76.49 m³		184,500 kg	1.05 m	194,625	2.59 m	478,715

weight of shaft for one half of abutment = 92300 kg

Seismic force = 92300 × .2 = ~~36900~~ 18500 kg



weight of earth on back of body

2.0 × 1.1 × 4.0 = 8.8 @ 1600 = 14100 kg arm hor. 2.02, vert 3.60

Earth pressure at normal state.

1/3 × 1600 × .5 = 267

1/3 × 1600 × 6.1 = 3253

3520 ÷ 2 = 1760 kg/m² average

1760 × 5.60 × 4.05 = 39900 kg arm 2.00

Earth pressure during earthquake

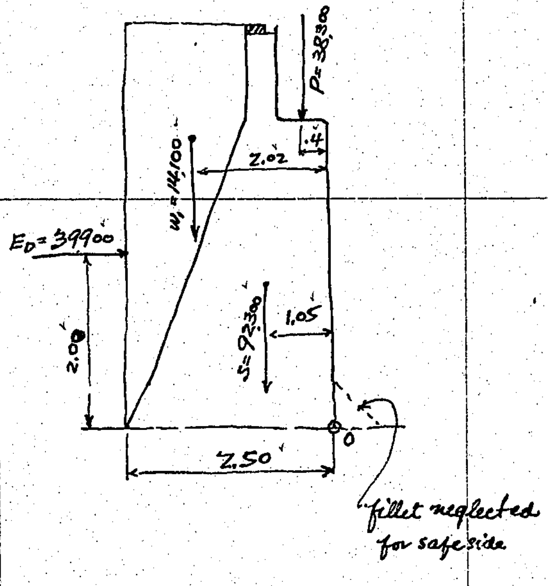
$0.48 \times 1600 \times \frac{5.6^2}{2} \times 4.05 = 48800$ kg arm 1.87

Superimposed Loads on abutment

	2 - Outside columns	1 - Inside cols.	total	1/2 of abutment
Dead Load	38,000	17800	55800	27,900
Live Load	12,480	8340	20,820 say	10,400
				38,300 kg

At Bottom Section

Case 1 Stresses at normal state



Taking moment about point O.

Loads	Hor. forces	Vert. forces	Lever arm		moment
P		38300 ×	.40	=	15,320
S		92300 ×	1.05	=	96900
W_1		14,100 ×	2.02	=	28,500
E_o	−39900	×	2.00	=	− 79,800
	−39900 kg	144,700 kg	0.42 m		60,920

Eccentricity $z = 1.25 - 0.42 = 0.83$ m $m = 144,700 \times .83 = 120000$ kgm

Try Reinforcements 6 − 22 mm φ bars = 22.8, for both sides = 45.6 cm²

$p_o = \frac{456}{200 \times 250} = .0009$, $z/h = \frac{83}{250} = .33$, $d'/h = 5/250 = .02$

From the prepared diagrams of combined stress.

$k = 0.57$, $L = .093$

$f_c = \frac{120000 \times 100}{.093 \times 200 \times 250^2} = 10.3$ kg/cm² ok

$f_s = 15 \times 10.3 \left(\frac{245}{.57 \times 250} - 1 \right) = 111$ " ok

unit shear $= \frac{39900}{200 \times \frac{7}{8} \times 245} = 0.93$ " ok

unit bond $= \frac{39900}{41.5 \times \frac{7}{8} \times 245} = 4.48$ " ok

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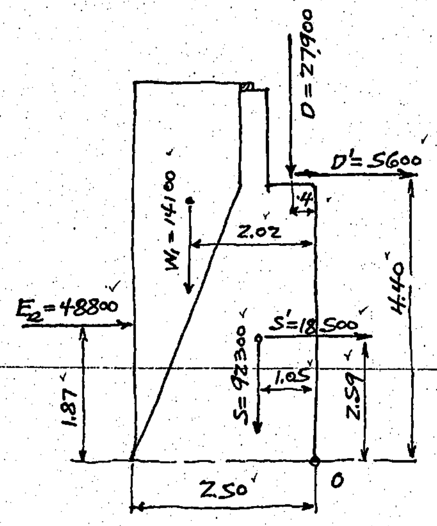
CALCULATIONS FOR

MADE BY K. Inaba DATE 6-1-28 FILE NO ______
CHECKED BY M. Jinda DATE 6-1-30 PAGE NO 45

Design of Takada Bashi for Fukushima Ken.

Case 2. Stresses during Earthquake. K assumed 0.200



Taking moment about point O.

Loads	Horizontal forces	Vertical forces		Lever arms		Moments
D		27900	×	.40	=	11,170
D'	5600		×	4.40	=	− 24,650
S		92300	×	1.05	=	96,900
S'	18500		×	2.59	=	− 47,900
W_1		14,100	×	2.02	=	28,500
Ee	48800		×	1.87	=	− 91,200
	72,900 kg	134,300 kg		−0.70 m		− 27,180

Eccentricity $\varepsilon = 1.25 + .20 = 1.45^{m}$ $m = 1.45 \times 134,300 = 195,000$ kgm.

$p_0 = .0009$, $\varepsilon/h = 145/250 = .58$, $d'/h = 105/250 = .02$

$k = .21$, $L = .058$

$f_c = \frac{195000 \times 100}{.058 \times 200 \times 250^2} = 26.9$ kg/cm² ok.

$f_s = 15 \times 26.9 \left(\frac{245}{.21 \times 250} - 1\right) = 1480$ kg/cm² ok $< 1200 \times 1.6 = 1920$

Unit shear $= \frac{72900}{200 \times \frac{7}{8} \times 245} = 1.7$ " "

unit bond $= \frac{72900}{~~200~~\,41.5 \times \frac{7}{8} \times 245} = 8.2$ " " $< 6.0 \times 1.6 = 9.6$

Stability of Abutment.

Case 1. Stability of abutment ~~due~~ at normal state.

weight of Base $2.8 \times 5.5 \times 6.0 = 92.8 @ 2300$ (average) $= 212,000$ kg

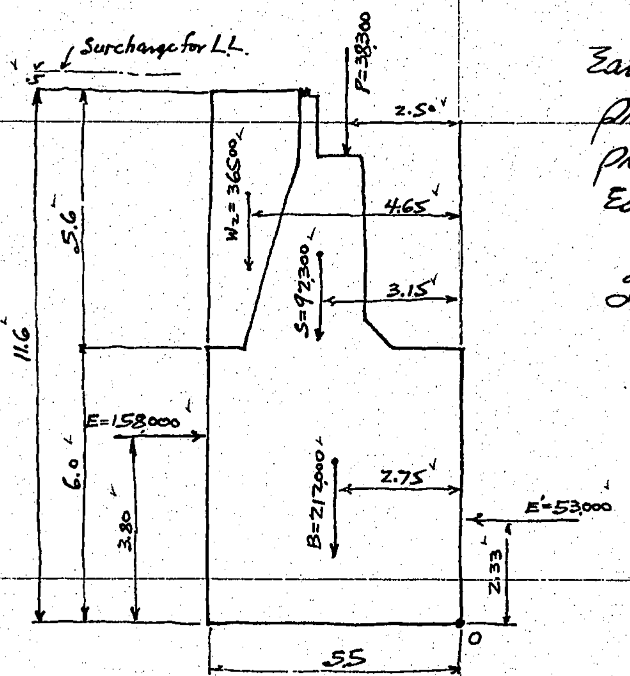
Seismic force $= 212,000 \times .2 =$ 42,400 kg

Earth pressure at normal state.

Pressure on rear say $1/6 \times 1600 \times 12.1^2 \times 4.05 = 158,000$ kg arm 3.80 m

pressure on front $1/6 \times 1600 \times 7.0^2 \times 4.05 = 53,000$ " arm 2.33

Earth on rear side say $2.4 \times 1.7 \times 5.6 @ 1600 = 36,500$ " arm 4.65



Taking moment about point O.

Loads	Hor. forces	Vert. forces		Lev. arm		moments
P		38,300	×	2.50	=	95,700
S		92300	×	3.15	=	291,000
W_2		36,500	×	4.65	=	169,900
B		212,000	×	2.75	=	583,000
E	− 158,000		×	3.80	=	− 600,000
E'	53,000		×	2.33	=	123,500
	− 105,000	379,100		1.75 m		663,100

Eccentricity $\varepsilon = 2.75 - 1.75 = 1.00^{m}$

Resultant force outside of middle third, neglecting tension on heel.

Pressure area $= 1.75 \times 3 \times 2.8 = 14.7$ m²

max. toe pressure $= \frac{379100 \times 2}{14.7} = 51,600$ kg/m² or (4.7 tons/□) ok.

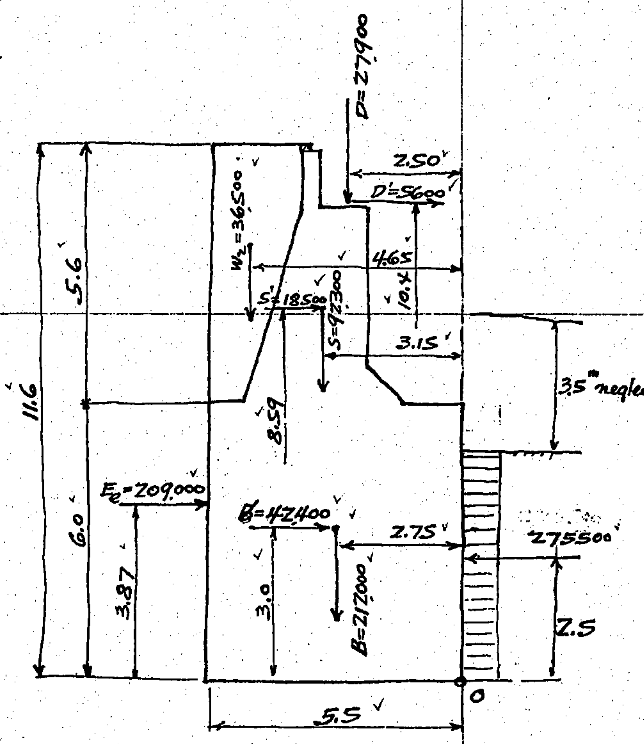
備考 基礎地質ハ「ボアリング」ニヨル実地調査ノ結果 径 15~40cm ノ玉石層ニシテ其空隙ハ砂利及砂ヲ以テ完全ニ填充シ居ル極メテ良好ナル地盤ニシテ安全荷重少クモ 8 tons/□ トスヒト認メタル

Design of Takada Bashi for Fukushima ken.

Case 2. Stability during earthquake. (Seismic force forward).

Earth pressure during earthquake.

$0.48 \times 1600 \times \frac{11.6^2}{2} \times 4.05 = 209{,}000$ kg. arm 3.87 m



Taking moment about point 0.

Load	Hor. forces	Vert. forces		Lev. arm		Moment
D		27,900	×	2.5	=	69,800
D'	− 5,600		×	10.4	=	− 58,200
S		92,300	×	3.15	=	291,000
S'	− 18,500		×	8.59	=	− 159,000
B		212,000	×	2.75	=	583,000
B'	− 42,400		×	3.00	=	− 127,200
W_2		36,500	×	4.65	=	169,700
E_e	− 209,000		×	3.87	=	− 809,000
	− 275,500	368,700				− 39,900

Reactional earth pressure 275500 kg

Average unit passive pressure $= \frac{275500}{4.05 \times 5.0} = 13{,}600$ kg/m²

Allowable passive pressure on soil $= 3.5 \times 1600 \times \frac{1.5}{.5} = 16{,}800$ kg/m² ok

Reactional moment of soil $= 275500 \times 2.5 = 689{,}000$ kgm
− 39,900
649,100

Point of application of resultant force $= \frac{649100}{368700} = 1.75$ m from 0.

Eccentricity $\mathcal{E} = 2.75 - 1.75 = 1.00$ m Resultant force outside of middle third.

Pressure area
$= 1.75 \times 3 \times 2.8 = 14.7$ sq.m

max. toe pressure $= \frac{368700 \times 2}{14.70} = 50{,}200$ kg/m² (4.60 tons/□') ok.

Case 3. Stability during Earthquake (Seismic forces backward).

Earth pressure during earthquake

$0.48 \times 1600 \times \frac{8.5^2}{2} \times 4.05 = 112{,}000$ kg. arm 2.83 m

Loads	Hor. forces	Vert. forces		Lev. arm		moments
D		27,900	×	2.5	=	69,800
D'	5,600		×	10.4	=	58,200
S	~~18,500~~	92,300	×	3.15	=	291,000
S'	18,500		×	8.59	=	159,000
B		212,000	×	2.75	=	583,000
B'	42,400		×	3.00	=	127,200
W_2		36,500	×	4.65	=	169,700
E_e'	112,000		×	2.83	=	317,000
	178,500	368,700				1,774,900

Reactional earth moment same process as for case 2.

178500 × 2.5 = − 446,000
1,328,900

Point of application of resultant force $= \frac{1328900}{368700} = 3.60$ m from 0.

Eccentricity $\mathcal{E} = 3.60 - 2.75 = .85$

max. toe pressure $= \frac{368700}{2.8 \times 5.5}\left(1 \pm \frac{6 \times .85}{5.5}\right) = 46{,}100$ kg/m² or (4.22 tons/□') ok.
(.927; 1750)

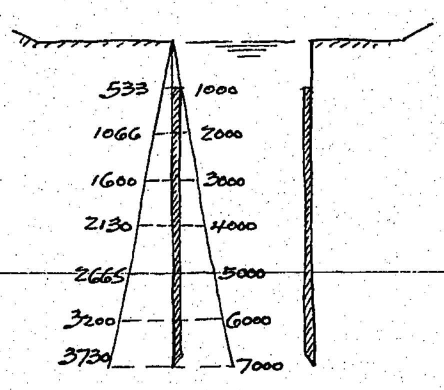
Design of Takada Bashi for Fukushima ken.

Design of well for Abutment.

External earthpressure on well. $\frac{1}{3}wh = \frac{1}{3}\times1600h = 533h$ kg/m²

Internal water pressure on well 1000 h "

max. depth of earth say 7.00 meters.



Depth of earth	Depth from top of well.	Earth pressure	Water pressure	Combined pressure.
1	0	533 kg/m²	- 1,000	- 467
2	1	1066	- 2000	- 934
3	2	1600	- 3,000	- 1,400
4	3	2130	- 4,000	- 1870
5	4	2665	- 5000	- 2335
6	5	3200	- 6,000	- 2,800
7	6	3730	- 7000	- 3270

Earth pressure governs.

Moment and shear on side wall. Span length assumed 2.55 meters.

Depth from top of well.	moment $\frac{1}{10}wl^2$	Shear $\frac{1}{2}wl$.
0	350	680
1	690	1360
2	1040	2040
3	1385	2715
4	1730	3400
5	2080	4080
6	2420	4750

At Bottom section

Effective depth required $= \sqrt{\frac{2420\times100}{100\times7.18}} = 18.35$ cm

Use effective depth of 37 cm with an insulation of 3 cm, total depth = 40 cm

Steel area required $= \frac{2420\times100}{1200\times\frac{7}{8}\times37} = 6.23$ cm² per meter strip.

Unit shear $= \frac{4750}{100\times\frac{7}{8}\times37} = 1.47$ kg/cm²

Required perimeter of bars for bond. $= \frac{4750}{6\times\frac{7}{8}\times37} = 24.5$ cm

Required no. of 12 mm φ bars. $= \frac{24.5}{3.77} = 6.50$ $A_s = 6.5 \times 1.13 = 7.34$ cm² o.k.

Spacing $= \frac{100}{6.5} = 15.40$ cm c to c.

At section 5.0 meter below top of well.

~~Steel area required~~ $= \frac{2080\times100}{1200\times\frac{7}{8}\times37} = 5.36$ cm² per meter strip.

Unit shear $= \frac{4080}{100\times\frac{7}{8}\times37} = 1.26$ kg/cm² o.k.

Required perimeter of bars for bonding $= \frac{4080}{6\times\frac{7}{8}\times37} = 21.0$ cm

Required no. of 12 mm φ bars $= \frac{21.0}{3.77} = 5.57$ $A_s = 5.57 \times 1.13 = 6.30$ cm² ok.

Spacing of bars $= \frac{100}{5.57} = 17.95$ cm c to c.

At section 4.0 meter below ~~top~~ of well.

~~Steel~~ area required $= \frac{1730\times100}{1200\times\frac{7}{8}\times37} = 4.46$ cm²

Reqd. perimeter of bars for bond $= \frac{3400}{6\times\frac{7}{8}\times37} = 17.50$ cm

Reqd. no. of 12φ bars $= \frac{17.5}{3.77} = 4.64$ $A_s = 4.64 \times 1.13 = 5.24$ cm² ok.

Spacing 21.6 cm c to c.

Design of Takada Bashi for Fukushima ken

At section 3 meter below top of well.

Steel area required = $\frac{1385 \times 100}{1200 \times \frac{7}{8} \times 37}$ = 3.57 cm²

Required perimeter of bars = $\frac{271.5}{6 \times \frac{7}{8} \times 37}$ = 13.95 cm

Required no of 12φ bars = $\frac{13.95}{3.77}$ = 3.70

Spacing = $\frac{100}{3.70}$ = 27.0 cm c to c — As = 3.70 × 1.13 = 4.18 cm²

At section 2 meter below top of well.

Steel area required = $\frac{1040 \times 100}{1200 \times \frac{7}{8} \times 37}$ = 2.68 cm²

Required perimeter of bars = $\frac{204.0}{6 \times \frac{7}{8} \times 37}$ = 10.50 cm

Required no of 12φ bars = $\frac{10.50}{3.77}$ = 2.79 — As = 2.79 × 1.13 = 3.15 cm²

Spacing = $\frac{100}{2.79}$ = 35.9 cm c to c.

Materials of Takada Bashi for Fukushima-ken

Materials

Concrete 1:2:4 mixture See sheet no.5

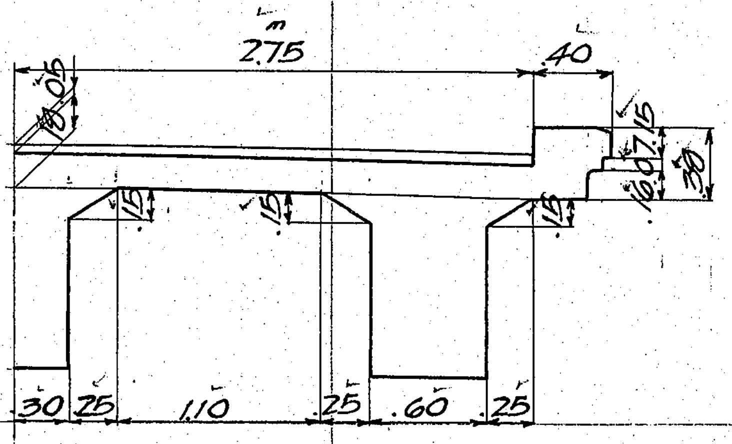
Floor Slab (Drain holes neglected)

Sectional area

Slab .18 × 5.50 = .990

Coping 2 @ .38 · .36 = .274

1.264 m^2



A-Rahmen (Slab No.1)

1.264 × 53.64 = 67.80

Bracket 4 @ .23 × .74 = .83

68.63 m^3

B-Rahmen (Slab No.2)

1.264 · 23.06 = 29.15

Bracket 4 @ .23 · .74 = .83

29.98 m^3

Main Beam See sheet no.6

A-Rahmen

Beam AC

.55 × 1.37 · .80 × 6 = 3.62
.845 · 1.12 · .70 · 6 = 3.69
7.205 · .97 · .60 · 6 = 25.16
fillets .25 · .15 · 7.055 · 4 = 1.06
" .20 · .12 · 2.03 · 2 = .10
" .18 · .11 · 1.88 · 2 = .07
" .25 · .15 · 9.60 · 2 = .72
39.41 m^3

Beam AS

.55 · 1.37 · .80 · 3 = 1.81
.845 · 1.12 · .70 · 3 = 4.34
14.335 · .97 · .60 · 3 = 25.03
.49 · .385 · .60 · 3 = .34
fillets .25 · .15 · 14.155 · 2 = 1.06
" .18 · .11 · 1.88 · 1 = .04
" .20 · .12 · 2.03 · 1 = .05
" .25 · .15 · 17.22 · 1 = .65
33.32 m^3

Beam ASA

.55 · 1.37 · .80 × 3 = 1.81
.845 · 1.12 · .70 · 3 = 4.34
14.825 · .97 · .60 · 3 = 25.88
fillets { Same as AS = 1.06
= .05
= .65
= .04
33.83 m^3

B-Rahmen

Beam B

7.205 · .97 · .60 · 6 = 25.16
1.10 · 1.37 · .80 · 6 = 7.23
(.845 + 1.87) · 1.12 · .70 · 6 = 17.48
less .49 · .385 · .65 · 6 = - .74
fillets .20 · .12 · (2.03 + 1.38) · 2 = .16
" .25 · .15 · 7.055 · 4 = 1.06
" .25 · .15 · 11.53 · 2 = .86
" .18 · .11 · (1.39 + 1.88) · 2 = .13
51.34 m^3

Materials of Takada Bashi for Fukushima-ken

Cross Beam

CB1
1.07 × 1.30 × .50 × 2 = 1.39
fillets .10 × .10 × 1.10 × 2 = .02
1.41 m^3

CB2
.586 × 1.60 × .30 × 2 = .56
fillets .10 × .10 × 1.10 × 2 = .02
.58 m^3

CB3
.36 × 1.60 × .30 × 2 = .35
fillets .10 × .10 × 1.10 × 2 = .02
.37 m^3

CB4
.53 × 1.60 × .30 × 2 = .51
fillets .10 × .10 × 1.10 × 2 = .02
.53 m^3

Summary of Concrete

End A-Rahmen

Floor Slab	No.1	1 @ 6.863	=	6.863
Main Beam	AC	1 @ 3.941	=	3.941
〃	AS	1 @ 3.332	=	3.332
〃	ASA	1 @ 3.383	=	3.383
Cross Beam	CB1	2 @ 1.41	=	2.82
〃	CB2	4 @ .58	=	2.32
〃	CB3	1 @ .37	=	.37
				18.070 m^3

Intermediate A-Rahmen

Floor Slab	No.1	1 @ 6.863	=	6.863
Main Beam	AC	1 @ 3.941	=	3.941
〃	AS	2 @ 3.332	=	6.664
Cross Beam	CB1	2 @ .141	=	.282
〃	CB2	3 @ .58	=	1.74
〃	CB3	2 @ .37	=	.74
				17.998 m^3

B-Rahmen

Floor Slab	No.2	1 @ 2.998	=	2.998
Main Beam	B	1 @ 5.134	=	5.134
Cross Beam	CB1	2 @ 1.41	=	2.82
〃	CB2	1 @ .58	=	.58
〃	CB4	2 @ .53	=	1.06
				8.578 m^3

Grand Summary of Concrete

End A-Rahmen	2 @ 18.070	=	36.140
Int. A-Rahmen	5 @ 17.998	=	89.990
B-Rahmen	6 @ 8.578	=	51.468
			177.598 m^3

架構材料（一径間分）

米松材

名称	寸法	長	一本当容積	員数	總容積	摘要
桁	.18m × .40m	1.85m	.133	12	1.596	両端
〃	.18 × .25	5.10	.230	12	2.760	中間
〃	.18 × .25	5.40	.243	6	1.458	仝上
上段梁	.15 × .20	6.80	.204	12	2.448	全部
束木	.15 × .15	3.60	.081	60	4.860	中間
〃	.15 × .15	4.60	.104	12	1.248	両端
縦貫木	.075 × .15	4.40	.055	12	.660	中間
〃	.075 × .15	6.30	.071	6	.426	仝上
〃	.05 × .15	2.10	.016	24	.384	両端
横貫木	.075 × .15	5.60	.063	14	.882	全部
筋違	.05 × .15	4.30	.032	24	.768	中間
〃	.05 × .15	3.10	.023	24	.552	両端
〃	.05 × .15	4.60	.035	16	.560	仝上
下段梁	.20 × .20	6.30	.252	10	2.520	全部

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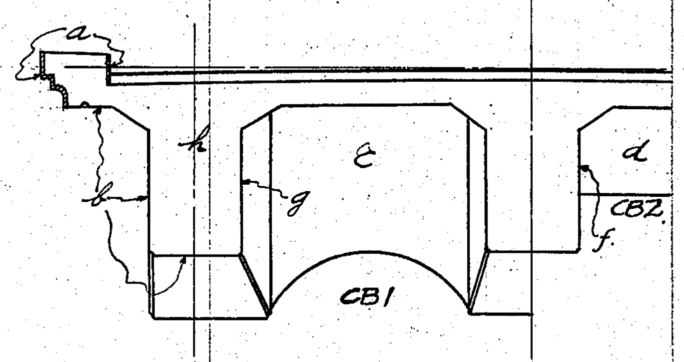
CALCULATIONS FOR

Materials of Takada Bashi for Fukushima-Ken

名稱	寸法	長	一本当容積	員数	總容積	摘要
小桁	.075·.12·1.00		.009	8	.072	両端
方杖	.075·.075·.40		.002	12	.024	仝上
〃	.075·.075·.60		.003	8	.024	仝上
束木	.075·.075·4.00		.023	6	.138	橋脚上
繼木	.06·.06·2.00		.007	6	.042	仝上
〃	.075·.075·1.80		.010	6	.060	仝上
					21.482 m³	
楔	.10·.15·.25		.004	144	.576 m³	全部貫堅キ良材
根杭	.15φ	3.00 m (mean length)		60本		全部
附属金物						
ボールト	19φ mm	.29 m	.82 kg	84	68.88	桁繼手、桁及繼木
〃	19φ	.26	.75	132	99.00	縱貫木及束木、横貫木及束木
〃	19φ	.24	.70	304	212.80	筋違及束木
〃	19φ	.34	.93	12	11.16	縱貫木及束木
〃	19φ	.25	.73	12	8.76	束木及繼木
〃	19φ	.16	.53	6	3.18	仝上
〃	19φ	.19	.59	8	4.72	小桁及小桁
鋲	09φ	.12	.12	288	34.56	楔
鋲	12□	.15	.34	384	130.56	梁及束木
座金	60·6·06		@ .17	1,116	189.72	全部
					763.34 kgs or .7633 kg tons	

上部工型枠（両端径間）



Copings	(a)	2 @ 6.70 m	× 17.22 m	=	230.7
Bracket (Side)		2 @	.28	=	.56
〃 (Bottom)		1 @ .130	× .74	=	.10
	(b)	1 @ 11.22	× 17.22	=	193.21
扇形ノ部分		6 @ 1.20	× .40	=	2.88
	(c)	2 @ 1.30	× 1.10	=	2.86
	(d)	8 @ 1.60	× .60	=	7.68
less	(f)	8 @ .40	× .30	=	-.96
〃	(g)	2 @ 1.30	× .50	=	-1.30
End	(h)	3 @ .60	× 1.00	=	1.80
〃		1 @ .10	× 6.06	=	.61
〃		2 @ .20	× .40	=	.16
less bearing		3 @ .44	× .60	=	-.79
					429.88 m²

型枠（中間径間）

Copings	(a)	2 @ 6.70	× 19.20	=	257.3
Bracket (Side)		4 @	.28	=	1.12
〃 (Bottom)		2 @ .13	× .74	=	.19
	(b)	1 @ 11.22	× 19.20	=	215.42
扇形ノ部分		12 @ 1.20	× .40	=	5.76
	(c)	4 @ 1.30	× 1.10	=	5.72
	(d)	4 @ 1.60	× .60	=	3.84
less	(f)	4 @ .40	× .30	=	-.48
〃	(g)	4 @ 1.30	× .50	=	-2.60
					485.70 m²

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CALCULATIONS FOR

Materials of Takada-Bashi for Fukushima Ken

For Beam CB3 & CB4

Side	4 @ .85	× 1.60	=	5.44	
Bottom	2 @ .30	× 1.60	=	.96	
end of slab	6 @ .15	× .80	=	.72	
	2 @ .10	× 6.06	=	1.21	
	4 @ .20	× .40	=	.32	
less	4 @ .30	× .70	=	-.84	
				7.81	m²

Summary of Forms for Super Structure

両端径間	2 @ 229.88	=	459.76
中間径間	25 @ 254.70	=	6367.50
CB3 & CB4	12 @ 7.81	=	93.72
			6920.98 m²

Reinforcements (plain bars)

2 - End A-Rahmens

Main Beams & Cross Beams 12.4178
Slab (NO.1) 5.5099
17.9277 × 2 = 35.8554 Kg tons

5 Intermediate A-Rahmens

Main Beams & Cross Beams 12.5031
Slab (NO.1) 5.5099
18.0130 × 5 = 90.0650 Kg tons

6 B-Rahmens

Main Beams & Cross Beams 6.7228
Slab (NO.2) 2.4620
9.1848 × 6 = 55.1088 Kg tons

Summary 181.0292 Kg tons

Granolithic Pavements (Drain holes neglected) See Sheet no.5

End A-Rahmen 2-Required
length 53.46 m
area 5.50 × 53.46 = 294.03
× 2
588.06 m²

Intermediate A-Rahmens 5-Required (Same as End A-Rahmen)
area 294.03
× 5
1470.15 m²

B-Rahmen 6-Required
length 22.79 m
area 5.50 × 22.79 = 125.35
× 6
752.10 m²

Summary of Pavements 2810.31 sq. meters

Cast iron Drain See sheet no.5
120 - Required @ 30 kgs = 3600 Kg tons

Materials of Takada Bashi for Fukushima-Ken

Mortar Finish (Coping & Brackets) see sheet no.5
1:2 mixture

End A-Rahmen 2-Required

Copings	2 @ .57 × 53.64	= 61.15
Brackets	4 @ .74 × .13	= .38
less (post)	62 @ .26 × .26	= -4.19
〃 〃	4 @ .47 × .74	= -1.39
		55.95 × 2 = 111.90 m²

Intermediate A-Rahmen 5-Required
Same as end A-Rahmens 55.95 × 5 = 279.75 m²

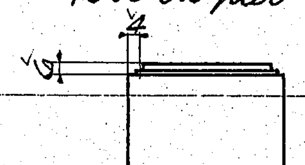
B-Rahmen 6-Required

Copings	2 @ .57 × 23.06	= 26.29
Brackets	4 @ .74 × .13	= .38
less (post)	26 @ .26 × .26	= -1.76
〃 〃	4 @ .47 × .74	= -1.39
		23.52 × 6 = 141.12 m²

Summary 532.77 sq.meters

Wire mesh in Main Beams (60 cm width 5 cm mesh about BWG No.16)
Total length = 51.46 × 3 = 154.38 m
area .60 × 154.38 = 92.628 sq.meters

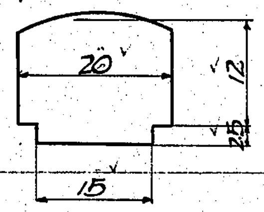
Handrails see sheet no.10 (Bothsides of total span)
Concrete 1:2:4 mixture
Post on pier 52-Required



.74 × .47 × 1.09 = .379
.66 × .39 × .06 = .015
.394 × 52 = 20.49 m³

Handrails post (HP & EHP) 590-Required
.26 × .26 × .92 = .062 × 590 = 36.58 m³ (wire mesh 共)

Top rails (TR, ETR & EER) 644-Required



.20 × .12 × 1.30 = .0312
.15 × .025 × 1.30 = .0049
.0361 × 644 = 23.25 m³

Summary of Concrete 80.32 cub.meters

Forms
Post on pier 52-Required
(.74 + .47) × 2 × 1.09 = 2.638
(.66 + .39) × 2 × .06 = .126
2.764 × 52 = 143.73 m²

Handrail Posts (HP & EHP) 590 Required
.26 × 4 × .92 = .957 × 590 = 564.63 m²

Top rails (TR.ETR & EER) 644-Required
.52 × 1.30 = .676 × 644 = 435.34 m²

Summary of Forms 1,143.70 sq.meters

Reinforcements, Plain bars 7.6050 kg tons

Materials of Takada Bashi for Fukushima-ken

Mortar Finish 1:2 mixture

Post on pier 52-Required

(.74+.47)×2×1.15 = 2.78
.74 ×.47 = .35
3.13×52 = 162.76 m²

Handrail posts (HP & EHP) 590-Required

.26×4×.92 = .96
.26×.26 = .07
1.03×590 = 607.70 m²

Summary 770.46 sq. meters

Handrail grates (Structural steel)

HG 616-Required

2Ls	45×45×6	1.400 m @ 3.96	= 11.09	
8Ls	30×30×5	.508 @ 2.16	= 8.78	
			19.87×616	= 12239.92 kgs

EEG 4-Required

2Ls	45×45×6	1.510 m @ 3.96	= 11.96	
8Ls	30×30×5	.508 @ 2.16	= 8.78	
			20.74×4	= 82.96 kgs

EHG^R_L 24-Required

2Ls	45×45×6	1.480 @ 3.96	= 11.72	
8Ls	30×30×5	.508 @ 2.16	= 8.78	
			20.50×24	= 492.00 kgs

Rivet heads — say 150.00

Summary 12,829.88 kgs or 12.8299 kg tons

Expansion joints for top rails 28-Required (Brass casting)

weight of one piece 82.81 kgs
× 28
2318.7 kgs

Expansion joints for grates (Cast iron) 56-Required

weight of one piece 2.77 kgs
× 56
155.12 kgs or 0.1551 kg tons

親柱(一本分) see sheet no. 11

Concrete 1:2:4 mixture

	Section	length	req'd no.	Volume
Bottom	1.00×.99	1.27	1	1.26
"	.16×.29	.70	1	.03
"	.86×.41	.86	1	.30
middle	.74×.74	1.30	1	.71
Top	.44×.44	1.00	1	.19
				2.49 cub. meters

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CALCULATIONS FOR

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Materials of Takada Bashi for Fukushima ken

Forms

	width	length	req'd no.	area
Bottom	.99	4.54	1	4.49
〃	.41	.86	4	1.41
〃	.16	.29	2	.09
Middle	.74	1.30	4	3.85
Top	.54	1.00	4	2.16
				12.00 sq. meters

Reinforcements, plain bars .0599 Kg tons (see sheet no. 11)

人造洗出仕上

Same as forms 12.00
1.00 × 1.27 1.27
13.27 sq meters

Lamps 4-sets (Bronze)

Gas pipe & wiring 一式

Name plate (bronze) 1 sheet
Bronze plate showing date of completion 1 sheet

袖高欄（一箇所分） (See sheet no. 11.)
Concrete 1:2:4 mixture

	section	length	req'd no.	volume
Top rail	.20 × .14	1.20	1	.03
wall	.10 × .61	1.20	1	.07
less hole	.10 × .15	.20	3	-.01
Bottom rail	.20 × .14	1.20	1	.03
Post	.50 × .50	1.15	1	.29
				0.41 cub meters

Forms

	width	length	req'd	area
handrail	1.00	1.20	2	2.40
Post	.50	1.15	4	2.30
				4.70 sq. meters

Reinforcements, plain bars .0520 Kg tons (see sheet no. 11)

人造洗出仕上

Same as Forms 4.70
handrail .20 × 1.20 × 1 = .24
post .50 × .50 × 1 = .25
5.19 sq. meters

Columns with footing (See sheet no. 7.)
concrete, 1:2:4 mixture

Columns over piers P4 & P23 (各一基分以下全様)
Root 3.90 × 2.10 × 1.40 = 11.47
〃 $1.05^2 \times \pi \times 1.40$ = 4.85 } 15.48
〃 (less) 3 @ .25 × .30 × 1.40 = -.84
Columns 3 @ 1.10 × .80 × 4.455 = 11.76
27.24 m^3

Columns over Piers P5 & P22
Root 15.48
Columns 3 @ .80 × 1.10 × 4.556 = 12.03
27.51 m^3

Materials of Takada Bashi for Fukushima-Ken

Columns over piers P6 & P21
Root = 15.40
Columns 3 @ .80 × 1.10 × 4.645 = 12.26
27.74 m³

Columns over Piers P8 & P19
Root = 15.40
Columns 3 @ .80 × 1.10 × 4.790 = 12.65
28.13 m³

Columns over Piers P7 & P20
Root = 15.40
Columns 3 @ .80 × 1.10 × 4.723 = 12.47
27.95 m³

Columns over piers P9 & P18
Root = 15.40
Columns 3 @ .80 × 1.10 × 4.846 = 12.79
28.27 m³

Columns over Piers P10 & P17
Root = 15.48
Columns 3 @ .80 × 1.10 × 4.891 = 12.91
28.39 m³

Columns over Piers P12 & P15
Root = 15.40
Columns 3 @ .80 × 1.10 × 4.946 = 13.06
28.54 m³

Columns over Piers P11 & P16
Root = 15.48
Columns 3 @ .80 × 1.10 × 4.924 = 13.00
28.48 m³

Columns over Piers P13 & P14
Root = 15.48
Columns 3 @ .80 × 1.10 × 4.958 = 13.09
28.57 m³

Columns over Piers P24
Root = 15.48
Columns 3 @ .80 × 1.10 × 4.344 = 11.47
26.95 m³

Columns over Pier P26
Root = 15.40
Columns 3 @ .80 × 1.10 × 4.087 = 10.79
26.27 m³

Columns over Piers P25
Root = 15.40
Columns 3 @ .80 × 1.10 × 4.221 = 11.14
26.62 m³

Columns over Pier P2
Root = 25.08
Columns 3 @ .80 × 1.10 × 4.221 = 11.14
36.22 m³

Columns over Pier P1
Root = 15.40
" (1.20 + 2.00) × 1/2 × 1.00 × 5.2 = 8.32
" 1.40 × .30 × 1.00 × 2 = .84
" 1.50 × .25 × 1.10 = .41
" .15 × .18 × 1.00 = .03
} 25.08
Columns 3 @ .80 × 1.10 × 4.087 = 10.79
35.87 m³

Columns over Pier P3
Root = 25.08
Columns 3 @ .80 × 1.10 × 4.344 = 11.47
36.55 m³

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CALCULATIONS FOR

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Materials of Takada Bashi for Fukushima Ken

Summary of Concrete

Columns over Piers	P4 & P23	2 e	27.24	= 54.48 m³
〃 〃	P5 & P22	2 e	27.51	= 55.02
〃 〃	P6 & P21	2 e	27.74	= 55.48
〃 〃	P7 & P20	2 e	27.95	= 55.90
〃 〃	P8 & P19	2 e	28.13	= 56.26
〃 〃	P9 & P18	2 e	28.27	= 56.54
〃 〃	P10 & P17	2 e	28.39	= 56.78
〃 〃	P11 & P16	2 e	28.48	= 56.96
〃 〃	P12 & P15	2 e	28.54	= 57.08
〃 〃	P13 & P14	2 e	28.57	= 57.14
〃 〃	P24	1 e	26.95	= 26.95
〃 〃	P25	1 e	26.62	= 26.62
〃 〃	P26	1 e	26.27	= 26.27
〃 〃	P1	1 e	35.07	= 35.07
〃 〃	P2	1 e	36.22	= 36.22
〃 〃	P3	1 e	36.55	= 36.55
Center columns 長キ分	26 e .80 × 1.10 ×	.032		= .73

750.85 cub. meters

Forms

Columns over Piers	P4 & P23	3.80 × 4.455 × 3 × 2	= 101.57
〃 〃	P5 & P22	3.80 × 4.556 × 3 × 2	= 103.88
〃 〃	P6 & P21	3.80 × 4.645 × 3 × 2	= 105.91
〃 〃	P7 & P20	3.80 × 4.723 × 3 × 2	= 107.68
〃 〃	P8 & P19	3.80 × 4.790 × 3 × 2	= 109.21
〃 〃	P9 & P18	3.80 × 4.846 × 3 × 2	= 110.49
〃 〃	P10 & P17	3.80 × 4.891 × 3 × 2	= 111.51
〃 〃	P11 & P16	3.80 × 4.924 × 3 × 2	= 112.27
〃 〃	P12 & P15	3.80 × 4.946 × 3 × 2	= 112.77
〃 〃	P13 & P14	3.80 × 4.958 × 3 × 2	= 113.04
〃 〃	P24	3.80 × 4.344 × 3 × 1	= 49.52
〃 〃	P25	3.80 × 4.221 × 3 × 1	= 48.12
〃 〃	P26	3.80 × 4.087 × 3 × 1	= 46.59

〃 〃 P1 3.80 × 4.087 × 3 = 46.59
1.077 × (10.40 + 3.60) = 15.08 A
2.5 × 2 × 1.60 = 8.00 B
} = 69.67

〃 〃 P2 3.80 × 4.221 × 3 = 48.12
A = 15.08
B = 8.00
} = 71.20

〃 〃 P3 3.80 × 4.344 × 3 = 49.52
A = 15.08
B = 8.00
} = 72.60

Center column 長キ分 3.80 × .032 × 26 = 3.16

1449.19 sq. meters

Reinforcements Plain bars

Piers P4, 5, 6, 7, 20, 21, 22 & 23	8 e	48.588	= 388.704
〃 P8 to P19	12 e	49.799	= 597.588
〃 P24, 25, 26	3 e	47.295	= 141.885
〃 P1, 2, & 3	3 e	48.596	= 145.788

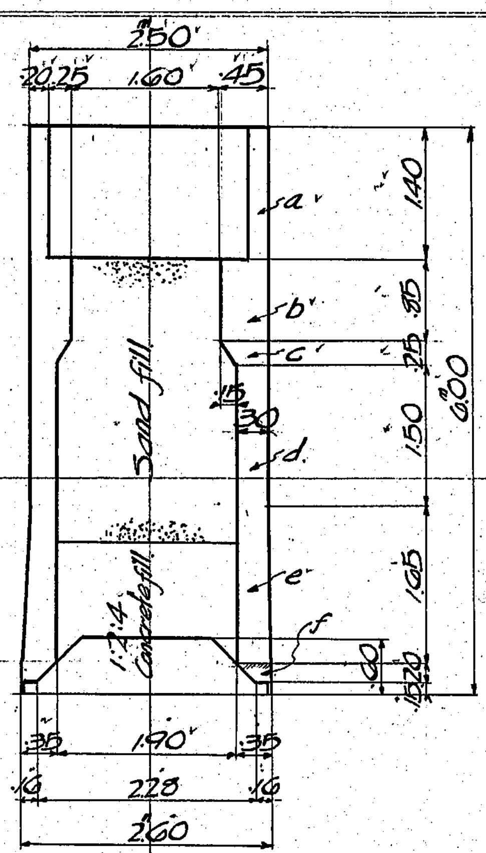
?

1273.965 Kg. tons

Materials of Takada Bashi for Fukushima-ken

Pier wells for P3 to P26

Shell concrete 1:2:4 mixture



a. 2.50 × 3.90 = 9.750 m²
1.25² × π = 4.909 } 14.659
less 2.10 × 3.90 = -8.190
" 1.05² × π = -3.464
.25 × .30 × 8 = .600
.3605 × 1.40 = .505 m³

b = 14.659
less 1.60 × 3.90 = -6.240
" .80² × π = -2.011
1.60 × .30 = .480
.6888 × .95 = .585 m³

c. = 14.659
less .875² × π = -2.405
" 1.75 × 3.90 = -6.825
1.75 × .30 = .525
.15 × .15 = .023
.5977 × .25 = .149 m³

d = 14.659
less 1.90 × 3.90 = -7.410
" .95² × π = -2.835
1.90 × .30 = .570
.15 × .15 × 2 = .045
.5029 × 1.50 = .754 m³

e 2.55 × 3.90 = 9.945
1.275² × π = 5.107
less 1.90 × 3.90 = -7.410
" .95² × π = -2.835
1.90 × .30 × 1.48/1.65 = .511
2 × .15 × .15 × " = .040
.5358 × 1.65 = .884 m³

f 2.60 × 3.90 = 10.140
1.30² × π = 5.309
less 2.25 × 3.90 = -8.775
" 1.125² × π = -3.976
.2698 × .20 = .54 m³

Summary of concrete for shell 2.931 cub. meters

Forms

outside	3.90 × 2 × 5.60 =	43.68
"	2.50 × π × 4.00 =	31.42
"	2.55 × π × 1.60 =	12.82
Inside a	3.90 × 2 × 1.40 =	10.92
" "	2.10 × π × 1.40 =	9.24
" "	.25 × 16 × 1.40 =	5.60
" (b+c)	3.60 × 2 × 1.10 =	7.92
" "	1.60 × π × 1.10 =	5.53
" "	1.60 × 2 × 1.10 =	3.52
" (d+e)	3.60 × 2 × 3.15 =	22.68
" "	1.90 × π × 3.15 =	18.80
" "	1.90 × 2 × 2.98 =	11.32
" f	3.90 × 2 × .26 =	2.03
" "	2.10 × π × .26 =	1.72
Bottom of Part. W.	.30 × 2.65 =	.80
" "	.15 × .15 × 2 =	.05

Summary 189.05 sq. meters

Reinforcements, Plain bars .20125 kg. tons

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MADE BY M.K DATE 6-1-24 FILE NO.

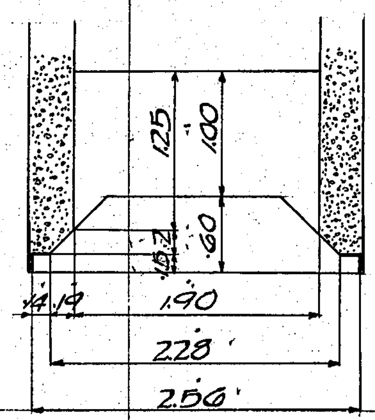
CALCULATIONS FOR

CHECKED BY F.Y & M.J DATE 6-1-26 PAGE NO 59

Materials of Takada Bashi for Fukushima-Ken

Fill
Concrete 1:2:4 mixture

1.90 × 3.90 × 1.25 = 9.26
.95² × π × 1.25 = 3.54
2.09 × 3.90 × .2 = 1.63
1.05² × π × .2 = .69
2.56 × 3.90 × .15 = 1.50
1.28² × π × .15 = .77
less part. w. 1.90 × .30 × 1.00 = -.57
" " (.3+.6) × ½ × .26 × .25 = -.03



Summary 16.79 cub. meters

Sand

1.60 × 3.90 × .85 = 5.30
.80² × π × .85 = 1.71
1.75 × 3.90 × .25 = 1.71
.88² × π × .25 = .61
1.90 × 3.90 × 1.90 = 14.08
.95² × π × 1.90 = 5.39
less part. w. .30 × 1.60 × 1.10 = -.53
" " .30 × 1.90 × 1.90 = -1.08
" " .15 × .15 × 2.03 × 2 = -.09

27.10 cub. meters

Curb shoe (Structural steel) 1.0199 Kg tons

Pier wells for P1 & P2 (一基分)
Shell concrete 1:2:4 mixture
P3 – P26 ト全一部分 29.31

2.60 × 3.90 = 10.140
1.30² × π = 5.309
less 1.90 × 3.90 = -7.410
" .95² × π = -2.835
1.90 × .30 = .570
.15 × .15 × 2 = .045

5.819 × 1.00 = 5.82

35.13 cub. meters

Forms
P3 ~ P26 ト全一部分 188.05

3.90 × 2 × 1.00 = 7.80
3.60 × 2 × 1.00 = 7.20
1.90 × π × 1.00 = 5.97
1.90 × 2 × 1.00 = 3.80
2.60 × π × 1.00 = 8.17

32.94

220.99 sq. meters

Reinforcements, Plain bars 2.3728 Kg. tons

Fill
Concrete 1:2:4 mixture
P3 to P26 ト全一 16.79 cub. meters

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MADE BY M.K. R.I DATE 6-1-28 **FILE NO** ______

CHECKED BY M.J & M.K DATE 6-1-29 **PAGE NO** 60

CALCULATIONS FOR

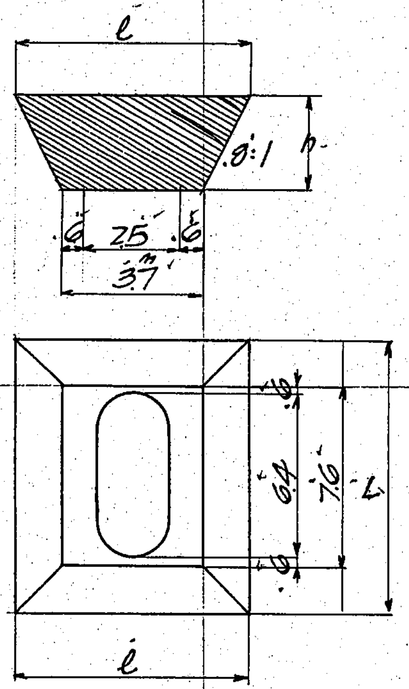
Materials of Takada Bashi for Fukushima Ken

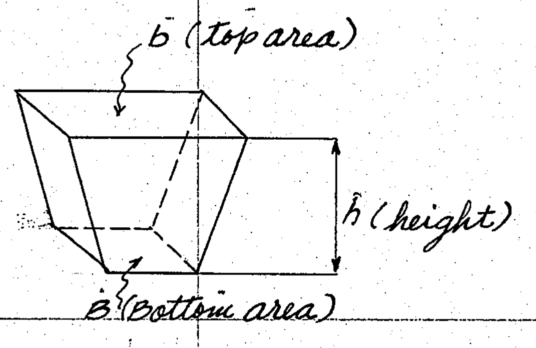
Fill sand

P3 to P26 ト全一部分	27.10	
1.90 × 3.90 × 1.00 = 7.41		
.95² × π × 1.00 = 2.84	9.63	
less .30 × 1.90 × 1.00 = -.57		
〃 .15 × .15 × 2 × 1.00 = -.05		
	36.73 cul meters	

curb shoe (Structural Steel) 1,0199 kg.tons

橋脚堀鑿





$$Volume = \frac{1}{3}h(B + b + \sqrt{Bb})$$

Pier no.	h (m)	l (m)	L (m)	$\frac{1}{3}h$ (m)	B (m²)	b	Bb	$\sqrt{Bb}$	B+b+$\sqrt{Bb}$ = A (m²)	$\frac{1}{3}h$(A) = Volume
P1 (水中)										
P2 (水中)										
P3	1.10	5.460	9.360	0.367	28.1200	51.11	1,437.21	37.91	117.14	43.0 cul.m.
P4	.87	5.092	8.992	0.290	〃	45.79	1,287.61	35.88	109.79	31.8
P5	.41	4.356	8.256	0.138	〃	35.92	1,011.00	31.81	95.85	13.0
P6	1.05	5.380	9.280	0.350	〃	49.93	1,404.03	37.47	115.52	40.4
P7	.36	4.276	8.176	0.120	〃	34.96	983.08	31.35	94.43	11.3
P8	.26	4.116	8.016	0.087	〃	32.99	927.68	30.46	91.57	8.0
P9	.46	4.436	8.336	0.153	〃	36.98	1,039.88	32.25	97.35	14.9
P10	.46	4.436	8.336	0.153	〃	36.98	1,039.88	32.25	97.35	14.9
P11	2.22	7.252	11.152	0.740	〃	80.87	2,274.06	47.69	156.68	115.9
P12	2.05	6.980	10.880	0.683	〃	75.94	2,135.43	46.21	150.27	102.6
P13	1.87	6.692	10.592	0.623	〃	70.88	1,993.15	44.64	143.64	89.6
P14	1.25	5.700	9.600	0.417	〃	54.72	1,538.73	39.23	122.07	50.9
P15	1.38	5.908	9.808	0.460	〃	57.95	1,629.55	40.37	126.44	58.2
P16	1.40	5.940	9.840	0.467	〃	58.45	1,643.61	40.54	127.11	59.4
P17	1.65	6.340	10.240	0.550	〃	64.92	1,825.55	42.73	135.77	74.6
P18	1.67	6.372	10.272	0.557	〃	65.45	1,840.45	42.90	136.47	76.0
P19	1.75	6.500	10.400	0.583	〃	67.60	1,900.91	43.60	139.32	81.2
P20	2.20	7.220	11.120	0.733	〃	80.29	2,257.75	47.52	155.93	114.3
P21	2.24	7.284	11.184	0.747	〃	81.46	2,290.66	47.86	157.44	117.5
P22	2.07	7.012	10.912	0.690	〃	76.51	2,151.46	46.38	151.01	104.2
P23	2.11	7.076	10.976	0.703	〃	77.67	2,184.08	46.73	152.52	107.2
P24	.91	5.156	9.056	0.303	〃	46.69	1,312.92	36.23	111.04	33.5
P25	1.58	6.228	10.128	0.527	〃	63.08	1,773.81	42.12	133.32	70.2
P26	2.26	7.316	11.216	0.753	〃	82.06	2,307.53	48.04	158.22	119.1
									Summary	1,551.7 cul meters

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MADE BY *M. Jinda* DATE *6-1-26* FILE NO ____

CHECKED BY *J. Matano* DATE *6-1-27* PAGE NO *61*

CALCULATIONS FOR

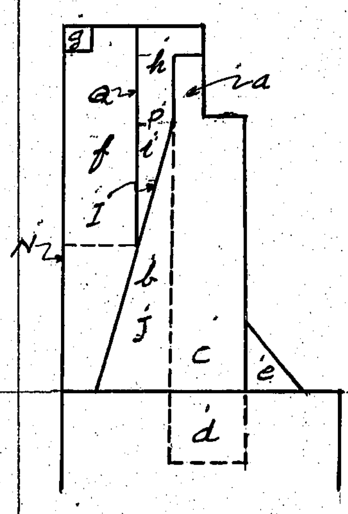
Materials of Takada Bashi for Fukushima Ken

Materials of abutments (see sheet no. 9)

Shaft (Common to both abutments)

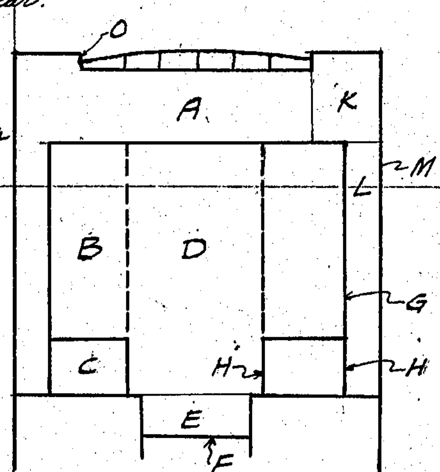
Concrete 1:3:6 mixture

Parapet	1 @	.40 × 1.11 × 5.50	=	2.44	a
Body	2 @	$\frac{1.10+2.50}{2}$ × 2.00 × 4.239	=	30.52	b
Curtain wall	1 @	1.10 × 3.30 × 4.239	=	15.39	c
〃 〃	1 @	1.10 × 1.20 × 2.50	=	3.30	d
Body	2 @	$\frac{1.00}{2}$ × 1.00 × 2.00	=	2.00	e
Wing	2 @	.40 × 2.70 × 5.689	=	12.29	f
Projection	2 @	.10 × .38 × .50	=	0.04	g
Column	2 @	.90 × 1.00 × 1.45	=	2.61	h
〃	2 @	.60 × .90 × .92	=	.99	i
				69.58	



Forms

Parapet	2 @	1.11	× 5.50	=	12.21	A front & rear.
Body front	2 @	2.00	× 3.239	=	12.96	B
〃 〃	2 @	1.41	× 2.00	=	5.64	C
Curtain wall	2 @	3.30	× 4.239	=	27.98	D front & rear
〃 〃	2 @	1.20	× 2.50	=	6.00	E
〃 〃	1 @	1.10	× 2.50	=	2.75	F Bottom
Body side	2 @	.70	× 4.239	=	5.93	G
〃 〃	4 @	½ × 1.00	× 1.00	=	2.00	H
Body rear	2 @	2.00	× 4.35	=	17.40	B
Less	2 @	.90	× 1.94	=	(−) 3.49	I (上図)
Body rear	2 @	½ × 1.40	× 4.239	=	5.93	J side (〃)
Column	2 @	1.30	× 1.45	=	3.67	K Front
〃	2 @	.40	× 4.239	=	3.39	L 〃
Wing	2 @	2.70	× 5.689	=	30.72	M side
〃	2 @	.40	× 5.689	=	4.55	N rear
column	2 @	.34	× 1.00	=	.68	O inside
〃	2 @	.60	× 2.00	=	2.40	P 〃 (上図)
〃	2 @	.90	× 3.23	=	5.81	Q rear (〃)
hollow	3 @	.60	× .30	=	.54	
〃	3 @	.20	× .20	=	.12	
Wing	2 @	.10	× 1.26	=	.25	depression
	2 @	1.70	× 3.30	=	11.22	
	2 @	$\frac{.9+1.7}{2}$	× 2.389	=	6.21	
					164.87 sq.m.	



踏掛石	6 -	.23 × .30 × .915	=	.379 cub.m.

人造洗出仕上

Front	2 @	1.30	× 1.41	=	3.67
〃	2 @	.40	1.40	=	1.12
Wing	2 @	$\frac{.50+2.80}{2}$	× 2.70	=	8.91
inside	2 @	.16	× 4.10	=	1.31
					15.01 sq.m.

Reinforcements plain bars 2.0980 kg tons

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MADE BY M. Jinda DATE 6-1-26 FILE NO ______
CHECKED BY J. Matano DATE 6-1-27 PAGE NO 62

CALCULATIONS FOR

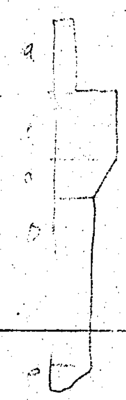
Materials of Takada Bashi for Fukushima Ken

Materials of well (see sheet no. 9)
For 6.00 meters well 一個当り (for Abutment A1) 右岸
Concrete 1:2:4 mixture
Shell

shell	2 @	.40 × 5.50 × 5.74	=	25.26
〃	2 @	.40 × 2.00 × 5.74	=	9.18
fillets	4 @	.25 × .25 × 5.20	=	1.30
Partition	1 @	.30 × 2.00 × 5.40	=	3.24
〃	1 @	.15 × .15 × .30	=	0.01
				38.99 cub.m.

Filling
Bottom filling 1:2:4 mixture (1.20 meters)

Filling	1 @	.15 × 2.76 × 5.46	=	2.26
〃	1 @	.30 × 2.29 × 4.99	=	3.43
〃	1 @	.75 × 2.00 × 4.70	=	7.05
less	1 @	.30 × .60 × 2.00	=	− .36
〃	1 @	.15 × .15 × .30	=	− .01
〃	4 @	.25 × .25 × .40	=	− .10
				12.27 cub.m.



Middle filling 1:4:8 mixture (3.30 meters)

Filling	2 @	2.00 × 2.20 × 3.30	=	29.04
less	4 @	.25 × .25 × 3.30	=	− .83
				28.21 cub.m.

Top filling 1:3:6 mixture (1.50 meters)

Filling	2 @	2.00 × 2.20 × 1.50	=	13.20
less	4 @	.25 × .25 × 1.50	=	− .38
				12.82 cub.m.

Forms

outside	2 @	5.50 × 5.60	=	61.60
〃	2 @	2.80 × 5.60	=	31.36
inside	2 @	6.40 × 5.10	=	65.28
〃	2 @	.30 × 8.40	=	5.04
Bottom	1 @	.57 × 13.40	=	7.64
〃 part.	1 @	.22 × 2.00	=	.44
fillet	8 @	.35 × 5.10	=	14.28
				185.64 sq.m.

Curb shoe (structural steel) 2 @ 1.0505 = 2.1010 Kg tons
Reinforcement plain bars 1.7044 Kg tons

Materials of Well
For 4.00 meters well 一個当り (for abutment A2) 左岸
Concrete 1:2:4 mixture
Shell

Shell	2 @	.40 × 3.74 × 5.50	=	16.46
〃	2 @	.40 × 2.00 × 3.74	=	5.98
fillets	4 @	.25 × .25 × 3.20	=	.80
Partition	1 @	.30 × 2.00 × 3.40	=	2.04
〃	1 @	.15 × .15 × .30	=	.01
				25.29 cub.m.

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MADE BY M.J. & K.I. DATE 6-1-27 FILE NO ______

CHECKED BY I.M. & J.M. DATE 6-1-27 PAGE NO 63

CALCULATIONS FOR

Materials of Takada Bashi for Fukushima ken

Filling

Bottom filling 1 : 2 : 4 mixture (1.20 meters)

Same as 6.00 meters well = 12.27 cub.m.

Middle filling 1 : 4 : 8 mixture (1.30 meters)

filling	2 @	2.00 × 2.20 × 1.30	= 11.44
less	4 @	.25 × .25 × 1.30	= − .33
			11.11 cub.m

Top filling 1 : 3 : 6 mixture (1.50 meters)

Same as 6.00 meters well = 12.82 cub.m

Forms

same as 6.00 meters well			= 185.64
less	1 @	2.00 × 16.60	= − 33.20
"	2 @	2.00 × 6.40	= − 25.60
"	8 @	.35 × 2.00	= − 5.60
			121.24 sq.m

Reinforcements plain bars 0.9863 kg tons

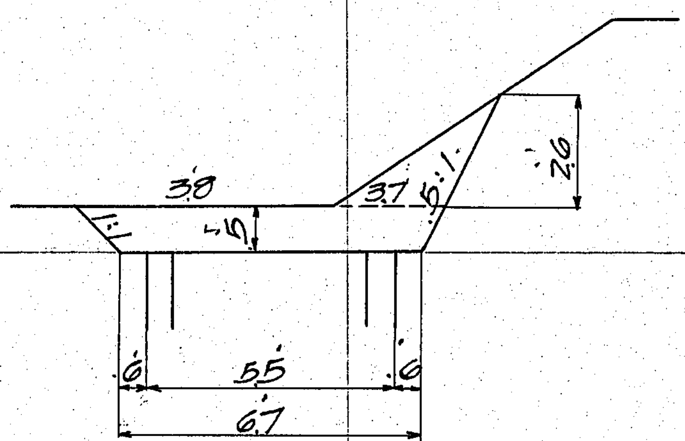
curb shoe (structural steel) 2 @ 1.0505 = 2.1010 kg tons

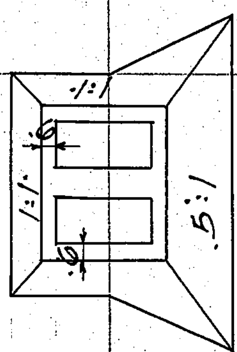
Excavation for Abutment A1. 右岸

$\frac{7.5}{\frac{6.7}{14.2}} \div 2 = 7.10^{m} \times .5 \times 9.8$ (8.1+1.2+.5 =) = 34.8

$\frac{3.7 \times 2.6}{2} = 4.81 \times 11.2$ = 53.8

88.6 cub.m



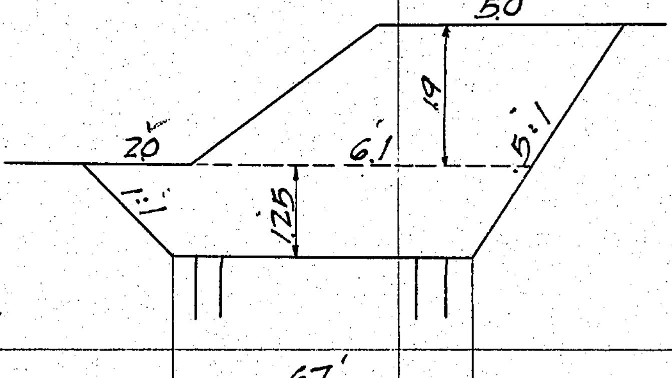


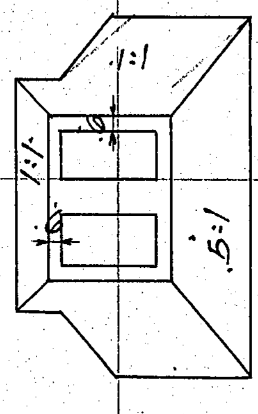
Excavation for Abutment A2. 左岸

$\frac{8.1}{\frac{6.7}{14.8}} \div 2 = 7.4 \times 1.25 \times 10.55$ = 97.6

$\frac{5.0}{\frac{6.1}{11.1}} \div 2 = 5.55 \times 1.90 \times 12.30$ = 129.7

227.3 cub.m.





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MADE BY I. M. DATE 6-1-15 FILE NO

CHECKED BY R. I DATE 6-1-17 PAGE NO 64

CALCULATIONS FOR

Material list of Takada Bashi for Fukushima-Ken.

TRUSSES T1 6 Req'd.

Top chords	2	L	150 × 100 × 9	2,530	17.000	86.02
Bottom chords	2	,	,	2,635	,	89.59
Verticals	4	,	100 × 75 × 10	1,040	13.000	54.08
,	2	,	75 × 75 × 9	1,040	9.960	20.72
Diagonals	2	,	,	1,100	,	21.91
Gusset-Pls.	1	Pl.	225 × 9	390	15.896	6.20
,	2	Pls.	220 × 9	225	15.543	6.99
,	1	Pl.	145 × 9	225	10.244	2.30
,	1	,	255 × 9	390	18.016	7.03
,	1	,	225 × 9	370	15.896	5.88
Filler	1	Fill	150 × 9	150	10.598	1.59
,	2	Fills.	100 × 6	390	4.710	3.67
,	2	,	70 × 6	220	3.297	1.45
,	2	,	,	370	,	2.44
						309.87 × 6 = 1,859.22

T2 81 Req'd.

Top chords.	2	L	150 × 100 × 9	10,130	17.000	344.42
Bottom ,	2	,	,	9,850	,	334.90
Verticals	2	,	75 × 75 × 9	1,040	9.960	20.72
,	2	,	100 × 75 × 10	1,040	13.000	27.04
Diagonals	12	,	75 × 75 × 9	1,070	9.960	127.89
Splice	8	,	150 × 100 × 9	650	17.000	88.40
,	2	Fills	70 × 9	600	4.946	5.94
,	2	,	70 × 21	600	11.540	13.85
Gusset Pls	2	Pls.	225 × 9	370	15.896	11.76
,	8	,	220 × 9	370	15.543	46.01
,	2	,	145 × 9	225	10.244	4.61
,	1	Pl.	160 × 9	225	11.304	2.54
,	1	,	225 × 9	460	15.896	7.31
Fillers	8	Fills.	70 × 6	370	3.247	9.76
,	4		,	145	,	1.91
,	2	,	,	460	,	3.03
,	4	Washers	70φ × 9		@ 0.27	1.08
,	4	,	70φ × 21		@ 0.63	2.52
						1053.69 × 81 = 85,348.89

T3 42 Req'd.

Top chords.	2	L	150 × 100 × 9	9,070	17.000	308.38
Bottom ,	2	,	,	9,650	,	328.10
Verticals.	4	,	75 × 75 × 9	1,040	9.960	41.43
,	2	,	,	1,160	,	23.11
,	4	L	100 × 75 × 10	1,640	13.000	85.28
Diagonals.	4	,	75 × 75 × 9	1,070	9.960	42.63
,	2	,	,	1,175	,	23.41
,	2	,	,	1,470	,	29.28
Gusset Pls.	4	Pls	145 × 9	225	10.244	9.22
,	2	,	220 × 9	370	15.543	11.50
,	2	,	230 × 9	380	16.250	12.35
,	2	,	225 × 9	230	15.896	7.31
,	2	,	290 × 9	320	20.489	13.11
,	1	Pl.	255 × 9	610	18.016	10.99
,	1	,	285 × 9	610	20.135	12.28
,	2	,	225 × 9	370	15.896	11.76

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MADE BY I. M. DATE 6-1-15 FILE NO

CHECKED BY R. I DATE 6-1-17 PAGE NO 65

CALCULATIONS FOR

Material list of Takada Bashi for Fukushima-Ken

Fillers	4	Fills.	70 × 6	370	32.970	4.88
,	4	,	,	380	,	5.01
,	4	,	,	330	,	4.35
,	4	Washers.	70ᶲ × 21		0.630	2.52
Bearing	1	Pl.	280 × 25	338	54.950	18.57
Fillers	2	Fills	95 × 9	150	6.712	2.01
,	1	,	150 × 9	150	10.598	1.59
,	2	,	200 × 6	610	9.420	11.49
						1020.56 × 42 = 42,863.52

T4 36 Req'd.

Top chords	2	Ls	150 × 100 × 9	2.530	17.000	86.02
Bottom ,	1	L	,	2.640	,	44.88
,	1	,	,	2.150	,	36.55
Vertical	2	,	75 × 75 × 9	1.040	9.960	20.72
Diagonal	1	,	,	1.070	,	10.66
Gussets & Fillers	1	Pl.	145 × 9	225	10.244	2.30
,	1	,	220 × 9	370	15.543	5.75
,	2	Fills	70 × 6	370	3.297	2.44
,	1	Pl.	350 × 9	350	24.728	8.65
,	2	Fills.	130 × 6	350	6.123	4.29
,	1	,	70 × 9	150	4.946	0.74
For Bearing	6	Ls	100 × 75 × 10	460	13.000	35.88
For Bearing	2	Fills.	225 × 9	275	15.896	8.74
For Bearing	1	Pl.	480 × 9	1.435	33.912	48.66
For Bearing	1	L	150 × 150 × 12	1.285	27.100	34.82
For Bearing	1	,	,	560	,	15.18
	1	,	75 × 75 × 9	690	9.960	6.87
	2	Ls	,	540	,	10.76
	1	Pl.	205 × 9	205	14.483	2.97
	2	Ls	100 × 75 × 10	150	13.000	3.90
	1	Pl.	150 × 9	210	10.598	2.23
						393.01 × 36 = 14,148.36

T5 36 Req'd.

Top chords	1	L	150 × 100 × 9	6.945	17.000	118.07
,	1	,	,	6.545	,	111.27
Bottom ,	2	Ls	,	7.370	,	250.58
Verticals	1	,	75 × 75 × 9	1.180	9.960	11.75
,	4	,	100 × 75 × 10	1.640	13.000	85.28
,	2	,	75 × 75 × 9	1.040	9.960	20.72
,	1	L	,	1.160	,	11.55
Diagonals	2	Ls	,	1.070	,	21.31
,	1	L	,	1.175	,	11.70
,	2	Ls	,	1.470	,	29.28
Gussets Pls.	2	Pls.	145 × 9	225	10.244	4.61
	1	,	220 × 9	370	15.543	5.75
	1	Pl.	230 × 9	380	16.250	6.18
	1	,	225 × 9	230	15.896	3.66
	1	,	290 × 9	320	20.489	6.56
	1	,	255 × 9	610	18.016	10.99
	1	"	285 × 9	610	20.135	12.28
	1	"	340 × 9	340	24.021	8.17
	2	Fills	200 × 6	610	9.420	11.49
	1	Pl.	225 × 9	370	15.896	5.88

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CALCULATIONS FOR

Material list of Takada Bashi for Fukushima-Ken

Filler	2	Fills.	70 x 6	370	3.297	2.44
"	2	"	"	380	"	2.51
"	2	"	"	330	"	2.18
"	2	"	95 x 9	150	6.712	2.01
"	1	"	150 x 9	150	10.598	1.59
"	3	Washers	70φ x 21		@ 0.630	1.89
"	1	Fill.	70 x 9	150	4.946	0.74
"	2	"	140 x 6	1,400	6.594	18.46
For Bearing	6	Ls	100 x 75 x 10	470	13.000	36.66
For Bearing	2	Fills	225 x 9	275	15.896	8.74
For Bearing	1	Pl.	640 x 9	1,440	45.216	65.11
For Bearing	1	L	150 x 150 x 12	1,125	27.100	30.49
For Bearing	1	"	"	490	"	13.28
	2	Ls	125 x 75 x 9	550	13.500	14.85
	1	L	75 x 75 x 9	545	9.960	5.43
	1	"	"	450	"	4.48
	1	Pl.	205 x 9	205	14.483	2.97
	1	L	100 x 75 x 10	210	13.000	2.73
	1	Pl.	180 x 9	240	12.717	3.05
Bearing	1	"	280 x 25	338	54.950	18.57
						985.26 x 36 = 35,469.36

EDGE PLATE OF CONCRETE (AT HINGE) 36 Reqd.

a	1	Pl.	230 x 8	490	14.440	7.08
a	2	Ls	75 x 50 x 6	255	5.610	2.86
a	2	"	50 x 50 x 6	255	4.430	2.26
b	1	Pl.	260 x 8	490	16.328	8.00
b	2	Ls	75 x 50 x 6	260	5.610	2.92
b	2	"	50 x 50 x 6	260	4.430	2.30
c	1	Pl.	490 x 8	560	30.772	17.23
c	2	Ls	75 x 50 x 6	560	5.610	6.28
c	2	"	50 x 50 x 6	560	4.430	4.96
d	1	Pl.	490 x 8	530	30.772	16.31
d	2	Ls	75 x 50 x 6	555	5.610	6.23
d	2	"	50 x 50 x 6	555	4.430	4.92
Bolts	20	Bolts	9φ x 25		@ 0.041	0.80
						82.15 x 36 = 2,957.40

Summary for Trusses 182,626.75 kgs

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CALCULATIONS FOR

Material list of Takada-Bashi for Fukushima-Ken

		STRUTS ST1 ℝ 4 Req'd.			
1 L	90 × 90 × 10	2.120	13.300	28.20	
2 Pls	170 × 9	330	12.011	7.93	
				36.13	× 4 = 144.52
		ST2 ℝ 100 Req'd.			
1 L	90 × 90 × 10	2.120	13.300	28.20	
2 Pls	170 × 9	170	12.011	4.08	
				32.28	× 100 = 3228.00
		ST3 ℝ 52 Req'd.			
1 L	90 × 90 × 10	2.120	13.300	28.20	
2 Pls	270 × 9	270	19.076	10.30	
				38.50	× 52 = 2,002.00
		ST4 ℝ 27 Req'd.			
2 Ls	90 × 90 × 10	2.120	13.300	56.39	
2 Pls.	320 × 9	330	22.608	14.92	
1 Pl.	330 × 9	420	23.315	9.79	
				81.10	× 27 = 2189.70
		Summary for struts	7.564.22 kgs		
		BEARING CS2 (at hinge) 36 Req'd.			
Top Pl. 1 Pl.	470 × 20	600	73.790	44.27	
〃 1 〃	320 × 25	390	62.800	24.49	
CB1 4 Bolts	25φ × 90		@ 0.500	2.00	
CB2 4 〃	25φ × 70		@ 0.420	1.68	
Cast steel bed Pl. 1	Cast steel		@ 61.000	61.00	
				133.44	× 36 = 4803.84
		BED PLATE ON PIER 78 Req'd.			
Bed Pl. 1 Pl.	400 × 19	400	59.660	23.86	
2 Pls	30 × 22	400	5.181	4.14	
2 Ls	75 × 75 × 9	240	9.960	4.78	
				32.78	× 78 = 2,556.84
		CAST STEEL BEARING CS1 (on abutment) 6 Req'd.			
Top Casting 1 cast steel Pl.			@ 42.000	42.00	
Bottom 〃 1 Cast steel bearing			@ 110.000	110.00	
1 Pl.	440 × 8	600	27.632	16.58	
2 Ls	50 × 50 × 8	440	5.770	5.08	
2 〃	〃	340	〃	3.92	
Anchor bolts 4 Bolts	25φ with one nut	500	@ 2.300	9.20	
1 L	50 × 50 × 8	600	5.770	3.46	
				190.24	× 6 = 1,141.44

summary for bearing (include casting) 8,502.12 kgs

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CALCULATIONS FOR

Material list of Takada Bashi for Fukushima-Ken

EXPANSION JOINT EJ1 2 Reqd.

Web Pl.	1	Pl.	225 × 9	5,700	15.896	90.61
	1	L	100 × 75 × 10	5,560	13.000	72.28
	1	L	75 × 75 × 9	5,700	9.960	56.77
Stiffeners	2	Ls	90 × 75 × 9	160	11.000	3.52
〃	2	〃	〃	175	〃	3.85
〃	2	〃	〃	190	〃	4.18
〃	2	〃	〃	200	〃	4.40
	3	Pls	75 × 9	280	5.299	4.45
	3	Is	150×125 @36.22 kgs	300		32.60
Anchor bolt	7	Bolts	12φ × 350		@ 0.380	2.66
	7	Washers	70 × 3	70	1.649	0.81
据付用ボールト	6	Bolts	12φ × 50		@ 0.110	0.66
I Beam 締付用	6	Beveled washers	50 × 9	50	@ 0.150	0.90
						277.69 × 2 = 555.38

EJ2 2 Reqd.

	1	checkered Pl.	200 × 9	5,540	15.900	88.09
	1	L	75 × 75 × 9	5,500	9.960	54.78
	3	Ls	150 × 90 × 9	310	16.300	15.16
	2	Pls.	130 × 8	1,830	8.164	29.88
Anchor pl.	4	Bars	70 × 9	320	4.946	6.33
取付用	6	Bolts.	19φ × 60		@ 0.330	1.98
						190.22 × 2 = 392.44

EJ3 12 Reqd.

	1	Bar	50 × 10	5,540	3.925	21.74
	1	L	125 × 75 × 9	5,560	13.500	75.06
	3	Ls	150 × 90 × 9	310	16.300	15.16
	2	Pls.	130 × 8	1,830	8.164	29.88
Anchor pl.	4	Bars	70 × 9	320	4.946	6.33
取付用	6	Bolts	19φ × 60		@ 0.330	1.98
						150.15 × 12 = 1,801.80

EJ4 12 Reqd.

	1	checkered Pl.	190 × 9	5,540	15.100	83.65
	1	L	75 × 75 × 9	5,500	9.960	54.78
	3	〃	150 × 90 × 9	310	16.300	15.16
	2	Pls.	130 × 8	1,830	8.164	29.88
Anchor pl.	4	Bars	70 × 9	320	4.946	6.33
取付用	6	Bolts.	19φ × 60		@ 0.330	1.98
						191.78 × 12 = 2,301.36

Summary for Expansion joints 5,050.98 kgs

RIVET HEADS

Shop rivets	24	22φ.	@ 0.09639	2.31
〃	55,390	19φ.	〃 0.06464	3,580.41
〃	3,900	12φ.	〃 0.02040	79.56
Field rivets	24,590	19φ.	〃 0.06464	1,589.50
				5,251.78 kgs

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CALCULATIONS FOR

Material list of Takada-Bashi for Fukushima-Ken.

Grand summary for structural steel

Summary for Trusses ✓	182,646.75 Kgs ✓	
〃 〃 Struts ✓	7.564.22 ✓	
〃 〃 Bearings ✓	8.502.12	(include castings).
〃 〃 Expansion joints ✓	5.050.98 ✓	
	203.764.07 ✓	
〃 〃 Rivet heads ✓	5.251.78 ✓	
	209.015.85 ✓	or 209.0159 Kgtons. ✓

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CALCULATIONS FOR
Preliminary Design of
Takada Bashi for Fukushima Ken.

Total length c to c dykes 521.98 m
2 @ 3.59 = 7.18

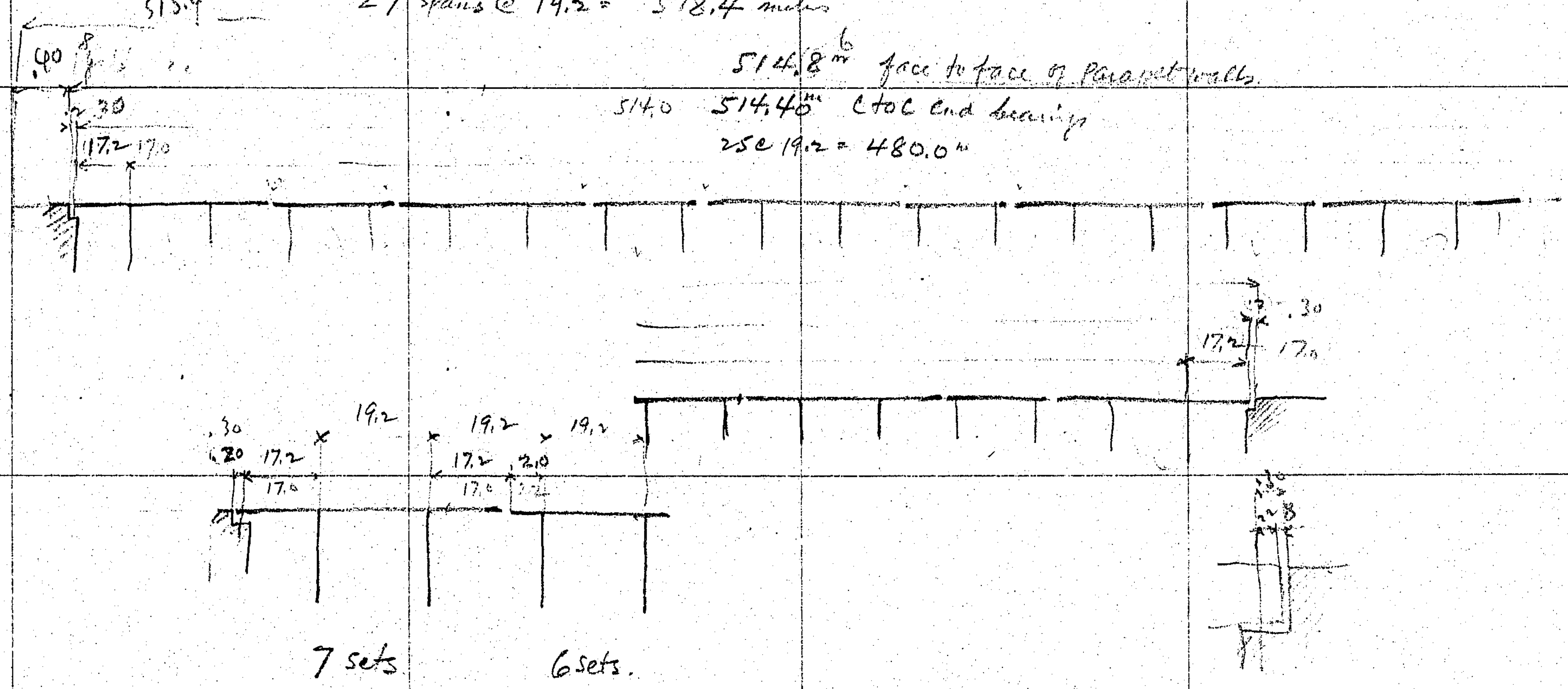
514.8 face to face of parapet walls.
.4
514.4 c to c end bearings.

2 @ 25

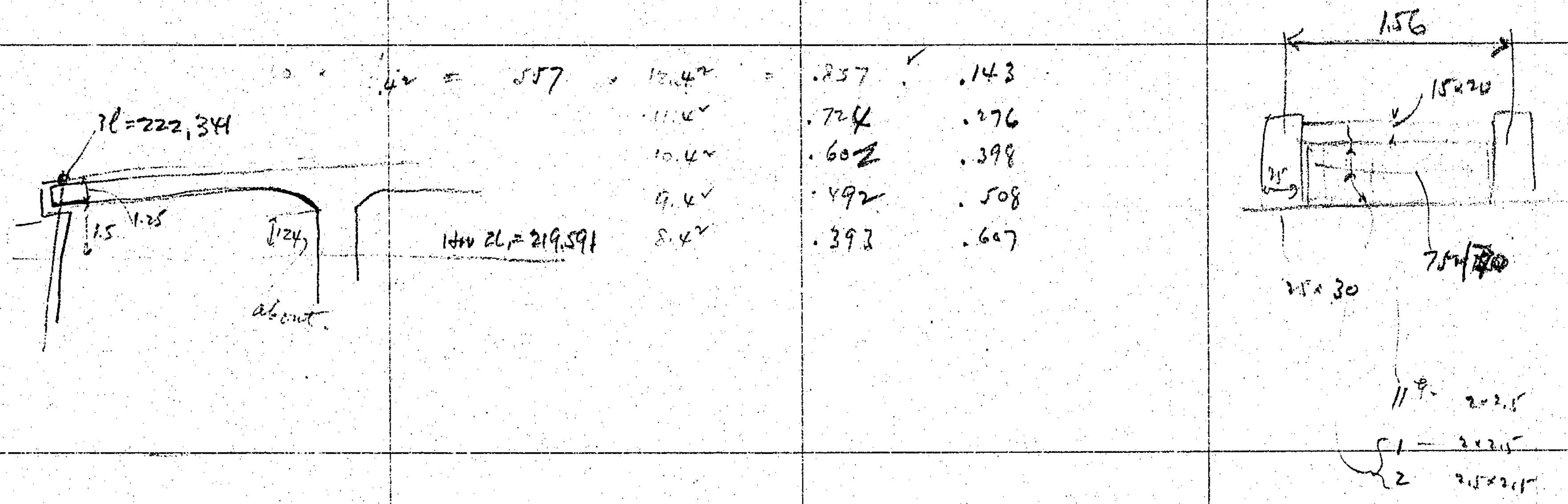
2 cantilever arms 2 @ 2.0 = 4.0
518.4 m

515.4 — 27 spans @ 19.2 = 518.4 meters

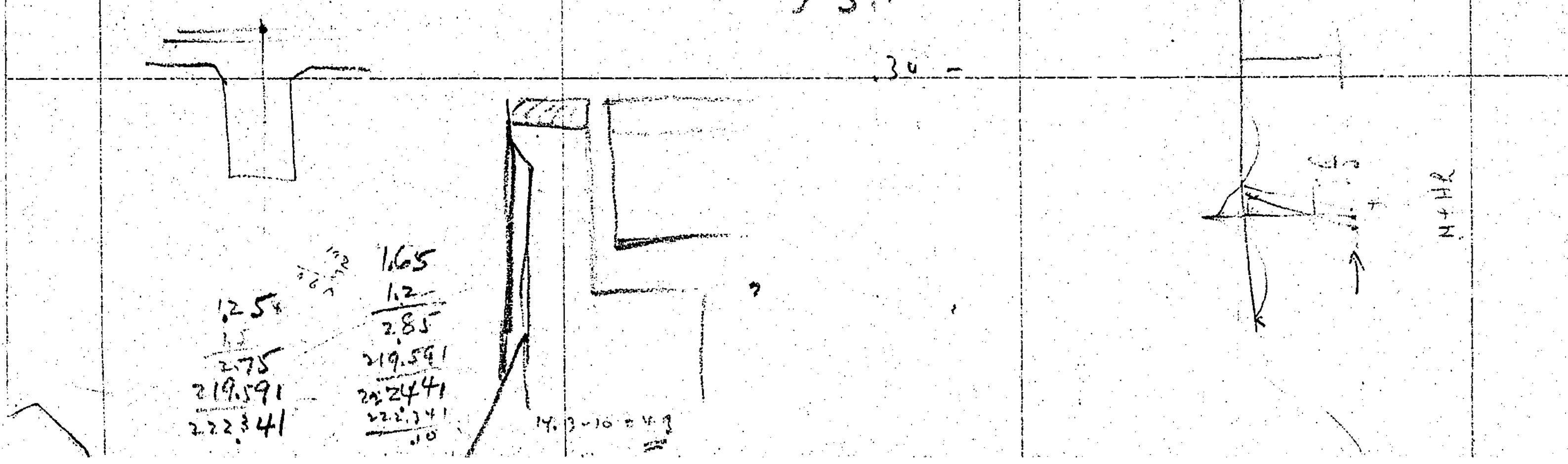
514.8(6) m face to face of parapet walls.
514.0 514.40 m c to c end bearings
25 @ 19.2 = 480.0 m



.42 = .557 10.4² = .837 .143
11.4² .724 .276
10.4² .602 .398
9.4² .492 .508
8.4² .393 .607



+20 25 @ 19.2 = 480.00
2 @ 16.95 = 33.90
2 @ .30 .60
between parapet faces 514.50
515.1



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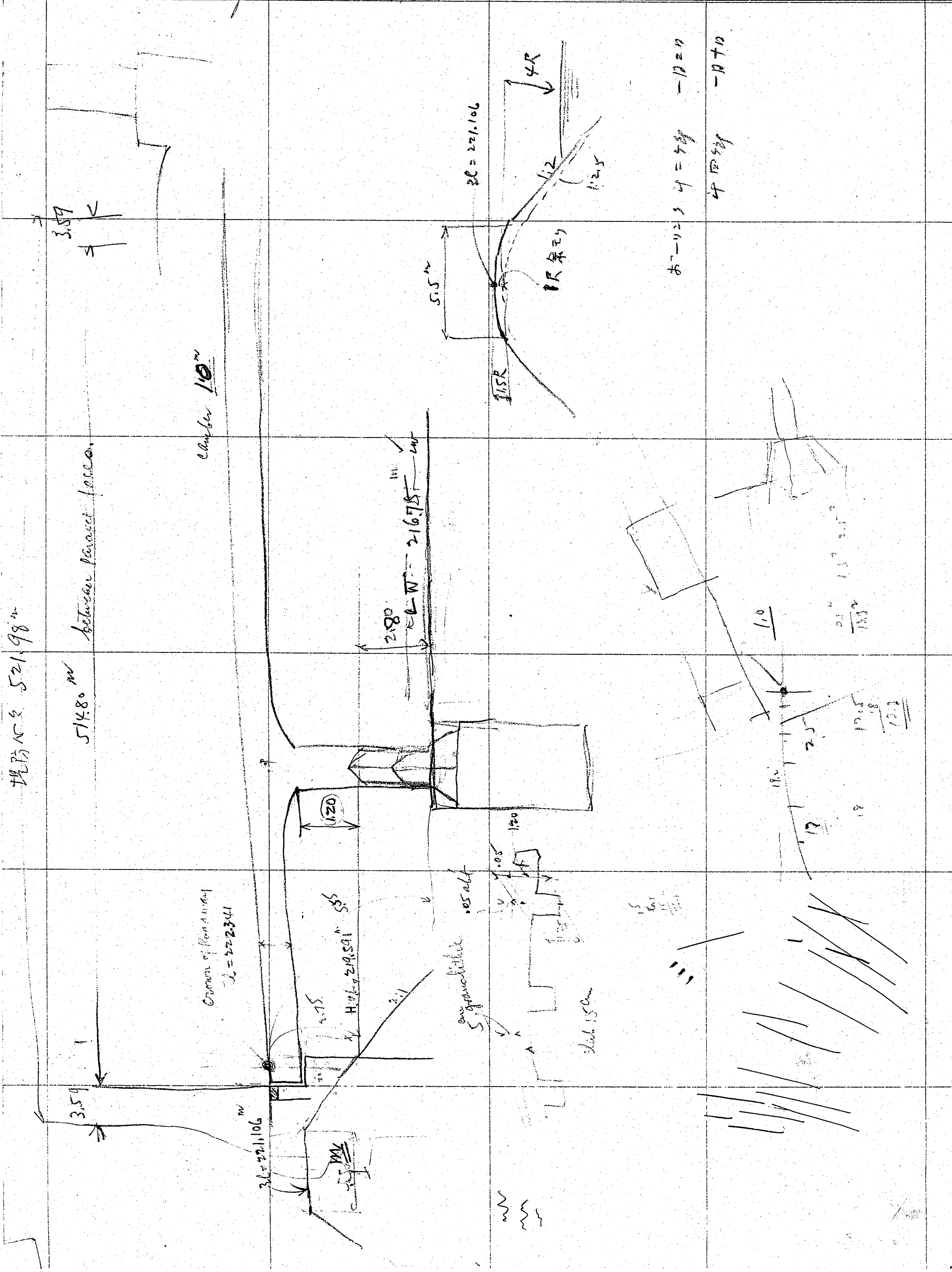
CALCULATIONS FOR Preliminary Design of Sakada Bashi for Fukushima Ken



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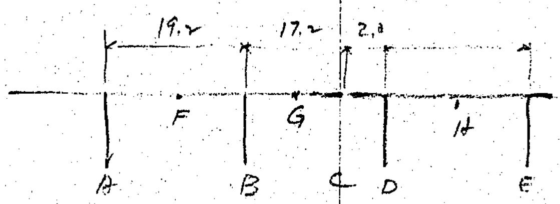
CALCULATIONS FOR

Takada Bashi

Dead Load.

floor slab	18cm @ 24 =	432
pavement	5 @ 21 =	105
	misc say	13
		550 kg/m²

slab + pavement	5.5 @ 550 =	3026
Copings	2·.35·.30·2400	504
handrails	2@240 =	480
		4,010
beam web	.6·1.0·3 = 1.8 @2400 =	4320
filler misc say	.3·.1·6 = .18 @ 2400 =	430
		4750
		8,760 kg call this 8800 kg/lin m.



Dead Load moment

point F	1/12·8800 × 19.2² =	270000 kgm
A+B	1/10·8800 × 19.2² =	324000 "
G.	1/10 × 8800 × 17.2² =	260000 "
D.	2nd concentration 8800 × 17.2 × 3/8 = 56800 kg.	
	56800 × 2.0 =	113600
	8800/2 × 2.0² =	17600
		−131,200 kgm
H.	1/8 × 8800 × 19.2² =	405000
		−131200
		273800 kgm.

Live Load 5.5 @ 550 = 3030 call this 3100 kg/m including concentration.

F.	1/10 × 3100 × 19.2² =	114,200 kgm
A+B	1/10 × 3100 × 19.2² =	114200 "
G.	1/10 × 3100 × 17.2² =	91,800 "
D.	2nd conc. 3100 × 17.2 × 3/8 = 20000 kg	
	20,000 × 2.0 =	−40000
	3100 × 2.0² / 2 =	−6100
		−46,100 kgm.
H.	1/10 × 3100 × 19.2² =	114,200 kgm

Summary for moments. Points

	F.	A+B.	G	D	H
D.L.	270000	−324000	260000	−131,200	273,800
L.L.	114200	−114200	91800	−46100	114200
	384200	−438,200	351,800	−177300	388,000
÷3	128,000	−146,000	117,000	−59,000	129,500

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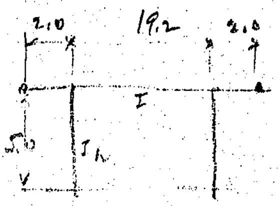
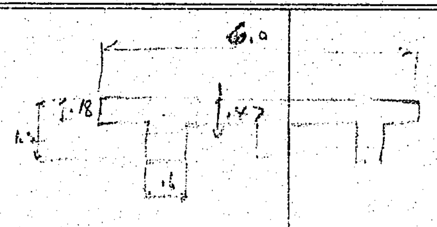
CALCULATIONS FOR

Takada Br. P.

check



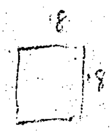


.18×6.0 = 1.08 × .09 = .097
.6×1.0×3 = 1.8 × .68 = 1.350
2.88 .47 1.347

I: $\frac{6.0\times .18^3}{12} + 1.08\times .38^2 = .00292 + 0.156 = 0.1589$

$\frac{1.8\times 1.0^3}{12} + 1.8\times .23^2 = .150 + .095 = 0.245$

$I = 0.404$



I_h: $\frac{.8\times .8^3}{12}\times 3 = 0.103$ (stiff = .12)

$v = \frac{I\,h}{I_h\,l} = \frac{0.404\times 5.0}{0.12\times 19.2} = 0.87$

$2+3v = 4.61$
$v+2 = 2.87$
$6v+1 = 6.21$

H.

D.L. 8800. full load.

$m = \frac{8800\times 19.2^2}{24}\times\frac{4.61}{2.87} - \frac{3\times 8800\times 2.0^2}{6.21}$

$= 217{,}200 - 17{,}000 = 200{,}200$ kgm

conc. load $56800\times 2.0\times\frac{.87}{2.87} = -34{,}400$

$+165{,}800$ kgm.

L.L. $m = \frac{3100\times 19.2^2}{24}\times\frac{4.61}{2.87} = 76500$

165800

D + L $m = 242300$ kgm

D. cantilever D.L. m.

$\left(\frac{6\times 8800\times 2.0^2}{6\times 2.87} - \frac{8800\times 19.2^2}{6\times 2.87} + \frac{3\times 8800\times 2.0^2}{6.21} - \frac{8800\times 19.2^2}{6\times 2.87}\right)$?

$= -176300 - (+17000 - 188400)$

$= -347200$ kgm

$-\frac{3100\times 19.2^2}{6\times 2.87} = -66500$

Concentration: 72 $+\frac{2\times 56800\times 2.0}{2.87} = +79{,}200$

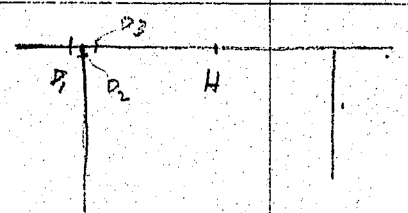
$-56800\times 2.0\times\frac{.87}{2.87} = -34{,}400$

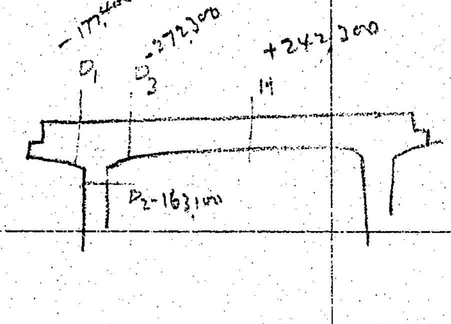
-113600, -17600, $-131{,}200$

+79200, −175800, −96600

−171400, −34400, −205800

	D_1	D_2	D_3	H
DL m	−131200	−96600	−205800	+165800
LL m	−46200	−66500	−66500	+76500
	−177,400	−163100	−272300	+242300





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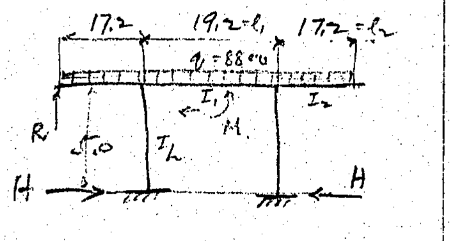
CALCULATIONS FOR

Sakada Bashi



$\nu_1 = \dfrac{I_1 h}{I_2 l_1} = \dfrac{0.40 \times 5.0}{0.12 \times 19.2} = 0.868$ $k_1 = 4 + 6 \times .868 + 3 \times .97 = 12.12$

$k_2 = 4 + 2 \times .868 + 3 \times .97 = 8.65$

$\nu_2 = \dfrac{I_2 h}{I_2 l_2} = \dfrac{0.40 \times 5.0}{0.12 \times 17.2} = 0.97$ $k_3 = 2 + .868 + 2 \times .97 = 4.81$

Fundamental formulas for M, H, R.

$M = \dfrac{q_1 l_1^2 k_1 - 6 q_2 l_2^2 \nu_1}{24 k_2} = \dfrac{12.12\, q l_1^2 - 5.21\, q l_2^2}{207.5} = \dfrac{2930 q}{207.5} = 14.10 q$

$H = \dfrac{2 q_1 l_1^2 - 3 q_2 l_2^2}{4 h k_2} = \dfrac{2 q l_1^2 - 3 q l_2^2}{20 \times 8.65} = \dfrac{2 q l_1^2 - 3 q l_2^2}{173} = -0.868 q$

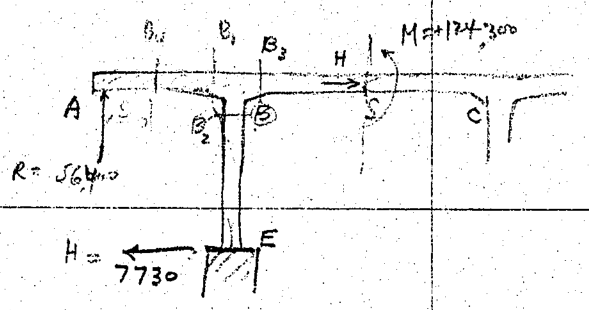
$R = \dfrac{3 q_2 l_2^2 k_3 - q_1 l_1^2 \nu_2}{4 l_2 k_2} = \dfrac{14.17\, q l_2^2 - 0.97\, q l_1^2}{34.60\, l_2} = 6.42 q$

Dead Load 8800 kg/m. q = 8800

M. = 14.10 × 8800 = + 124000 kgm — center of center span.

H = − 0.868 × 8800 = − 7640 kg

R = 6.42 × 8800 = + 56400 kg.



M_{B_1} = 56400 × 17.2 = + 970000 kgm
½ × 8800 × 17.2² = − 1301000
− 331000 kgm

M_E: $R l_2$ 56400 × 17.2 = − 970,000
M = + 124000
½ × 8800 × 17.2² = + 1,301,000
½ × 8800 × 9.6² = − 405300
+ 49700
HR 7640 × 5.0 = − 38200
+ 11500 kgm

M_{B_2} HR 7640 × 5.0 = + 38200
M_E + 11500
+ 49700 kgm

M_{B_3} M. + 124000
½ × 8800 × 9.6² = − 405300
− 281300 kgm

M_{B_4} 56400 × 8.0 = + 451200
½ × 8800 × 8² = − 282000
+ 168000 kgm

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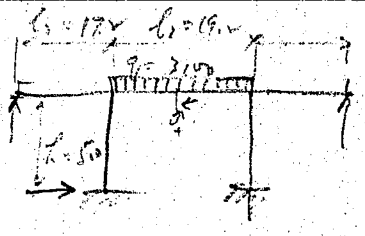
CALCULATIONS FOR

Takada Bashi



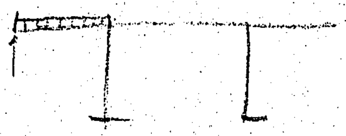
$M_S = \frac{q_1 l_2^2}{24} \cdot \frac{2+3r}{2+2r} = \frac{3100 \times 19.2^2}{24} \cdot \frac{4.604}{2.868} = +76500$ kgm

$M_{B_1} = 0$ $H = \frac{3100 \times 19.2^2}{4 \times 5 \times 2.868} = +20000$ kg.

$M_{B_3} =$ +76500
$\frac{1}{8} \times 3100 \times 19.2^2 =$ −143000
−66500 kgm

M_{B_2} −66500

M_E $\frac{3100 \times 19.2^2}{12 \times 2.868} = +33300$ kgm

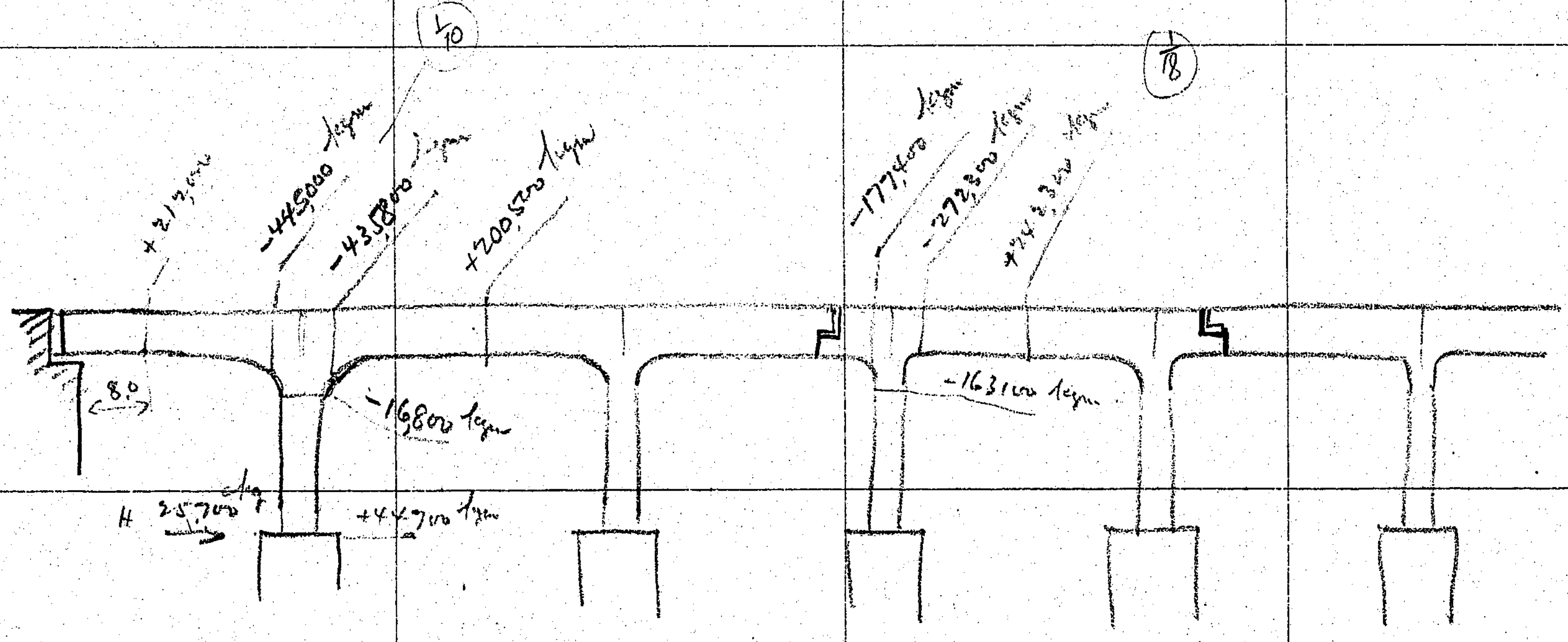


Assume $R = \frac{3}{8} \times 3100 \times 17.2 = 20000$ kg.

M_{B_1} $20000 \times 17.2 = +344000$
$\frac{1}{2} \times 3100 \times 17.2^2 = -459000$
−115000 kgm

Summary of moments. Point

	B1	B2	B3	S	E	H	B4
D.L.	−331000 −277000	+49700 +3400	−281300 −279000	+124000 +126300	+11500 −34500	−7640 −6560	+168000 190000
L.L.	0	−66500	−66500	+76500	+33300	+20000	[illegible]
″	(−115000)	(+26500)	(−88000)	say −(10500)	say −29800	say −18000	
Max.	−445000 −392000	+16800 −63100	−435800 −433300	+200500 +202500	+44700	−25700	+212000 [illegible]



$\frac{11900 \times 19.2^2}{x} = 445000$

$x = \frac{11900 \times 19.2^2}{445000} = 9.86$

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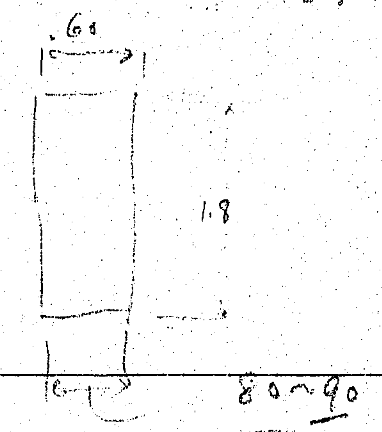
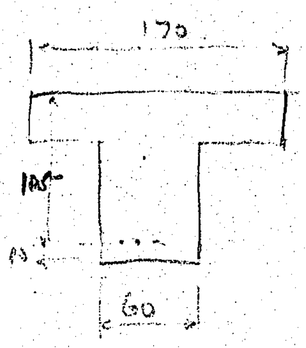


m = 450 tm, $450 \div 3 = 150$ tm

Eff. depth req'd = $\sqrt{\frac{150000 \cdot 100}{60 \times 218}}$ = 187

$\sqrt{\frac{150 \text{ m}\times\text{tm}}{90 \times 218}}$ = 153 cm



m = 81 tm

(+) steel area req'd = $\frac{8100000}{1300 \times \frac{7}{8} \times 100}$ = 77.1 cm²

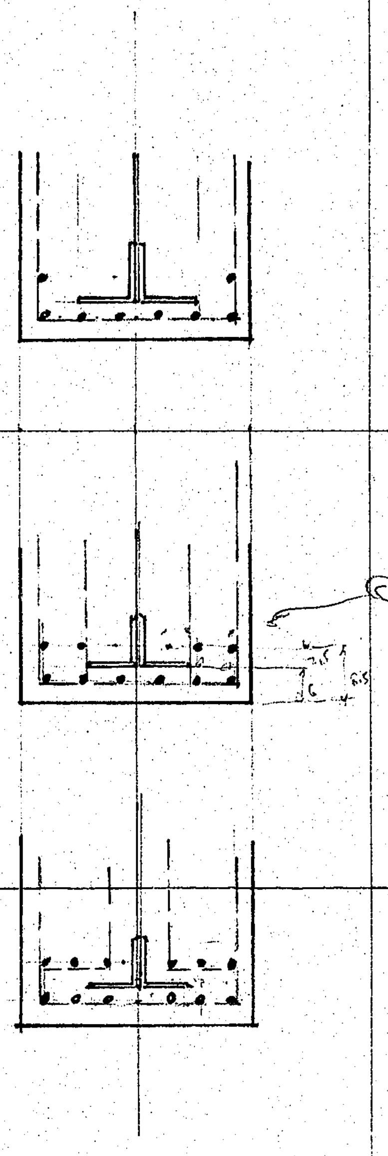
(−) steel area req'd = $\frac{150000000}{1200 \times \frac{7}{8} \times 170}$ = 84.0 cm² +12 = 96.0 (direct tension)

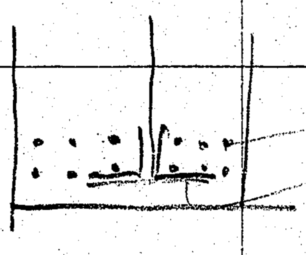
2LS 150×150×11 = 63.56 − 5.5 = 58.06
8 bars 22φ = 30.44
88.5 cm² net

10 − 25φ = 58.06 + 49.09 = 107.15

2LS 130×130×9 = 45.18 − 4.5 = 40.68
10 bars 25φ = 49.09
89.77 cm² net

2LS 130×130×9 = 〃 40.68
12 bars 22φ = 46.65
87.33 cm² net





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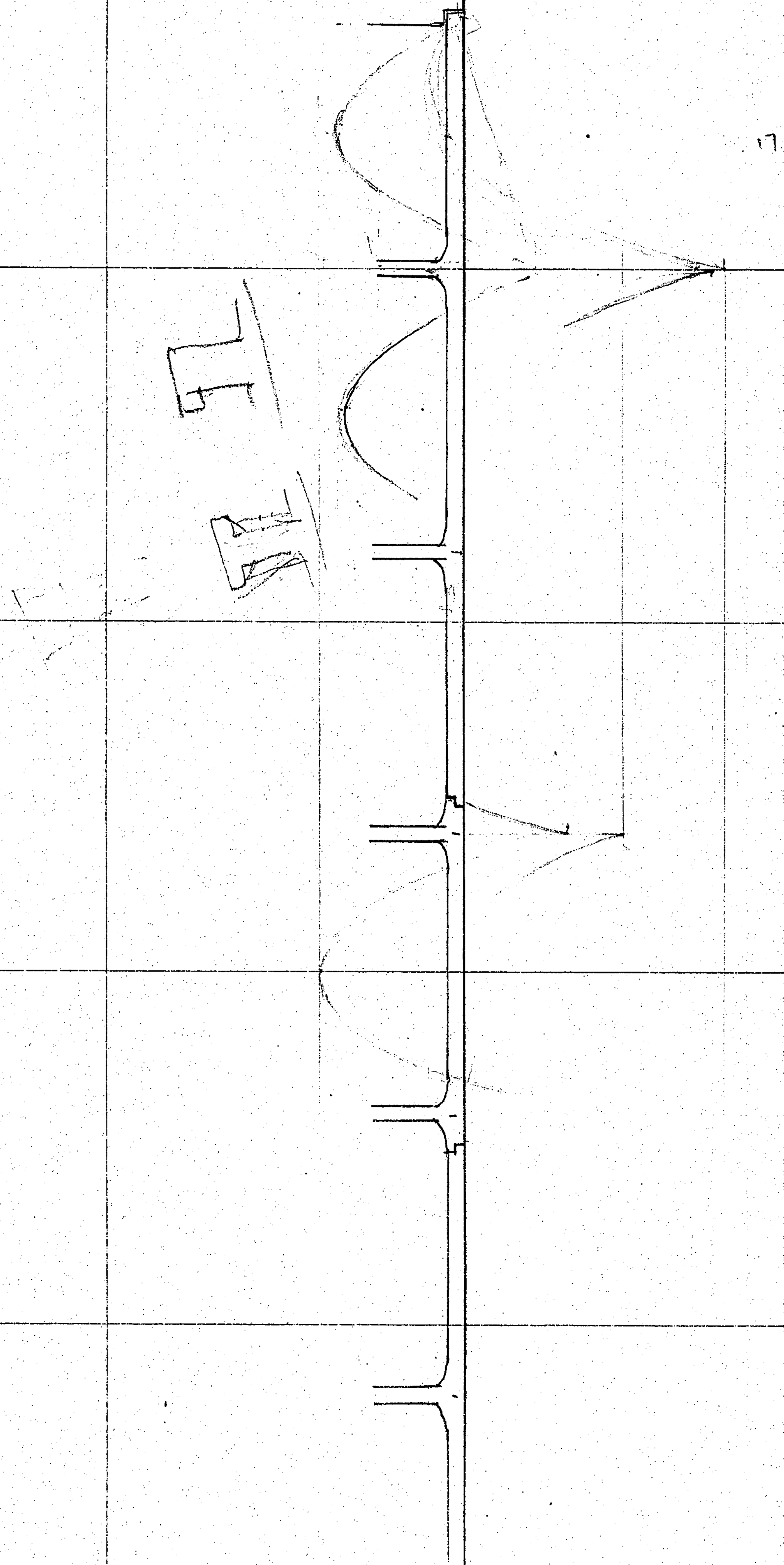
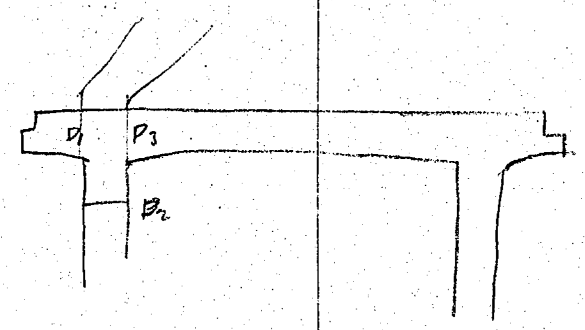
Takada Kashi





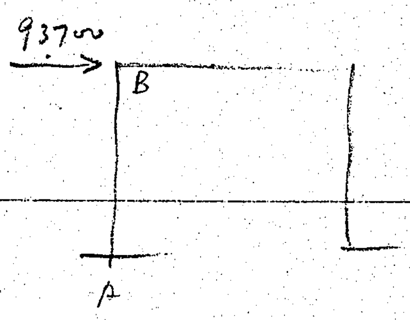
	P_1	P_2	P_3	M
DL m	-14600	-8640	-20600	165800
LL m	-5100	-6660	-6660	7650
	-19700	-15300	-27260	+242300

max moment on column = $\frac{163000}{3}$ = 54400 call this 60000 kgm/col.

" " during earthquake

seismic force = 8800 × 0.2 = 1760 × 53.2 = 93700 kg

19.0
17.0
34.0
19.2
53.2



$M_A = -\frac{93700 \times 5}{2} \cdot \frac{3 \times .868 + 1}{6 \times .868 + 1} = \pm 135800$ kgm ±

(234000, 3.604)

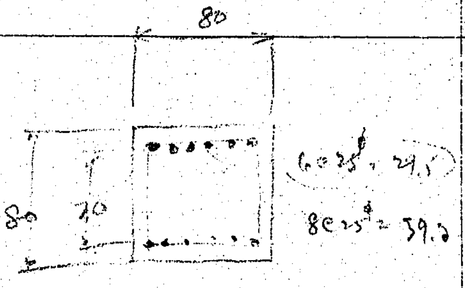
$M_B = \pm \frac{93700 \times 5}{2} \cdot \frac{3 \times .868}{6 \times .868 + 1} = \pm 98000$ kgm

vert load DL LL 170000

155000.

moment on one column 60000 kgm abt.

~~normal state governs~~

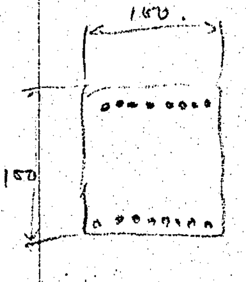


$e = \frac{60000}{70000} = .86$ m $\quad e/h = \frac{.86}{.8} = 1.07$

$d'/h = .05/.8 = .0625 \quad p_o = \frac{59.}{80 \times 80} = .0092$

$K = .37 \quad L = .145$

$f_c = \frac{60000 \times 100}{.145 \times 80 \times 80^2} = 81.0$ kg/cm²



1.00 8-25φ

$e/h = \frac{.86}{1.0} = .86$

$d'/h = 5/100 = .05 \quad p_o = \frac{78.6}{100^2} = .0079$

$K = .38 \quad L = 1.34$

$f_c = \frac{60000 \times 100}{1.34 \times 100 \times 100^2} = 44.8$ kg/cm² c

$f_s = 15 \times 44.8 \left(\frac{.95}{.38} - 1\right) = 1010$ kg/cm² } ok.

1.20 10-25φ

$e/h = \frac{.86}{1.2} = .715$

$d'/h = 5/120 = .0417 \quad p_o = \frac{100}{120^2} = .007 \quad K = .40 \quad K = 1.27$

$f_c = \frac{60000 \times 100}{1.27 \times 120 \times 120^2} = 27.4$

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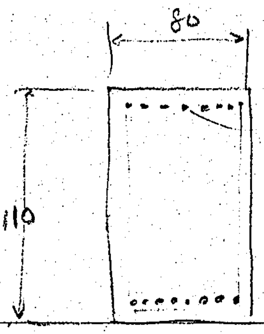
CALCULATIONS FOR

Takada Bashi

column



8-25φ = 39.25

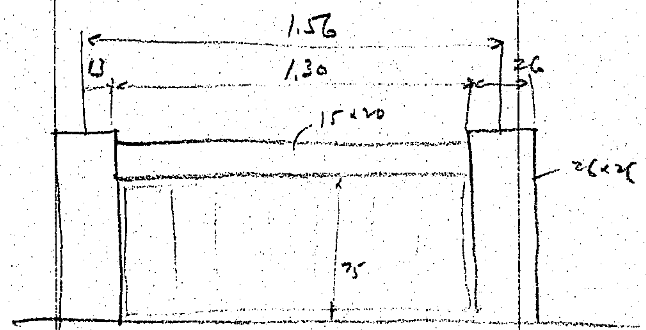
$z/h = \frac{.86}{1.1} = .782$ $d'/h = 5/110 = .045$ $p_0 = \frac{78.5}{110 \times 80} = .00892$

$k = .412$ $L = .141$

$f_c = \frac{6000000 \times 100}{.141 \times 80 \times 110^2} = 44.0$ kg/cm²

$f_s = 15 \times 44 \left(\frac{105}{.412 \times 110} - 1\right) = 865$ "

} o/k.



post .26 × .26 × .93 = .063 @ 2400 = 151
top rail .2 × .15 = .03 @ 2400 = 72
223

casting

2 × 2.5 = 5.0 cm × 11 × 71 = 3900
.25 × 2 = .50
2 × .75 × .25 × 12.5
17.5 × 132 = 2310
140
100
6450 cm³ @ .00725
= 46.8 kg
call it 47
223
270 kg

$\frac{270}{1.56} = 173$ kg/m.

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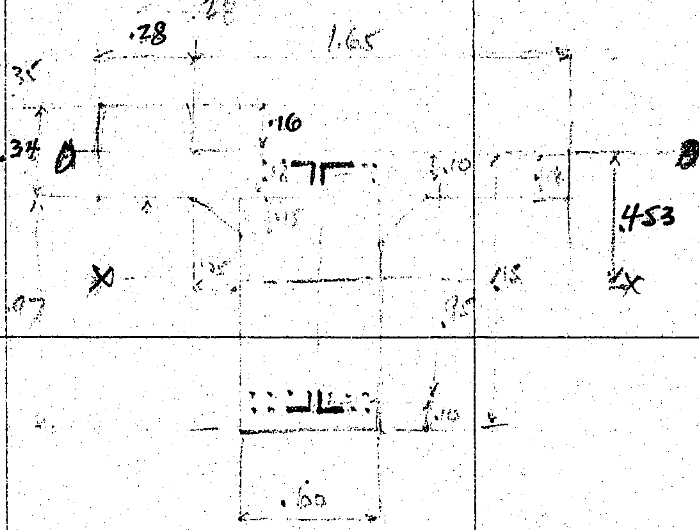
moment of inertia of Beam

Outside beam



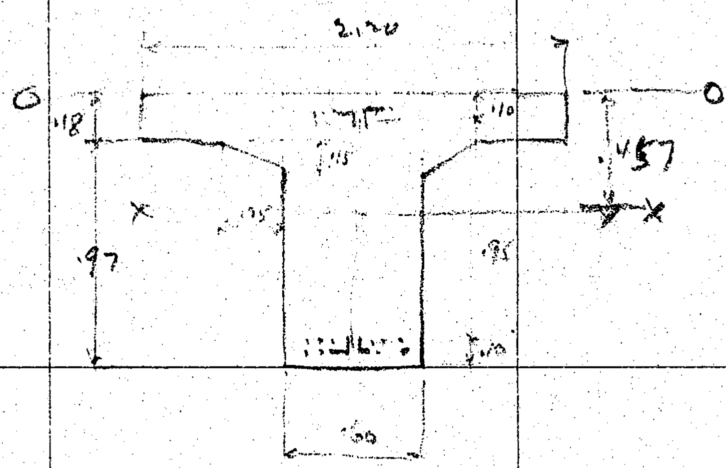
moment about O–O line

Coping	.34 × .28 =	.095	× .101 =	.0010
slab	1.65 × .18 =	.297	× .09 =	.0267
fillets	.15 × .195 =	.038	× .23 =	.0087
web.	.60 × .97 =	.581	× .665 =	.3862
Steel	200 cm² × 14 ÷ 10,000 =	.280	× 1.575 =	.1620
		1.295	.453 m	.5846

moment of inertia about X–X

Coping	$\frac{.28 \times .34^3}{12} + .095 \times .443^2$ (.00092, .01866) =	.01957
Slab	$\frac{1.65 \times .18^3}{12} + .297 \times .363^2$ (.0008, .03915) =	.03995
fillets	$.038 \times .223^2$ =	.00189
web.	$\frac{.60 \times .97^3}{12} + .581 \times .212^2$ (.0456, .02615) =	.07165
Steel area	$.280 \times .122^2$ =	.004168
		.13732 m⁴

Inside beam



moment about O–O.

slab.	2.20 × .18 =	.396	× .09 =	.0357
fillet	.15 × .195 =	.038	× .23 =	.0087
web	.60 × .97 =	.581	× .665 =	.3862
Steel	200 cm² × 14 ÷ 10,000 =	.280	× 1.575 =	.1620
		1.295 (1.305)	.46 m (.457)	.5926

moment of inertia about X–X.

Slab	$\frac{2.20 \times .18^3}{12} + .396 \times .37^2$ (.00107, .0535, .0548, .367) =	.05537 (.05557)
fillet	$.038 \times .23^2$ (.227) =	.00201 (.00196)
web	$\frac{.60 \times .97^3}{12} + .581 \times .205^2$ (.0457, .0250, .208) =	.0690 (.07085)
steel	$.280 \times .115^2$ (.290, .118) =	.00371 (.00390)
		.13009
		~~.1328~~
		.13142

.13720
.13142
.13431

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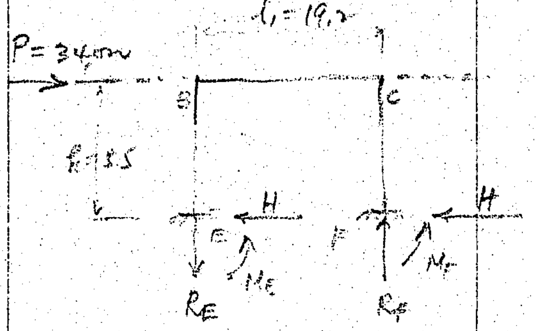
Outside column
Total wt of super structure = 53.2 @ 2950 = 157000
column wt. 1.8×1.1×5.5×2 = 9.70÷2 = 4.85 @ 2400 = 11600
misc. 1400
13000
170000 kg.

Seismic force say 0.2 @ 170000 = 34000 kg.

Zero reaction magnitude
$\nu = \nu_T = 0.331$ page 7. $H = \frac{P}{2} = \frac{34000}{2} = 17000$ kg

$3\nu+1 = 3\times.331+1 = 1.993$
$6\nu+1 = 6\times.331+1 = 2.986$



$R_E = -\frac{3Ph\nu}{l_1(6\nu+1)} = -\frac{3\times34000\times5.5\times.331}{19.2\times2.986} = -3240$ kg

$R_F = -R_E = +3240$ kg.

$M_E = -\frac{Ph}{2}\cdot\frac{3\nu+1}{6\nu+1} = -\frac{34000\times5.5}{2}\times\frac{1.993}{2.986} = -62400$ kgm.

$M_F = -M_E = +62400$ "

$M_B = +\frac{Ph}{2}\times\frac{3\nu}{6\nu+1} = +\frac{34000\times5.5}{2}\times\frac{.993}{2.986} = +31100$ kgm

$M_C = -M_B = -31100$ "

62400
5200
67600

$e = \frac{67600}{59500} = 1.135$ $\frac{e}{h} = \frac{1.135}{1.1} = 1.030$

$d'/h = \frac{5}{110} = 0.05$ $p_0 = 0.0089$

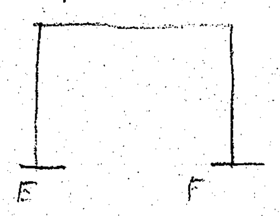
$k = .37$ $j = .143$

$f_c = \frac{6760000\times100}{.143\times80\times110^2} = 49$ kg/cm² o/c $35\times1.6 = 56$

$f_s = 15\times49\left(\frac{104.5}{.37\times110}-1\right) = 1145$ o/c $1200\times1.6 = 1920$

59500
+2500
57000

$\frac{67600}{57000} =$



		M_E		R_E
→	DL.	−5,150	+	59,500
	Earthquake	−48500	−	2,510
		−53,650 kgm		+56,990 kg
←	DL.	−5,150		+59,500
	E.Q.	+48500		+ 2,510
		+43,350 kgm		+62,010 kg

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$+ql_2 \quad -R_F \quad -R_E \quad -R_A$

$R_D = 17.0q \mp R_F + 0.800R_F - 10.67q \mp 0.112R_F - 6.716q$

$= -0.312R_F - 0.386q$ ——— (33)

$R_D = \dfrac{17.0(+0.112R_F - 6.716q) + 144.5q + 0.862R_F - 5.905q + 19.2R_F + 2.50R_F - 14.78q}{36.2}$

$= \dfrac{\sout{+13.934}\ {+24.466} R_F + 9.615q}{36.2}$

$= \sout{-0.385}\ {+.676} R_F + 0.266q$ ——— (34)

(34−33) $0 = \sout{-0.697}\ {+0.364} R_F + 0.652q$

$R_F = \dfrac{0.652q}{\sout{0.697}\ .364} = -\sout{0.935q}\ 1.79q$ ——— (35)

from (33) $R_D = -0.312 \times \sout{0.935q}\ 1.79 - 0.386q$

$= \sout{-0.094q}$ ——— (36)

$-0.926q$

$\Delta \Rightarrow$

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$R_D = 17.0q + R_F - 0.80R_F - 8.10q\ (10.678q) + 0.112R_F - 8.045q\ (6.716q)$

$= 0.312R_F - 0.855q\ (0.386q)$ (33)

$R_D = \dfrac{17.0(+0.112R_F + 6.716q) + 144.5q + 0.862R_F - 5.905q + 19.2R_F + 2.50R_F - 14.780q}{36.2}$

$= \dfrac{24.465R_F\ (-13.934R_F) + 9.615q}{36.2}$

$= 0.676R_F\ (-0.385R_F) + 0.266q$ (34)

(34)-(33) $0 = 0.364\ (+0.697)\ R_F + 0.120q\ (0.652q)$

or $R_F = \dfrac{0.120q\ (0.652q)}{0.364\ (0.697)} = 3.30q\ (1.79q)\ (+0.935q)$ (35)

from 33. $R_D = +0.312 \times 3.30q\ (1.79q) + 0.386q = +1.416q\ (0.926q)\ (\pm 0.094q)$ (36)

+3.357q −0.078q = +3.280q

from (32)

$R_A = +0.112 \times 3.30q\ (1.79) + 6.716q = +6.347q \quad +6.921q$

$R_E = -0.800 \times 3.30q\ (1.79) + 10.670q = +8.03q\ (13.310q) \quad +9.238q$

$H = +0.908 \times 3.30q\ (1.79) + 5.373q = +2.378q \quad +6.998q$

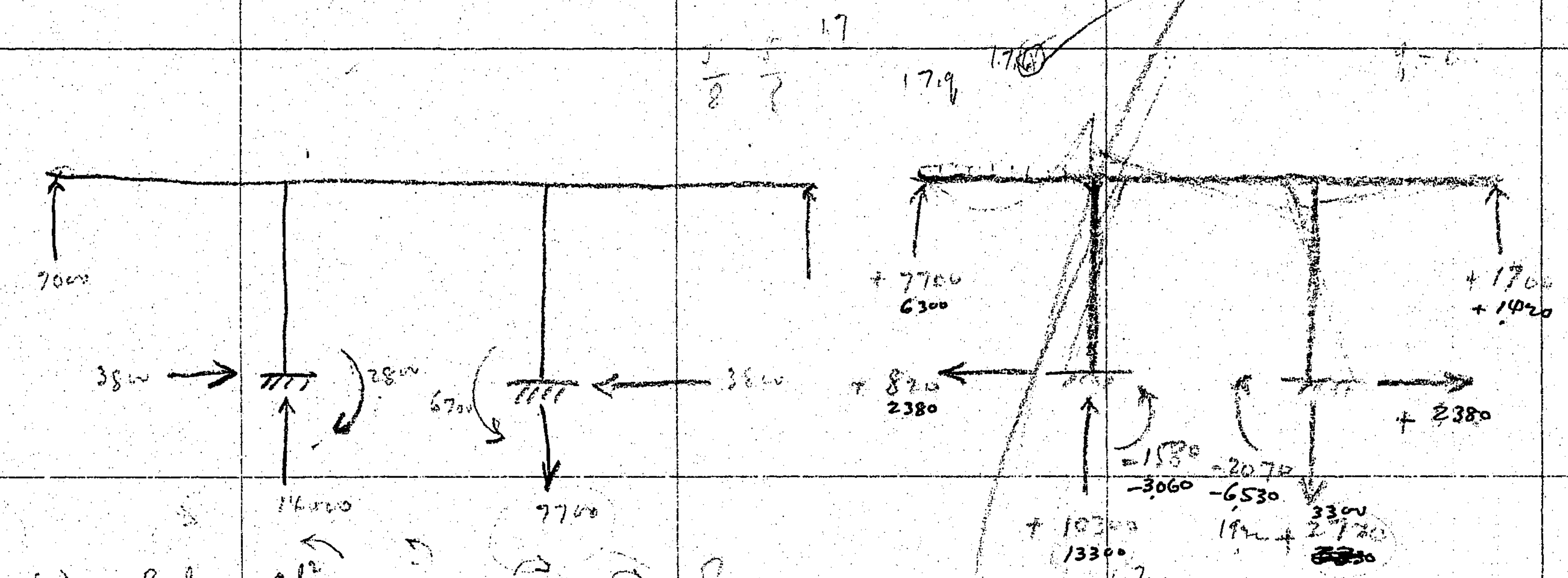
$M_E = -0.862 \times 3.30q\ (1.79) - 5.905q = -3.060q \quad -7.447q$

$M_F = -2.50 \times 3.30q\ (1.79) - 14.780q = -6.530q \quad -19.255q$

$R_F = \quad = +3.30q\ (-1.79q)$

$R_D = \quad = +1.416q\ (-0.926q)$

17.02q



$R_D(l_1+l_2)$ · $R_A l_2$ · $\frac{ql^2}{2}$ · M_E · $R_F l_1$ · M_F

− + − + + −

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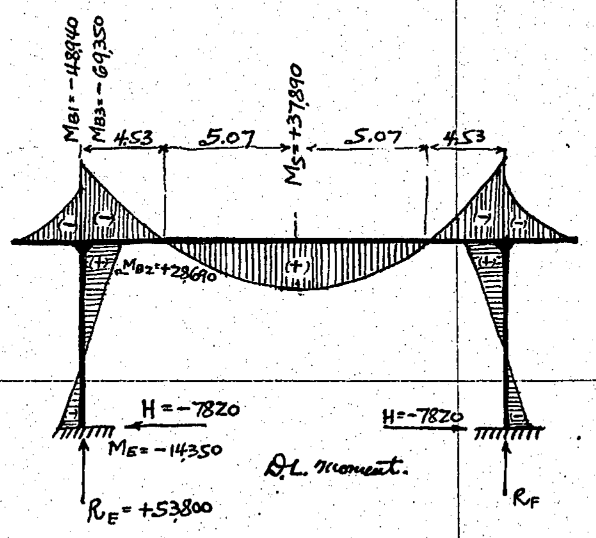
CALCULATIONS FOR

Design of Takada Bashi for Fukushima Ken.

Summary of Dead Load moments, reactions, and shears for out-side Rahmen.



D.L. moment.

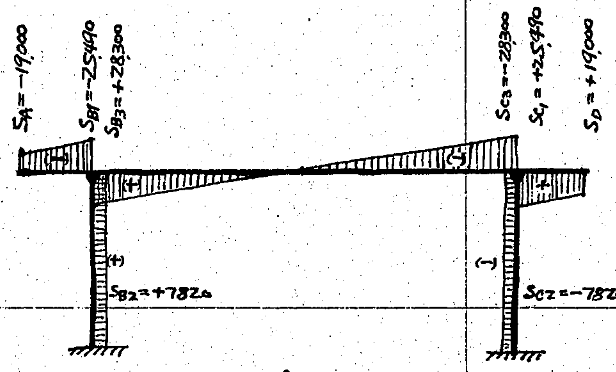
	Unif. load	Concentration	Total.
moments			
$M_E = M_F$	+ 35,800	− 17,930	− 14,350 kgm
$M_{B_2} = M_{C_2}$ =	− 71,600	+ 35,850	+ 28,690
$M_{B_3} = M_{C_3}$	− 63,420	− 5,930	− 69,350 "
M_S	+ 43,820	− 5,930	+ 37,890 "
$M_{B_1} = M_{C_1}$	− 7,140	− 41,800	− 48,940 "
Reactions			
$R_E = R_F$	+ 34,800	+ 19,000	+ 53,800 kg
H	+ 19,500	− 9,770	− 7,820 "
Shears			
S_{B1}	− 6,490	− 19,000	− 25,490 kg
S_{B2}	− 19,500	+ 9,770	+ 7,820 "
S_{B3}	+ 28,300	0	+ 28,300 "

Point of 0 moment in center span.

$M_S - \frac{qx^2}{2} = 0$

$x^2 = \frac{2M_S}{q} = \frac{2 \times 37890}{2950} = 25.69$

$x = \sqrt{25.69} = 5.07^m$



D.L. Shear.

Dead Load Stresses for Inside Rahmen.

Coefficient $= \frac{2760}{2950} = 0.936.$

moments				
$M_E = M_F$	− 14,350	× 0.936	=	− 13,430 kgm
$M_{B2} = M_{C2}$	+ 28,690	"		+ 26,850 "
$M_{B3} = M_{C3}$	− 69,350	"		− 64,900 "
M_S	+ 37,890	"		+ 35,450 "
$M_{B1} = M_{C1}$	− 48,940	"		− 45,800 "
Reactions				
$R_E = R_F$	+ 53,800	"		+ 50,350 kg
H	− 7,820	"		− 7,320 "
Shears.				
S_{B1}	− 25,490	"		− 23,850 "
S_{B2}	+ 7,820	"		+ 7,320 "
S_{B3}	+ 28,300	"		+ 26,480 "

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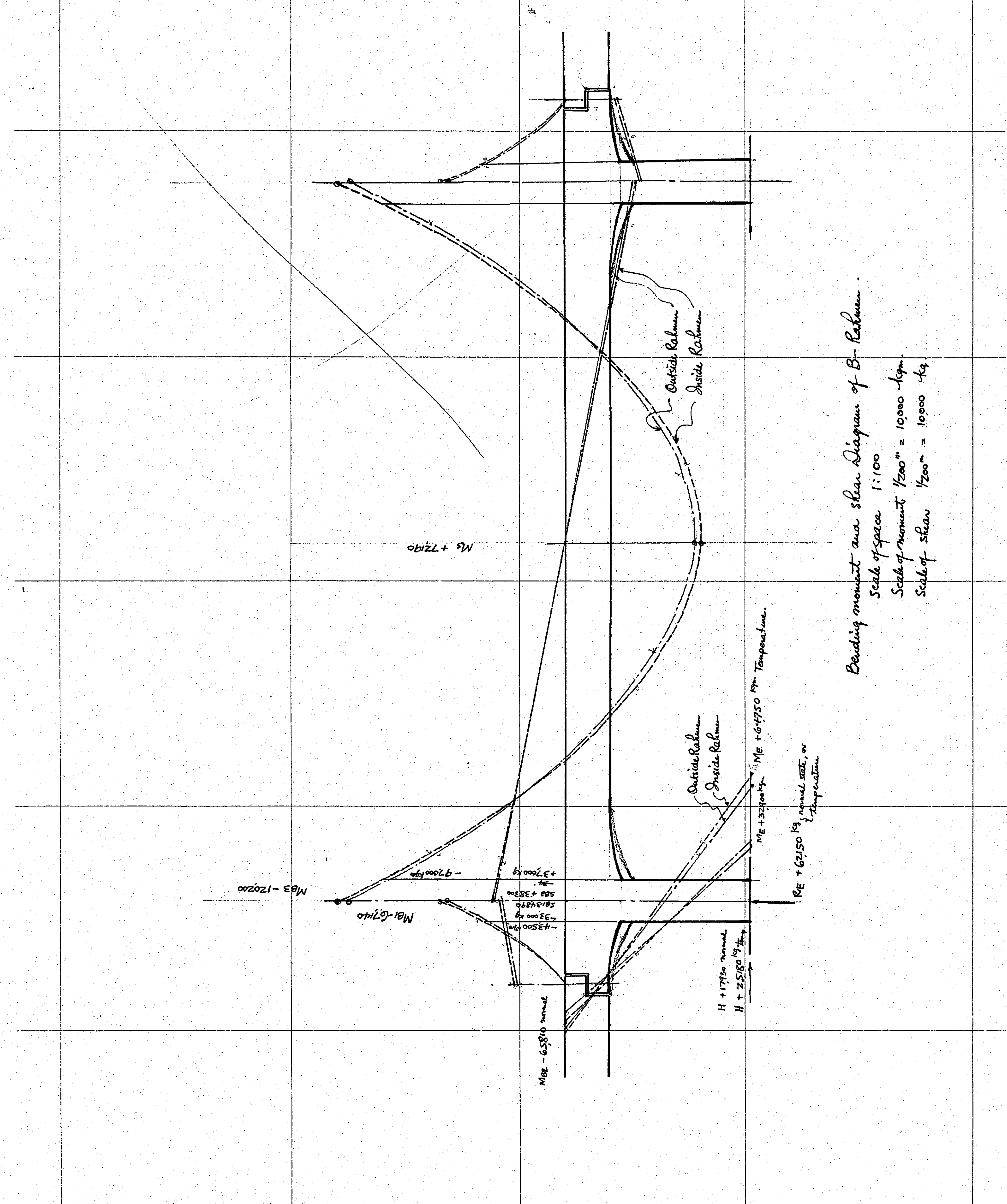
CALCULATIONS FOR

Design of Takada Bashi for Fukushima Ken.
Moment + Shear Diagram for B-Rahmen.



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Design of Fakada Bashi for Fukushima Ken.

Design of Sections.

moments and shears for Outside and Inside Rahmen are nearly equal. Let us design the sections using larger stresses and use the same section for both rahmen. (Inside Rahmen governs)

Sections for A-Rahmen.

Positive moment in side span +86,050 kgm with a direct tension H = −11,200 kg

8 − 25ϕ = 39.45

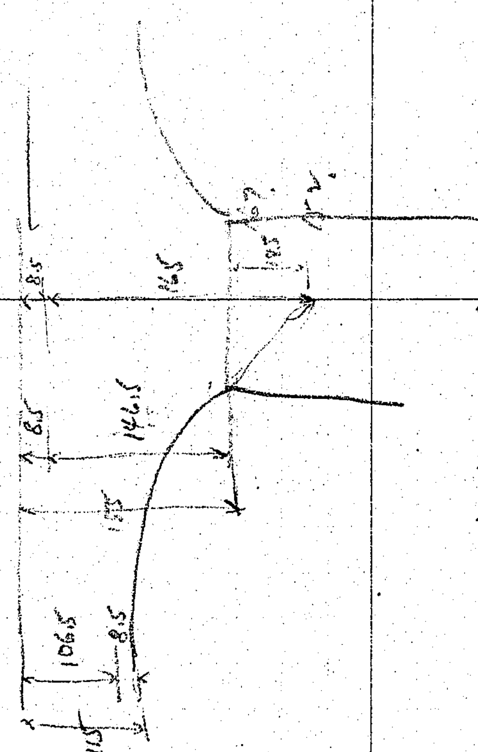
2L5 150×100×9 = 43.38 − 4.5 = 38.88 +39.45 = 78.33

2L5 150×100×12 = 57.12 − 6.0 = 51.12 +39.45 = 90.57

2L5 150×100×15 = 70.50 − 7.5 = 63.00

2L5 150×100×9 = 43.38 − 4.5 = 38.88 +39.45 = 78.33

2PL 510×9 = 25.20 − 4.5



Design of Takada Bashi for Fukushima Ken.

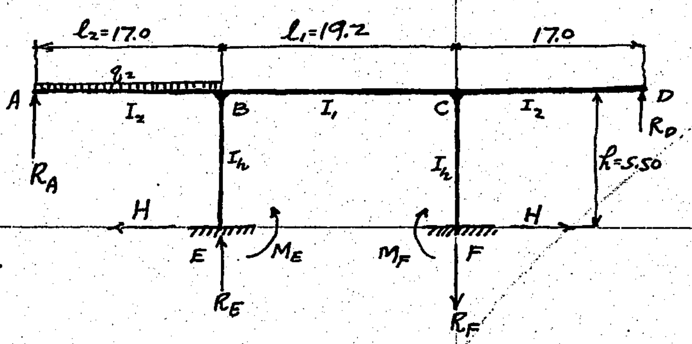
(Case 2) Inside Rahmen

M_s	+	17,350	×	1.336	=	+ 23,180	kgm
H	+	5,330	×	"	=	+ 7,120	kg
R_A	−	320	×	"	=	− 430	"
R_E	+	9,150	×	"	=	+ 12,230	"
M_{B1}	−	5440	×	"	=	− 7,270	kgm
M_{B3}	−	25,050	×	"	=	− 33,450	"
M_E	+	9,730	×	"	=	+ 13,000	"
M_{B2}	−	19,610	×	"	=	− 26,200	"
M_{B4}	−	2060	×	"	=	− 2,750	" at $x = 6.44$

(Case 3) Max. negative moment at support B

In the following calculations, the stresses are devided into 2 parts due to load on sidespan only and center span only. The latter is the same for case 2 as above calculations.

Outside Rahmen. Equivalent uniform live load = 920 kg per lin meter of side span.



This structure will have 5 redundancies. We will select R_A, H, R_E, M_E, and M_F as above redundancies, but M_F can be eliminated as $M_F = \frac{Hh}{2}$. Then, after an elaborate deduction, we have following 4 simultaneous equations of Redundancies.

$$8R_A(2v_1l_2^2 + l_1^2 + 3l_1l_2 + 3l_2^2) + 4R_E(2l_1^2 + 3l_1l_2 + 2v_1l_2^2) + 12Hh(l_1 + 2l_2) - 12M_E(l_1 + 2l_2) = 8R_F v_1 l_2^2 + q_2(18l_1l_2^2 + 11v_1l_2^3 + 8l_1^2l_2 + 12l_2^3)$$

$$2R_A(2l_1^2 + 3l_1l_2 + 2v_1l_2^2) + 4R_E(l_1^2 + v_1l_2^2) + 6Hh\,l_1 - 6M_E l_1 = 4R_F v_1 l_2^2 + q_2 l_2(4l_1^2 + 3l_1l_2 + 4v_1l_2^2)$$

$$6R_A(l_1 + 2l_2) + 6R_E l_1 + Hh(12 + 5v_2) - 6M_E(v_2 + 2) = 6q_2 l_2(l_1 + l_2)$$

$$R_A(l_1 + 2l_2) + R_E l_1 + Hh(v_2 + 2) - 2M_E(v_2 + 1) = q_2 l_2(l_1 + l_2)$$

Substituting $l_1 = 19.20$, $l_2 = 17.00$, $q_2 = 920$, $h = 5.50$, $v_1 = .331$, $v_2 = .374$ into above equations and simplifying we have following equations.

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CALCULATIONS FOR

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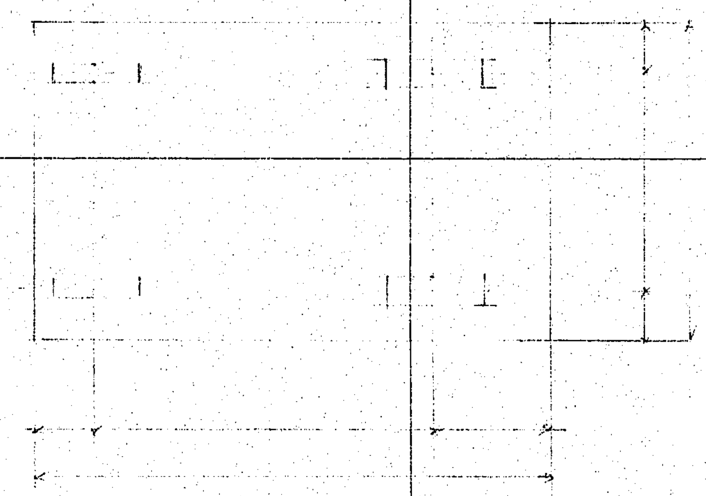

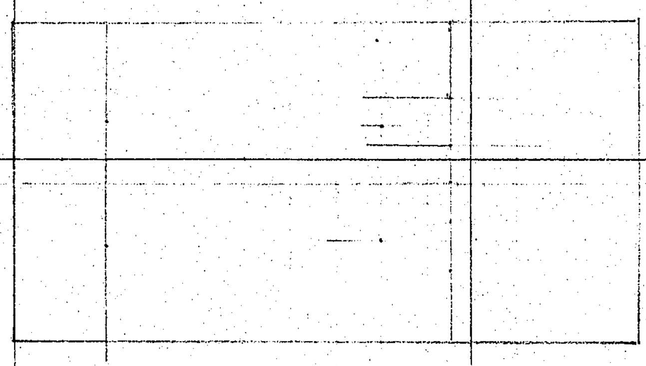

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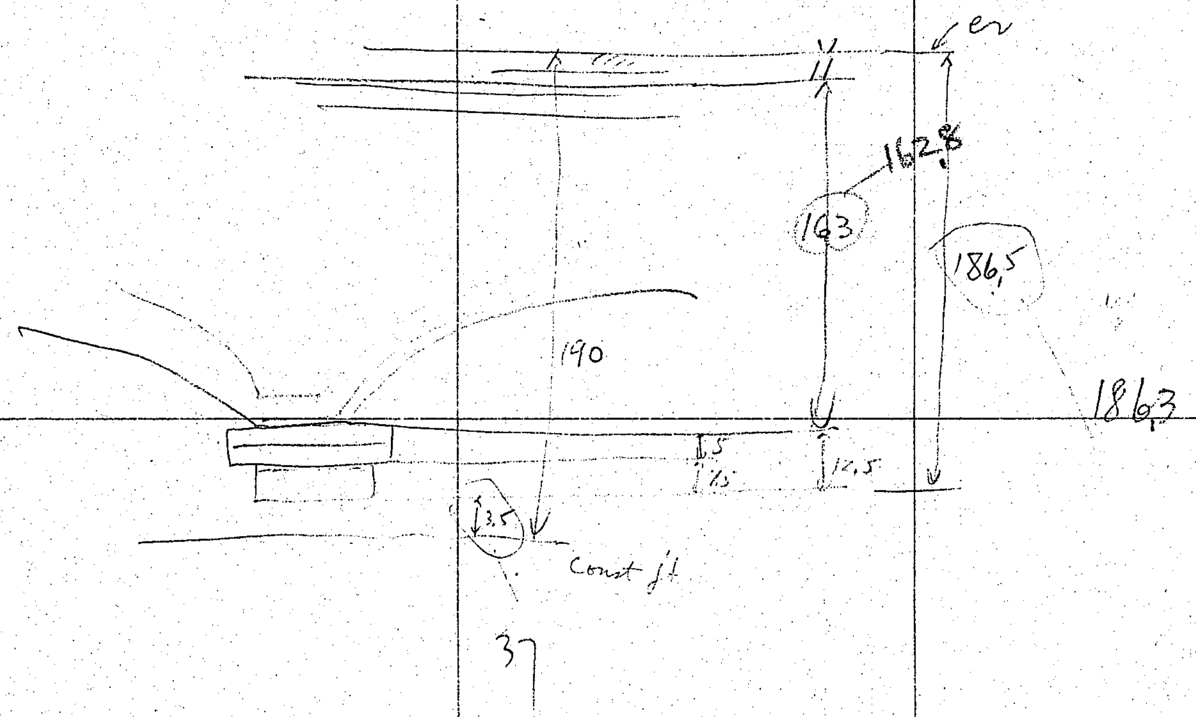
CHECKED BY ______ DATE ______ PAGE NO ______

Takada Bashi for Fukushima Ken

Length of pier columns.

Pier no.		Crown of roadway		El. top of col. (inside col.)	Top of well	Inside height of col.	Outside height of col.		
1	26	222.469	−1.60 =	220.869	− 216.750 =	4.119	4.087	1	26
2	25	222.603		221.003		4.253	4.221	2	25
3	24	222.726		221.126		4.376	4.344	3	24
4	23	222.837		221.237		4.487	4.455	4	23
5	22	222.938		221.338		4.588	4.556	5	22
6	21	223.027		221.427		4.677	4.645	6	21
7	20	223.105		221.505		4.755	4.723	7	20
8	19	223.172		221.572		4.822	4.790	8	19
9	18	223.228		221.628		4.878	4.846	9	18
10	17	223.273		221.673		4.923	4.891	10	17
11	16	223.306		221.706		4.956	4.924	11	16
12	15	223.328		221.728		4.978	4.946	12	15
13	14	223.390 (340)		221.790		5.040	5.008	13	14



190
155
35

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MADE BY M. Juda DATE 5-1-9 FILE NO ______

CHECKED BY ______ DATE ______ PAGE NO ______

CALCULATIONS FOR

高田橋親柱及袖高欄

LIST OF REINFORCEMENTS 一箇所分

Mark	NO.	Dia.	Length	Wt./m	Piece wt.	Total wt.	Remarks
L 06	12	12	.80	.88	.70	8.4	stab bars
L 01	8	16	360	1.57	5.65	45.2	vertical
L 02	3	9	320	.49	1.57	4.7	hoops
L 43	3	9	230	〃	1.13	3.4	〃
L 04	3	9	270	〃	1.32	4.0	〃
L 05	3	9	150	〃	.74	2.2	〃
L 08	12	12	170	.88	1.50	18.0	horiz.
L 07	16	12	110	〃	.97	15.5	vertical
L9	7	9	.65	.49	.32	2.2	hoop
L10	4	9	165	〃	.81	3.2	〃
L11	4	12	130	.88	1.14	4.6	vertical
						111.4 kgs	

END EXPANSION TOP RAIL (EER)

4 .12
6 .6

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CHECKED BY ______ DATE ______ **PAGE NO** ______

CALCULATIONS FOR

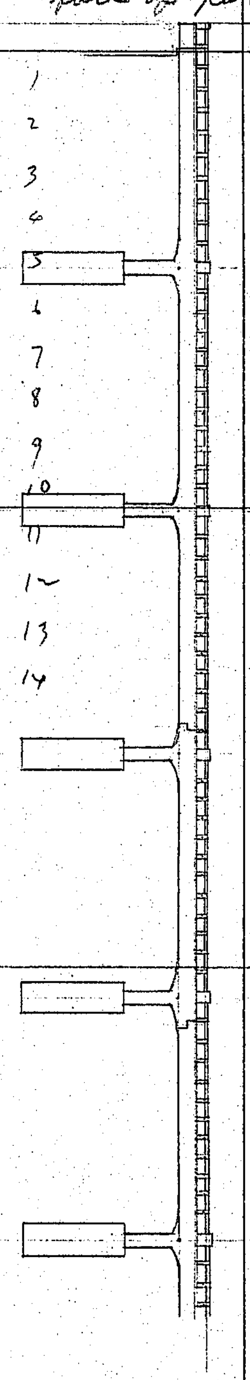
				222.339 — face of parapet.	
	0		222.341	222.341	
.0072080	1	.127.920	222.4089	222.469	1
.0739128	2	.261.872	222.6029	222.603	2
.0615340	3	.384.66	222.7257	222.726	3
.0503714	4	.496.286	" .8373	222.837	4
.0403249	5	.596.751	" .9378	222.938	5
.0313948	6	.686.052	223.0271	223.027	6
.0235810	7	.764.190	223.1052	223.105	7
.0168835	8	.831.165	" 1722	223.172	8
.0113022	9	.886.978	" 2280	223.228	9
.0068371	10	.931.629	" 2726	223.273	10
.0034883	11	.965.117	" 3061	223.306	11
.0012559	12	.987.442	" 3284	223.328	12
.0001395	13	.998.605	3396	223.340	13
			3410 ℄	223.341	14

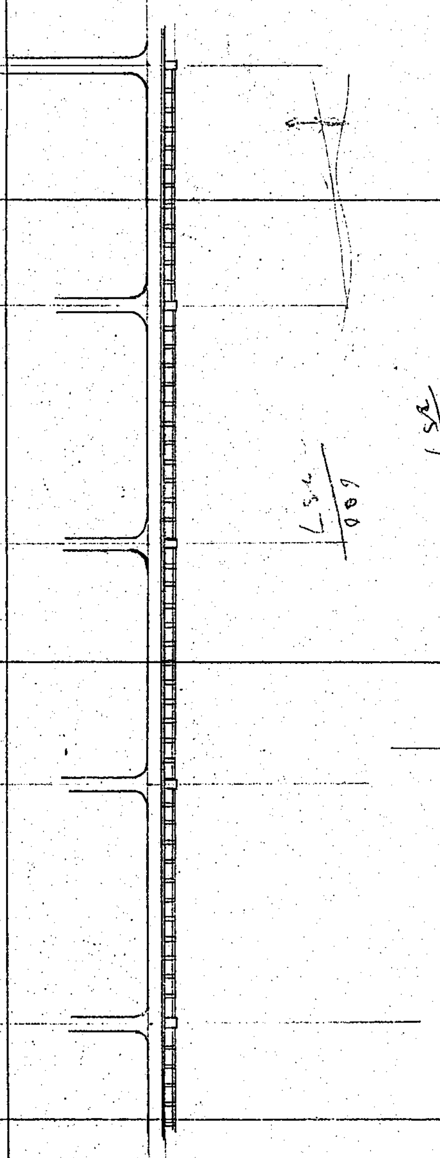
257.3

102 / 257.3

1920 − 360 = 1560

1560 / 12 = 130





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MADE BY M. Jmda DATE 6-1-13 FILE NO
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CALCULATIONS FOR
(1箇所分)
Materials of Takeda Bashi for Fukushima Ken

親柱及袖高欄 1/4 - Required (little projection and depression neglected)

Concrete 1:2:4 mixture

	Section	length	required no.	volume	remarks
Bottom	1.00 × .99	1.30	1	1.29	pedestal
〃	.16 × .32	.70	1	.04	〃
〃	.86 × .41	.86	1	.30	〃
middle	.74 × .74	1.30	1	.71	〃
~~top~~	~~.44 × .44~~	~~1.00~~	1	.19	〃
Top rail	.20 × .14	1.20	1	.03	handrail
wall	.10 × .61	1.20	1	.07	〃
less hole	.10 × .15	.20	3	-.01	〃
Bottom rail	.20 × .14	1.20	1	.03	〃
post	.50 × .50	1.15	1	.29	post
				2.94 cub. meters	

Forms

	width	length	required no	area	remarks
Bottom	.99	4.60	1	4.55	pedestal
〃	.41	.86	4	1.41	〃
〃	.16	.32	2	.10	〃
middle	.74	1.30	4	3.85	〃
~~top~~	.54	1.00	4	2.16	〃
~~handrail~~	1.10 (1.00)	1.20	2	(2.64) 2.40	handrail
post	.50	1.15	4	2.30	post
				(17.01) 16.77 sq. meters	

人造洗出仕上

	same as forms			16.77	
	~~1.00~~	~~1.30~~	1	~~1.30~~	pedestal upper side
	.20	1.20	1	.24	handrail 〃 〃
	.50	.50	1	.25	post 〃 〃
				(1.79) 18.56 sq. meters	

電燈装置

4 - Bronze fixtures
4 - 100 watt lamps

Reinforcements plain bars 0.1119 Kg ton

Bronze name plate
1 — 18cm × 70cm
1 — 14cm × 50cm

gas pipe
1 — 2½"φ × 2.00m
1 — 2"φ × 3.70
4 — 1"φ × .23

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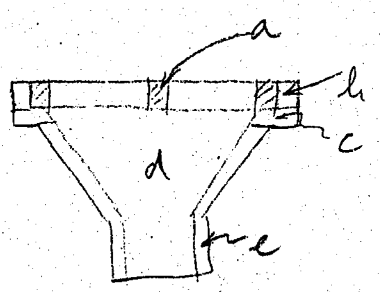
Takada-Bashi

蓋 - - -



a	22 × 25 × 31.5 =	17325	✓
less	10 × 12 × 2 × 2.5 =	− 600	✓
b	1.5 × 2.5 × 101 =	379	✓
c	1.5 × 3 × 95 =	427	✓
d	21.5 × 1.2 × 21 =	542	✓
〃	21.5 × 1.2 × 28 =	722	✓
	2 × 14.5 × 1.2 × 24 =	835	✓

4,037.5 × .00725 = 29.3 kg

≒ 30 kg

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CALCULATIONS FOR

Materials of Takada Bashi for Fukushima Ken

Floor Slabe

LIST OF REINFORCEMENTS plain bars

mark	NO	Dia cm	unit wt	Length m	piece wt	Total wt. kg	Remarks	
			slab No.1					
S1	248 [244]	1.2	.88	6.25	5.50	1364.0	1342.0	straight
S2	468 [464]	"	"	3.45 [3.50]	3.04 [3.08]	1422.7	1429.1	bent
S3	360	"	"	1.90	1.67	601.2		"
S4	360 [352]	"	"	1.50	1.32	475.2	464.6	hoop
S5	60	"	"	8.00	7.04	422.4		straight
S6	180	"	"	7.05	6.21	1,117.8		"
S8	288 [248]	"	"	.65 [.90]	.58 [.79]	167.0	195.9	slab bars
S9	20	"	"	1.65	1.46	29.2		bracket
S10	20	"	"	1.15	1.02	20.4		"
S11	20	"	"	1.65	1.46	29.2		"
S12	20	"	"	.90	.79	15.8		"
S13	40	1.6	1.57	1.30	2.04	81.6		slab bars "
							5,749.2	
			slab No.2					
S1	108	1.2	.88	6.25	5.50	594.0		straight
S2	200 [192]	"	"	3.45 [3.50]	3.04 [3.08]	608.0	591.4	bent
S3	156	"	"	1.90	1.67	260.5		
S4	156 [148]	"	"	1.50	1.32	205.9	195.4	hoop
S6	60	"	"	7.05	6.21	372.6		straight
S7	60	"	"	5.50	4.84	290.4		"
S8	144 [104]	"	"	.65 [.90]	.58 [.79]	83.5	82.2	slab bars "
S9	20	"	"	1.65	1.46	29.2		bracket
S10	20	"	"	1.15	1.02	20.4		"
S11	20	"	"	1.65	1.46	29.2		
S12	20	"	"	.90	.79	15.8		"
S13	40	1.6	1.57	1.30	2.04	81.6		slab bars "
							2562.7	

Total Reinforcements 5,749.2
Slab No.1 7 @ 5664.9 = 39654.3 → 40,244.4
Slab No.2 6 @ 2509.5 = 15057.0 → 15,376.2
[2509.5 → 2562.7]
54711.3 kgs → 55,620.6 kgs
or 54.7113 kg tons
55.6206 kg tons

小数点以下二位ニ変更

coping area .152
.138

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MADE BY M. [illegible] DATE 6-1-6 FILE NO ____
CHECKED BY M.K DATE 6-1-9 PAGE NO 1

CALCULATIONS FOR

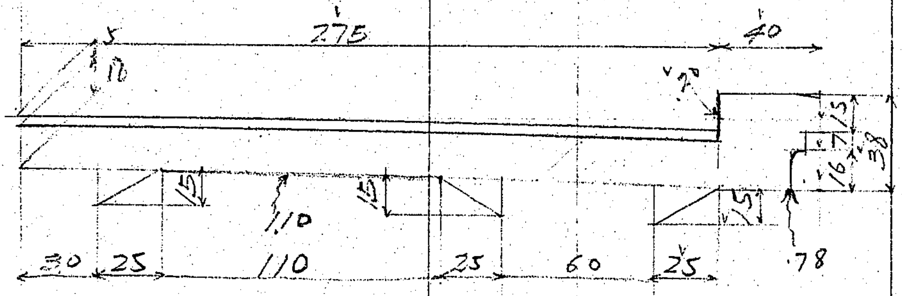
Materials of [illegible] Bridge for [illegible]

Materials for Floor Slab (Drain holes neglected)

Concrete 1:2:4 mixture

Sectional area

Slab .18 × 5.50 = .990
Coping 2 c .38 × (.18/.36) = .137 .274
1.127 sq.m 1.264



Total length of span (out to out of slab) = 514.44 m

Total length of slab
0 to 0 514.44
Expansion joint 12 c .05 = - .60
513.84 m

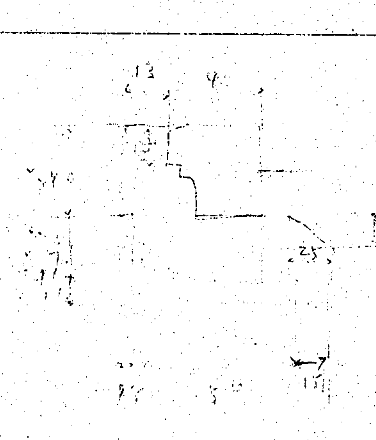
Total volume of concrete
1.264 1.127 × 513.84 = 579.10 649.49
bracket 52 c .31 × .74 = 11.93 5.77 10.77
.15 .28
591.03 cub meters
643.72 660.26

Forms
Slab & Coping 2 c 2.08 × 513.84 = 2,137.57
bracket 104 c .28 × .31 = 32.24 15.60 sides
" 52 c .74 × 1.60 = 53.20 61.57 outside
less 52 c .74 × .78 = − 30.01 out and bottom sides of coping
" 104 c .50 × 1.10 = − 57.20 strut on pier
" 82 (80) c .30 × 1.10 = − 27.06 26.40 strut
2138.74 sq meters
2,101.13

Reinforcements plain bars

人造洗出仕上

Coping 2 c 1.11 × 513.84 = 1,140.72
less 52 c 1.11 × .74 = − 42.71
bracket 104 c .28 × .31 (.15) = 32.24
" 52 c .74 × .30 (.78) = 30.01 88.50
less 590 c .26 × .26 = − 39.88 handrail post
" 52 c .47 × .74 = − 18.09 post on pier
1,102.29 sq meters
1,144.14



area of bracket
.53 × .72 = .396
.29 × .10 = .029
.33 × .17 = .057
less .13 × .10 = .013
" .07 × .15 = .006
" .07 × .40 × ½ = .014
.174
.153

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CALCULATIONS FOR

MADE BY ________ DATE ________ FILE NO ________

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型枠及支撐ニ関スル仕様

一、本図ハ型枠及支撐ニ関スル標準ヲ示セルモノニシテ本図ニ明示ナキ場合ハ総テ監督者ノ指揮ニ従ヒ本図ニ準ジテ施工スベシ

二、本図ハ地盤ノ[illegible]ニ示セルモノニシテ[illegible]支撐ヲ示セルモノニシテ[illegible]地盤ノ高低ニ従ヒ[illegible]使用スベシ

三、本図ニ示セル材料ハ[illegible]ニ[illegible]必要ト認メタル場合ハ之レヲ補強シ[illegible]スベシ

四、本図ニ於テハ型枠及支撐ノ[illegible]ヲ[illegible]トス
但シA型及ビB型柱ニ[illegible]三組[illegible]トス

五、[illegible]一[illegible]九[illegible]使用スベシ

又[illegible]型枠ニ[illegible]

六、[illegible]

七、[illegible]図面ニ[illegible]
[illegible]使用スベシ

八、[illegible]型枠ニ[illegible]二十[illegible]

九、型枠ノ内面ハ[illegible]ニ[illegible]

一〇、型枠及支撐ハ[illegible]二十八日間
[illegible]
但シ[illegible]十四日[illegible]
[illegible]

一一、[illegible]型枠[illegible]

一二、[illegible]型枠ノ内側ニ[illegible]二十[illegible]三十[illegible]
[illegible]型枠[illegible]
又[illegible]
[illegible]

[illegible]（[illegible]）ヲ[illegible]

一三、[illegible]型枠ハ[illegible]
[illegible]
[illegible]

一四、[illegible]

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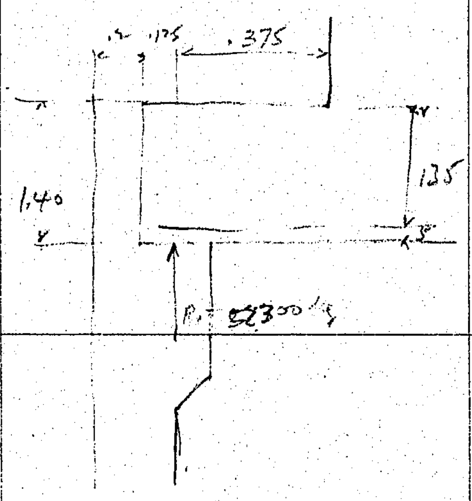
CALCULATIONS FOR

Reinforcements in footing



moment on footing

$52300 \times .375 = 19600$ kgm/m

Steel reqd $= \frac{19600 \times 100}{1500 \times \frac{7}{8} \times 135} = 13.6$ cm²/m strip

use 5 – 22φ = 19.0 cm²

use extra bond bars of 5 – 22φ = 19.0

Steel ratio $= \frac{38}{100 \times 135} = .0028$

$k = .1248$, $j = .917$

$f_s = \frac{19600 \times 100}{38 \times .917 \times 135} = 416$ kg/cm² ok

$f_c = \frac{416 \times .1248}{15 \times .752} = 9.14$ " "

unit shear $= \frac{52300}{100 \times .917 \times 135} = 4.22$ " $< 4 \times 1.25 = 5.0$ ok

unit bond $= \frac{52300}{69.1 \times .917 \times 135} = 6.12$ " $< 6 \times 1.25 = 7.5$ "

Sakada Bashi

Design of column footing.
Superimposed loads and moment on columns.
A-Rahmen.

	2 - Outside columns			1 - Inside column			Total		
	R_E	H	M_E	R_E	H	M_E	R_E	H	M_E
Dead Load	+119000	-6020	-10300	+55700	-2820	-4820	+174700	-8840	-15120
Live Load	+18800	-12540	-23000	+12560	-8380	-15370	+31360	-20920	-38370
	+137800	-18560	-33300	+68260	-11200	-20190	+206060	-29760	-53490
Dead Load	+119000	-6020	-10300	+55700	-2820	-4820	+174700	-8840	-15120
Earthquake	+5020	-26460	-97000	+2370	-12450	-45750	+7390	-38850	-142750
	+124020	-32480	-107300	+58070	-15270	-50570	+182090	-47690	-157870
Dead Load	+119000	-6020	-10300	+55700	-2820	-4820	+174700	-8840	-15120
Live Load	+18800	-12540	-23000	+12560	-8380	-15370	+31360	-20920	-38370
Temperature	—	-14280	-63700	—	-7240	-31850	—	-21520	-95550
	+137800	-32840	-97000	+68260	-18440	-52040	+206060	-51280	-149040

B-Rahmen

	2 - Outside columns			1 - Inside column			Total		
	R_E	H	M_E	R_E	H	M_E	R_E	H	M_E
Dead Load	+107600	+19460	+35740	+50350	+9110	+16720	+157950	+28570	+52460
Live Load	+17660	+13220	+24240	+11800	+8830	+16180	+29460	+22050	+40420
	+125260	+32680	+59980	+62150	+17930	+32900	+187410	+50620	+92880
Dead Load	+107600	+19460	+35740	+50350	+9110	+16720	+157950	+28570	+52460
Earthquake	+3420	+18040	+66200	+1630	+8550	+31450	+5050	+26590	+97650
	+111020	+37500	+101940	+51980	+17660	+48170	+163000	+55160	+150110
Dead Load	+107600	+19460	+35740	+50350	+9110	+16720	+157950	+28570	+52460
Live Load	+17660	+13220	+24240	+11800	+8830	+16180	+29460	+22050	+40420
Temperature	—	+14480	+63700	—	+7240	+31850	—	+21720	+95550
	+125260	+47160	+123680	+62150	+25180	+64750	+187410	+72340	+188430
wt of column - strut [illegible], wt of footing	+26000			+13300			+39300		
							+226710		
							+37100		
							+263810		
Call these							+263860 kg	+72,300 kg	+18840 kgm

Bearing area on wall

0.25 × 3.9 = 0.975
2.1 × 1.6 = 1.453
0.30 × 1.6 = 0.480
less .25 × .3 × 8 = − 0.600
2.308 m²

wt of footing

3.9 × 2.1 = 8.18
2.1 = 3.46
less 0.3 × .25 × 8 = − 0.60
11.04 × 1.4 = 15.45 m³
15.45 × [illegible] = 37,100 kg

3.90
[illegible]
1.2
4.30

Average bearing pressure = $\frac{263800}{2.308}$ = 114,500 kg/m²

114,500 × 0.25 = 28600 kg per lin meter of support on wall.

Bearing pressure due to moment — lever arm say 1.85 meters — length of support say 4.3 m

$\frac{188400}{1.85}$ = ±101800 kg

101800 ÷ 4.3 = ±23700 kg

Combined bearing pressure due to: vert load = 28600
moment = ±23700
52300 kg C or 4900 kg C. per lin m.

unit comp. = 52300 ÷ (25×100) = 20.9 kg C. < 45 × 1.25 = 56.2 ok

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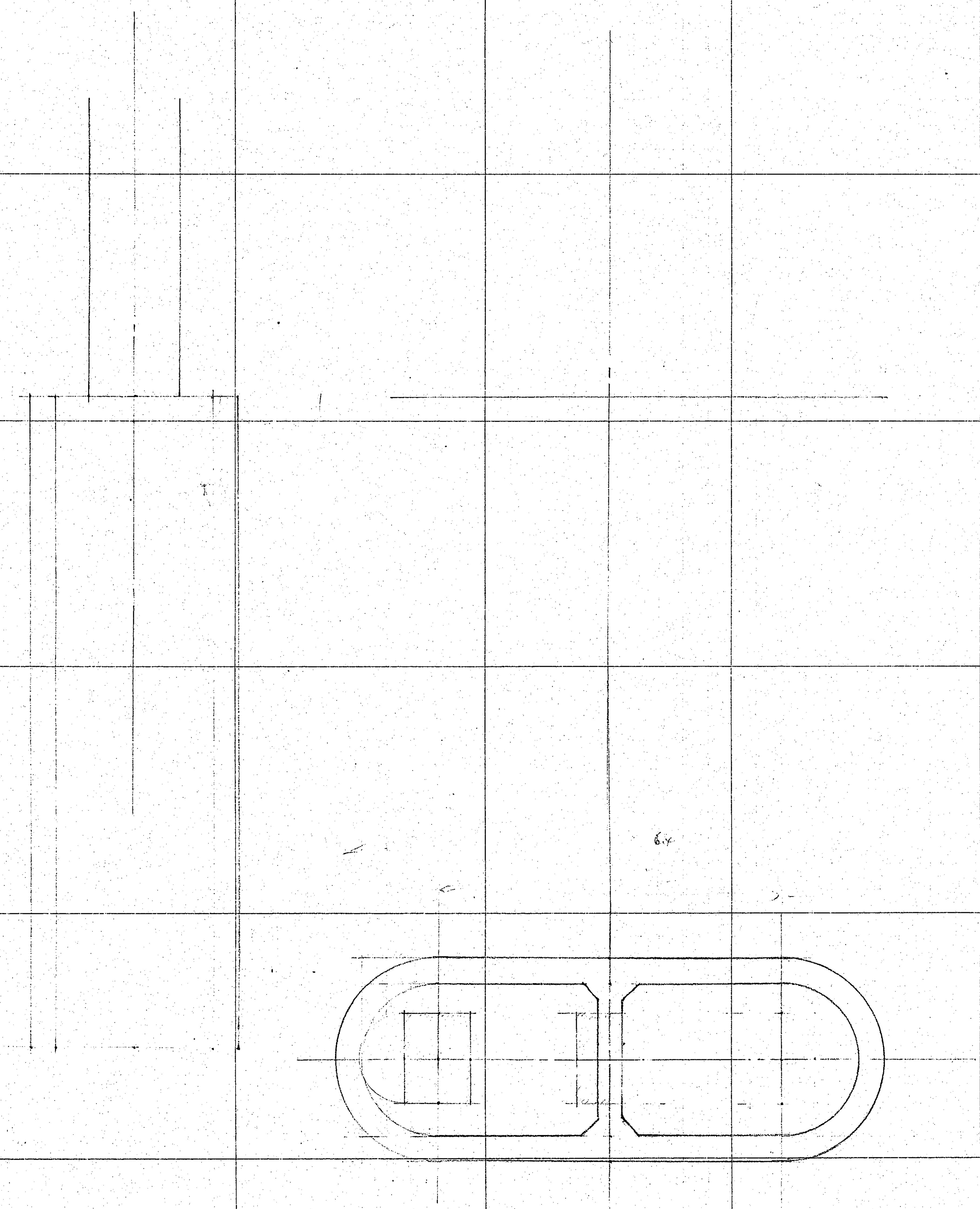
CALCULATIONS FOR

Design of Takada Bashi for Fukushima Ken.
Design of Pier well.



Earth pressure during excavation. Depth of earth assumed 6.0m.

Bottom Section

Earth pressure = $\frac{1600 \times 6.0}{3}$ = 3200 kg/m²

moment on side wall. span length assumed 2.8 meters

$\frac{1}{10} \times 3200 \times 2.8^2$ = 2500 kgm   Shear say 3200 × 1.4 = 4480 kg

Eff. depth reqd = $\sqrt{\frac{2500 \times 100}{100 \times 7.18}}$ = 18.7 cm

use eff. depth of 27 cm with 3 cm c to c   total depth = 30

Steel required = $\frac{2500 \times 100}{1200 \times \frac{7}{8} \times 27}$ = 8.82 cm²/m strip

use 12φ bars 12.5cm c to c = 9.04

unit shear = $\frac{4480}{100 \times \frac{7}{8} \times 27}$ = 1.9 kg/cm² o.k.

unit bond = $\frac{4480}{3.77 \times 8 \times \frac{7}{8} \times 27}$ = $\frac{6.3}{5.1}$ " o.k.

Section 2m above bottom   depth of earth 4.0m

Earth pressure = 2130 kg/m²

moment = $\frac{1}{10} \times 2130 \times 2.8^2$ = 1670 kgm

Shear = $\frac{1}{2} \times 2130 \times 2.8$ = 2985 kg

Steel reqd = $\frac{1670 \times 100}{1200 \times \frac{7}{8} \times 27}$ = 5.90 cm²

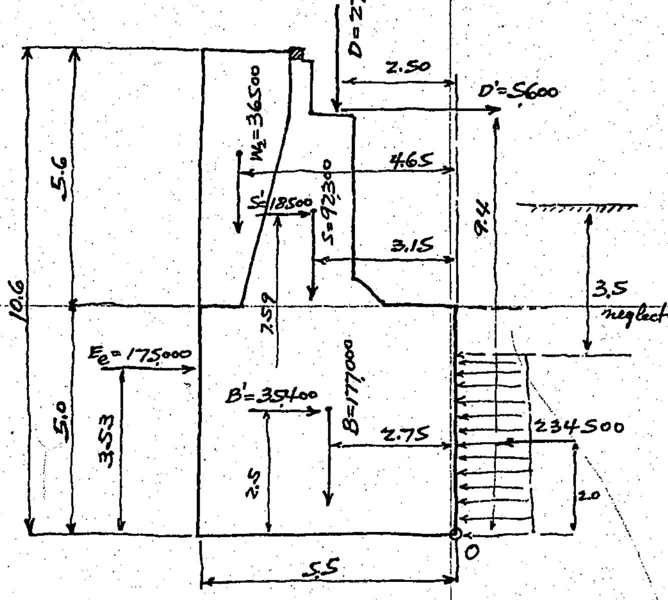
use 12φ bars 19.1cm = 5.90

unit shear = $\frac{2985}{100 \times \frac{7}{8} \times 27}$ = 1.26

unit bond = $\frac{2985}{19.7 \times \frac{7}{8} \times 27}$ = 6.4

Design of Takada Bashi for Fukushima Ken.

Case 2. Stability during earthquake (Seismic force forward).



Earth pressure during earthquake

$0.48 \times 1600 \times \frac{10.6^2}{2} \times 4.05 = 175,000$ kg   arm 3.53

Taking moment about O.

Loads	Hor. forces	Vert. forces	Lev. arms	Moment
D		27,900	× 2.50 =	69,800
D'	5600		× 9.40 =	− 52,600
S		92,300	× 3.15 =	290,600
S'	18500		× 7.59 =	− 140,500
B		177,000	× 2.75 =	486,500
B'	35,400		× 2.50 =	− 88,500
W2		36,500	× 4.65 =	169,800
Ee	175000		× 3.53 =	− 617,000
	234,500 kg	333,700 kg		118,100

Reactional earth pressure 234,500 kg

average unit pressure = $\frac{234500}{4.0 \times 4.05}$ = 14,500 kg/m²

allowable pressure on soil = $3.5 \times 1600 \times \frac{1+0.5}{0.5}$ = 16800 kg/m² ok

Reactional moment = 234500 × 2.00 = 469,000
118,100
587,100 kgm abt O.

Point of application of resultant force = $\frac{587100}{333700}$ = 1.76 m from O.

Eccentricity ξ = 2.75 − 1.76 = 0.99 m

Resultant force outside of middle third, pressure area = 1.76 × 3 × 2.8 = 14.8 m²

max. toe pressure = $\frac{333700 \times 2}{14.80}$ = 45100 kg/m² (4.14 tons/□') ok

Case 3. Stability during earthquake (Seismic force backward).

Earth pressure during earthquake

$0.48 \times 1600 \times \frac{7.5^2}{2} \times 4.05 =$ 87,500 kg   arm 2.5 m

Loads	Hor. forces	Vert forces	lever arms	moments
D		27,900	× 2.50 =	69,800
D'	5600		× 9.40 =	52,600
S		92,300	× 3.15 =	290,600
S'	18,500		× 7.59 =	140,500
B		177,000	× 2.75 =	486,500
B'	35,400		× 2.50 =	88,500
W2		36,500	× 4.65 =	169,800
Ee'	87,500		× 2.50 =	218,800
	~~234,500~~ 147,000 kg	333,700 kg	4.55 m	1,517,100

Reactional earth pressure assumed same as above process.

Reactional moment = ~~23~~ 147,000 × 2.00 = −294,000
1,517,100
1223100

Point of application of Resultant force = $\frac{1223100}{333700}$ = 3.67 m

Eccentricity = 3.67 − 2.75 = .92   2.75 − .92 = 1.83

pressure area 1.83 × 3 × 2.8 = 15.37 m²

max. heel pressure = $\frac{333700 \times 2}{15.37}$ = 43400 kg/m² or (3.97 ~~kg~~ tons/□') ok

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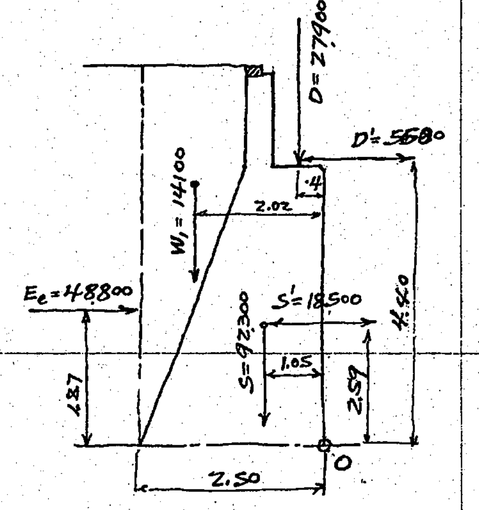
CALCULATIONS FOR

Design of Takada Bashi for Fukushima Ken.

Case 2. Stresses during Earthquake, K assumed 0.200



Taking moment about point O.

Loads	Hor. forces	Vert. forces		Lev. arms		Moments
D		27,900	×	.40	=	11,170
D'	5,600		×	4.40	=	− 24,650
S		92,300	×	1.05	=	96,900
S'	18,500		×	2.59	=	− 47,900
W_1		14,100	×	2.02	=	28,500
E_e	48800		×	1.87	=	− 91,200
	72,900 kg	134,300 kg		−0.20 m		− 27180

Eccentricity $\xi = 1.25 + .20 = 1.45$ m. $m = 1.45 \times 134300 = 195,000$ kgm

$p_0 = .0009$, $\xi/h = 145/250 = .58$, $d'/h = .05/250 = .02$

$k = .21$ $L = .058$

$f_c = \dfrac{195000 \times 100}{.058 \times 200 \times 250^2} = 26.9$ kg/cm² ok

$f_s = 15 \times 26.9 \left(\dfrac{245}{.21 \times 250} - 1\right) = 1480$ kg/cm² ok $< 1200 \times 1.6 = 1920$

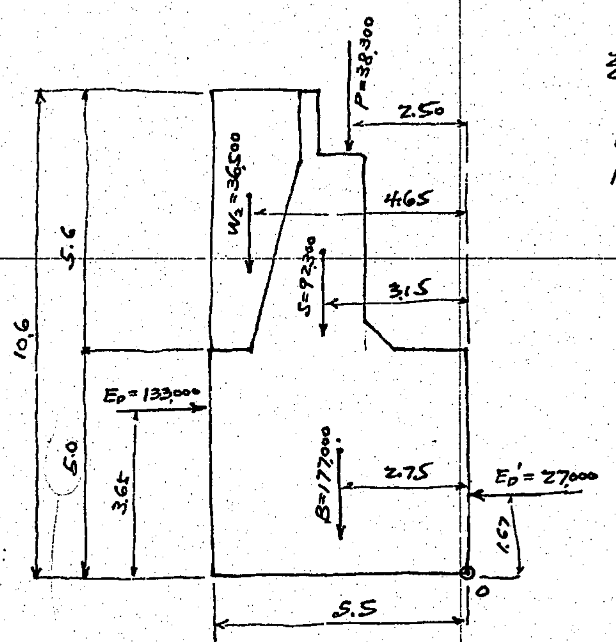
Unit shear $= \dfrac{72900}{200 \times \frac{7}{8} \times 245} = 1.7$ " ok

Unit bond $= \dfrac{72900}{41.5 \times \frac{7}{8} \times 245} = 8.2$ " ok $< 6.0 \times 1.6 = 9.6$

k L
.02 .21 .058
.05 .22 .059
.1 .23 .061

Stability of Abutment

Case 1. Stability at normal state.



weight of Base. $2.8 \times 5.5 \times 5.0 - 77$ @ 2,300 (average) = 177,000 kg

Seismic force = 177000 × .2 = 35,400 kg

Earth pressure at normal state

pressure on rear.	say	$\frac{1}{6} \times 1600 \times 11.1^2 \times 4.05 =$	133,000 kg	arm 3.65
pressure on front	"	$\frac{1}{6} \times 1600 \times 5.0^2 \times 4.05 =$	27000 "	" 1.67
Earth on rear side	say	2.4 × 1.7 × 5.6 @1600 =	36,500 "	arm 4.65

Taking moment about toe O.

Loads	Hor. forces	Vert. forces		Lev. arm		moment
P.		38,300	×	2.50	=	95,700
S		92,300	×	3.15	=	290,600
W_2		36,500	×	4.65	=	169,800
B		177,000	×	2.75	=	486,500
E_p	27,000		×	1.67	=	45,100
$E_{p'}$	−133,000		×	3.65	=	−486,000
	−106,000 kg	344,100		1.75 m		601,700

Eccentricity $\xi = 2.75 - 1.75 = 1.00$ m

Resultant force outside of middle third, neglecting tension on heel

pressure area $= 1.75 \times 3 \times 2.8 = 14.7$ m²

max. toe pressure $= \dfrac{344100 \times 2}{14.7} = 46800$ kg per sq. meter (4.28 tons/□') ok

備考. 基礎地質ハ「ボアリング」ノ結果 至30～40cmノ玉石層ニシテ 其空隙ハ充分砂利及砂ヲ以テ填充サレ居ル極メテ良好ナル地盤ニシテ耐荷力ハ少クモ 8tons/□' 以上ト認メラル.

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CALCULATIONS FOR

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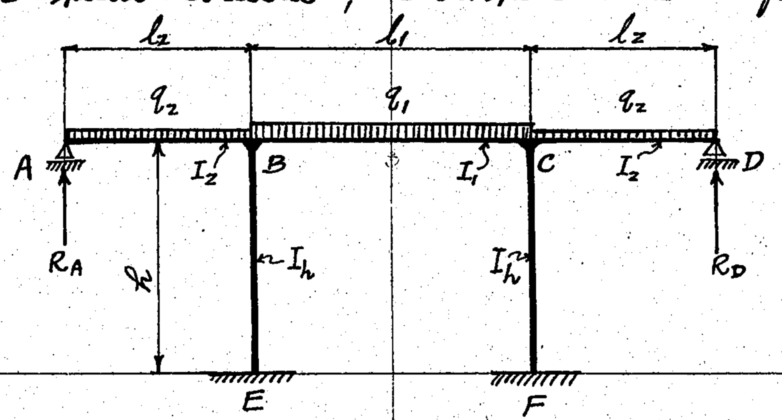
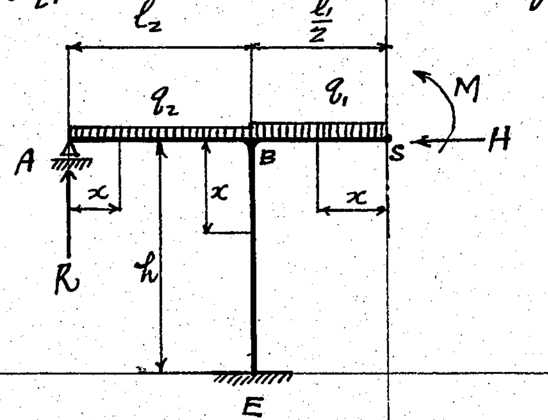
Solution of

3 Span Rahmen with Columns
fixed at Base,
and
1 Span Rahmen with overhanging
Arms at both ends and columns
fixed at Base.

3 span - Rahmen of a symmetrical construction.
3 spans loaded ; center span with uniform load q_1 and side span with uniform load q_2





V at S = 0.

Note for full uniform load of same intensity put $q_1 = q_2$; figuring dead load stresses.
Let us consider the left half of of the above structure. As the structure is symmetrical and loaded symmetrically, the shear at center of the center span will be zero.
Moments in every members are as follows.
Equations of moments at any point in the structure.

In beams SB. $M_x = M - \frac{q_1 x^2}{2}$

In beam AB $M_x = Rx - \frac{q_2 x^2}{2}$

Note :- For load on center span only put $q_2 = 0$ in case of figuring live load.

In column BE $M_x = M + Hx - Rl_2 - \frac{q_1 l_1^2}{8} + \frac{q_2 l_2^2}{2}$

Partial differentiations of above moments M_x.

In Beam SB $\frac{\partial M_x}{\partial M} = 1$, $\frac{\partial M_x}{\partial H} = 0$, $\frac{\partial M_x}{\partial R} = 0$.

In Beam AB $\frac{\partial M_x}{\partial M} = 0$, $\frac{\partial M_x}{\partial H} = 0$, $\frac{\partial M_x}{\partial R} = x$.

In column BE $\frac{\partial M_x}{\partial M} = 1$, $\frac{\partial M_x}{\partial H} = x$, $\frac{\partial M_x}{\partial R} = -l_2$.

Equations of Internal work

$$\frac{1}{EI_1}\int_0^{\frac{l_1}{2}}\left(M - \frac{q_1 x^2}{2}\right)dx + \frac{1}{EI_h}\int_0^{h}\left(M + Hx - Rl_2 - \frac{q_1 l_1^2}{8} + \frac{q_2 l_2^2}{2}\right)dx = 0$$

$$\frac{1}{EI_h}\int_0^{h}\left(M + Hx - Rl_2 - \frac{q_1 l_1^2}{8} + \frac{q_2 l_2^2}{2}\right)x\,dx = 0$$

$$\frac{1}{EI_2}\int_0^{l_2}\left(Rx - \frac{q_2 x^2}{2}\right)x\,dx - \frac{1}{EI_h}\int_0^{h}\left(M + Hx - Rl_2 - \frac{q_1 l_1^2}{8} + \frac{q_2 l_2^2}{2}\right)l_2\,dx = 0$$

Integrating above equations, we have

$$\frac{1}{EI_1}\left(M\frac{l_1}{2} - \frac{q_1 l_1^3}{48}\right) + \frac{1}{EI_h}\left(Mh + H\frac{h^2}{2} - Rl_2 h - \frac{q_1 l_1^2 h}{8} + \frac{q_2 l_2^2 h}{2}\right) = 0 \text{ ------------ (1)}$$

$$\frac{1}{EI_h}\left(M\frac{h^2}{2} + H\frac{h^3}{3} - Rl_2\frac{h^2}{2} - \frac{q_1 l_1^2 h^2}{16} + \frac{q_2 l_2^2 h^2}{4}\right) = 0 \text{ ------------ (2)}$$

$$\frac{1}{EI_2}\left(R\frac{l_2^3}{3} - \frac{q_2 l_2^4}{8}\right) - \frac{1}{EI_h}\left(Ml_2 h + Hl_2\frac{h^2}{2} - Rl_2^2 h - \frac{q_1 l_1^2 l_2 h}{8} + \frac{q_2 l_2^3 h}{2}\right) = 0 \text{ ------------ (3)}$$

Solving these 3 equations, we have, required 3 unknown quantities M, H, and R.

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CALCULATIONS FOR

3 span - Rahmen of a symmetrical construction

Simplifying above 3 equations

For Equation 1 multiply by $\frac{EI_1}{l_1} \neq 0$ and substitute $v_1 = \frac{I_1 h}{I_h l_1}$

$$M\frac{l}{2} - \frac{q_1 l_1^2}{48} + v_1\left(M + H\frac{h}{2} - Rl_2 - \frac{q_1 l_1^2}{8} + \frac{q_2 l_2^2}{2}\right) = 0$$

$$\text{or } M\left(\frac{1}{2} + v_1\right) + Hh\frac{v_1}{2} - Rl_2 v_1 = q_1 l_1^2\left(\frac{1}{48} + \frac{v_1}{8}\right) - q_2 l_2^2 \frac{v_1}{2} \quad \text{------ (4)}$$

For Equation 2 multiply by $\frac{2EI_h}{h^2} \neq 0$

$$M + Hh\frac{2}{3} - Rl_2 = \frac{q_1 l_1^2}{8} - \frac{q_2 l_2^2}{2} \quad \text{------ (5)}$$

For Equation 3 multiply by $\frac{EI_2}{l_2} \neq 0$ and substitute $v_2 = \frac{I_2 h}{I_h l_2}$

$$R\frac{l_2^2}{3} - \frac{q_2 l_2^3}{8} - v_2\left(Ml_2 + Hh\frac{l_2}{2} - Rl_2^2 - \frac{q_1 l_1^2 l_2}{8} + \frac{q_2 l_2^3}{2}\right) = 0$$

divided by l_2

$$R\frac{l_2}{3} - \frac{q_2 l_2^2}{8} - v_2\left(M + Hh\frac{1}{2} - Rl_2 - \frac{q_1 l_1^2}{8} + \frac{q_2 l_2^2}{2}\right) = 0$$

$$\text{or } Mv_2 + Hh\frac{v_2}{2} - Rl_2\left(\frac{1}{3} + v_2\right) = q_1 l_1^2 \frac{v_2}{8} - q_2 l_2^2\left(\frac{1}{8} + \frac{v_2}{2}\right) \quad \text{------ (6)}$$

Arranging Equations 4 5 and 6 in order, we get the following

$$\left(\frac{1}{2} + v_1\right) M + \frac{v_1 h}{2} H - v_1 l_2 R = q_1 l_1^2\left(\frac{1}{48} + \frac{v_1}{8}\right) - q_2 l_2^2 \frac{v_1}{2}$$

$$M + \frac{2h}{3} H - l_2 R = \frac{q_1 l_1^2}{8} - \frac{q_2 l_2^2}{2}$$

$$v_2 M + \frac{v_2 h}{2} H - \left(\frac{1}{3} + v_2\right) l_2 R = \frac{q_1 l_1^2 v_2}{8} - q_2 l_2^2\left(\frac{1}{8} + \frac{v_2}{2}\right)$$

Solving M by determinants

$$M = \frac{\begin{vmatrix} +q_1 l_1^2\left(\frac{1}{48} + \frac{v_1}{8}\right) - q_2 l_2 \frac{v_1}{2} & +\frac{v_1 h}{2} & -v_1 l_2 \\ +\frac{q_1 l_1^2}{8} - \frac{q_2 l_2^2}{2} & +\frac{2h}{3} & -l_2 \\ +\frac{q_1 l_1^2 v_2}{8} - q_2 l_2\left(\frac{1}{8} + \frac{v_2}{2}\right) & +\frac{v_2 h}{2} & -\left(\frac{1}{3} + v_2\right) l_2 \end{vmatrix}}{\begin{vmatrix} +\left(\frac{1}{2} + v_1\right) & +\frac{v_1 h}{2} & -v_1 l_2 \\ +1 & +\frac{2h}{2} & -l_2 \\ +v_2 & +\frac{v_2 h}{2} & -\left(\frac{1}{3} + v_2\right) l_2 \end{vmatrix}} = \frac{-Hl_2 \begin{vmatrix} q_1 l_1^2\left(\frac{1}{48} - \frac{v_1}{8}\right) - q_2 l_2^2 \frac{v_1}{2} & \frac{v_1}{2} & v_1 \\ \frac{q_1 l_1^2}{8} - \frac{q_2 l_2^2}{2} & \frac{2}{3} & 1 \\ \frac{q_1 l_1^2 v_2}{8} - q_2 l_2^2\left(\frac{1}{8} + \frac{v_2}{2}\right) & \frac{v_2}{2} & \frac{1}{3} + v_2 \end{vmatrix}}{-Hl_2 \begin{vmatrix} \frac{1}{2} + v_1 & \frac{v_1}{2} & v_1 \\ 1 & \frac{2}{3} & 1 \\ v_2 & \frac{v_2}{2} & \frac{1}{3} + v_2 \end{vmatrix}}$$

$$M = \frac{-\frac{l_2 h}{24}\left\{\left(q_1 l_1^2\left(\frac{1}{9} + \frac{v_1}{6} + \frac{v_2}{12}\right) - q_2 l_2^2 \frac{v_1}{6}\right\}}{-\frac{l_2 h}{24}\left(\frac{24}{9} + \frac{4}{3}v_1 + 2v_2\right)} = \frac{q_1 l_1^2 (4 + 6v_1 + 3v_2) - 6 q_2 l_2^2 v_1}{24(4 + 2v_1 + 3v_2)}$$

$$M = \frac{q_1 l_1^2 k_1 - 6 q_2 l_2^2 v_1}{24 k_2} \quad \text{where } k_1 = 4 + 6v_1 + 3v_2$$

$$k_2 = 4 + 2v_1 + 3v_2$$

Solving H by determinants

$$H = \frac{\begin{vmatrix} \frac{1}{2}+v_1 & +q_1l_1^2\left(\frac{1}{48}+\frac{v_1}{8}\right)-q_2l_2^2\frac{v_1}{2} & -v_1l_2 \\ +1 & +\frac{q_1l_1^2}{8}-\frac{q_2l_2^2}{2} & -l_2 \\ +v_2 & +\frac{q_1l_1^2v_2}{8}-q_2l_2^2\left(\frac{1}{8}+\frac{v_2}{2}\right) & -\left(\frac{1}{3}+v_2\right)l_2 \end{vmatrix}}{\text{Denominator same as for } M.} = \frac{-l_2}{-hl_2}$$

$$= \frac{-\frac{l_2}{24}\left(\frac{1}{3}q_1l_1^2-\frac{1}{2}q_2l_2^2\right)}{-\frac{l_2h}{24}\left(\frac{24}{9}+\frac{4}{3}v_1+2v_2\right)} = \frac{\frac{1}{3}q_1l_1^2-\frac{1}{2}q_2l_2^2}{h\left(\frac{24}{9}+\frac{4}{3}v_1+2v_2\right)} = +\frac{q_1l_1^2-3q_2l_2^2}{4h(4+2v_1+3v_2)}$$

$$= \frac{2q_1l_1^2-3q_2l_2^2}{4hK_2} \qquad \text{where } k_2 = 4+2v_1+3v_2$$

Solving R by determinants

$$R = \frac{\begin{vmatrix} +\left(\frac{1}{2}+v_1\right) & +\frac{v_1h}{2} & +q_1l_1^2\left(\frac{1}{48}+\frac{v_1}{8}\right)-q_2l_2^2\frac{v_1}{2} \\ +1 & +\frac{2}{3}h & +\frac{q_1l_1^2}{8}-\frac{q_2l_2^2}{2} \\ +v_2 & +\frac{v_2h}{2} & +\frac{q_1l_1^2v_2}{8}-q_2l_2^2\left(\frac{1}{8}+\frac{v_2}{2}\right) \end{vmatrix}}{\text{Denominator same as for } M} = \frac{-h}{-hl_2}$$

$$= \frac{-\frac{h}{24}\left\{q_2l_2^2+\frac{1}{2}q_2l_2^2v_1-\left(\frac{1}{6}q_1l_1^2-q_2l_2^2\right)v_2\right\}}{-\frac{h}{24}l_2\left(\frac{24}{9}+\frac{4}{3}v_1+2v_2\right)} = +\frac{q_2l_2^2+\frac{1}{2}q_2l_2^2v_1-\left(\frac{1}{6}q_1l_1^2-q_2l_2^2\right)v_2}{l_2\left(\frac{24}{9}+\frac{4}{3}v_1+2v_2\right)}$$

$$= +\frac{\frac{18}{36}\left(2q_2l_2^2+q_2l_2^2v_1-\frac{1}{3}q_1l_1^2v_2+2q_2l_2^2v_2\right)}{\frac{6}{9}l_2(4+2v_1+3v_2)} = +\frac{\frac{3}{4}q_2l_2^2(2+v_1+2v_2)-\frac{1}{4}q_1l_1^2v_2}{l_2(4+2v_1+3v_2)}$$

$$= +\frac{3q_2l_2^2(2+v_1+2v_2)-q_1l_1^2v_2}{4l_2(4+2v_1+3v_2)} = \frac{3q_2l_2^2k_3-q_1l_1^2v_2}{4l_2k_2}$$

where $k_2 = 4+2v_1+3v_2$
$k_3 = 2+v_1+2v_2$

Final equations for M, H and R as shown below.

$$M = \frac{q_1l_1^2K_1-6q_2l_2^2v_1}{24K_2} \qquad \text{where } v_1 = \frac{I_1h}{I_hl_1}, \quad v_2 = \frac{I_2h}{I_hl_2}$$

$$H = \frac{2q_1l_1^2-3q_2l_2^2}{4hk_2} \qquad k_1 = 4+6v_1+3v_2$$

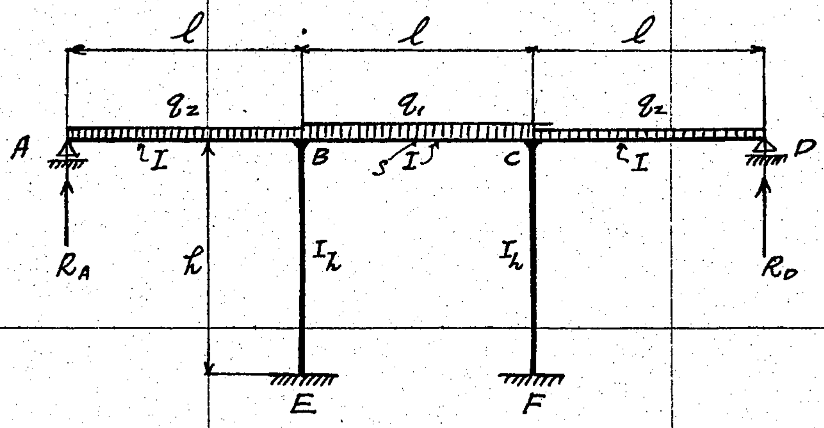
$$k_2 = 4+2v_1+3v_2$$

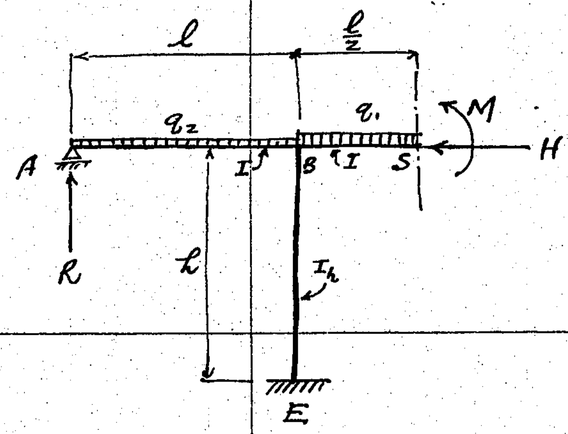
$$R = \frac{3q_2l_2^2k_3-q_1l_1^2v_2}{4l_2k_2} \qquad k_3 = 2+v_1+2v_2$$

Moments Mx at various points of beams and columns can be found from the general equations shown on page no 1 inserting the values of M, H and R in the above formulas.

Equal spans and equal moment of inertia of Beams.

$v = v_1 = v_2$, $V = 0$, $l_1 = l_2 = l$, $I_1 = I_2 = I$





$$R = -q_1 l \frac{v}{4(4+5v)} + q_2 l \frac{3(2+3v)}{4(4+5v)} \quad \text{------} \quad (15)$$

where $v = \frac{I.h}{I_h l}$

$$M = \frac{q_1(4+9v)l^2}{24(4+5v)} - \frac{q_2 v l^2}{4(4+5v)} \quad \text{------} \quad (16)$$

$$H = \frac{2q_1 l^2}{4(4+5v)h} - \frac{3q_2 l^2}{4(4+5v)h} \quad \text{------} \quad (17)$$

From these, we have for moments at various points.

$$M_B = M_C = M - \frac{q_1 l^2}{8} = -\frac{q_1 l^2(4+3v) + 3q_2 l^2 v}{12(4+5v)}$$ Center span side.

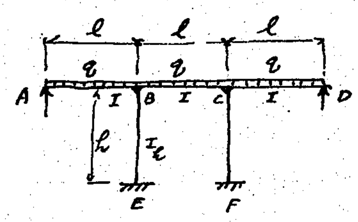
$$M_B = M_C = Rl - \frac{q_2 l^2}{2} = -\frac{q_1 l^2 v + q_2 l^2(2+v)}{4(4+5v)}$$ Side span side.

$$M_B = M_C = M - Rl - \frac{q_1 l^2}{8} + \frac{q_2 l^2}{2} = -\frac{2q_1 l^2 - 3q_2 l^2}{6(4+5v)}$$ on top of columns.

$$M_E = M_F = M - Rl - \frac{q_1 l^2}{8} + \frac{q_2 l^2}{2} + Hh = \frac{2q_1 l^2 - 3q_2 l^2}{12(4+5v)}$$ on bottom of columns.

— o —

For $q_1 = q_2 = q$.



$$R = \frac{(3+4v)}{2(4+5v)} \cdot ql$$

$$M = \frac{(4+3v)}{24(4+5v)} \cdot ql^2$$

$$H = -\frac{1}{4(4+5v)} \cdot ql^2$$

$$M_B = M_C = -\frac{(2+3v)}{6(4+5v)} ql^2$$ on center span side

$$M_B = M_C = -\frac{1+v}{2(4+5v)} ql^2$$ on sidespan side

$$M_B = M_C = \frac{1}{6(4+5v)} ql^2$$ on top of columns.

$$M_E = M_F = -\frac{1}{12(4+5v)} ql^2$$ on bottom of columns.

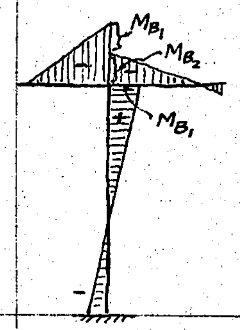
$$M_S = M = \frac{(4+3v)}{24(4+5v)} ql^2$$ at center of center span.

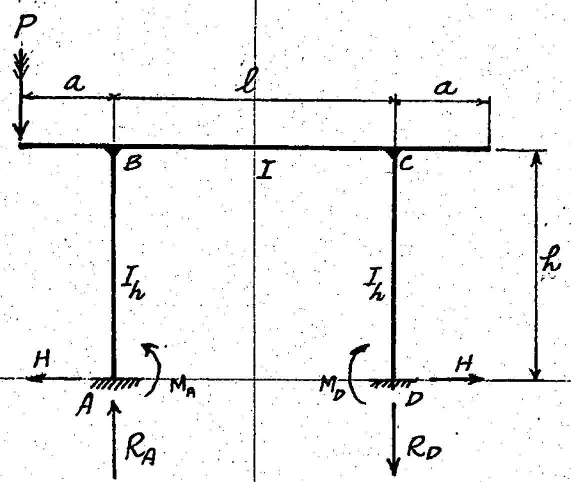
$$x_0 = \frac{(3+4v)}{2(4+5v)} l$$ distance from A of the point of max(+) moment in end span A-B

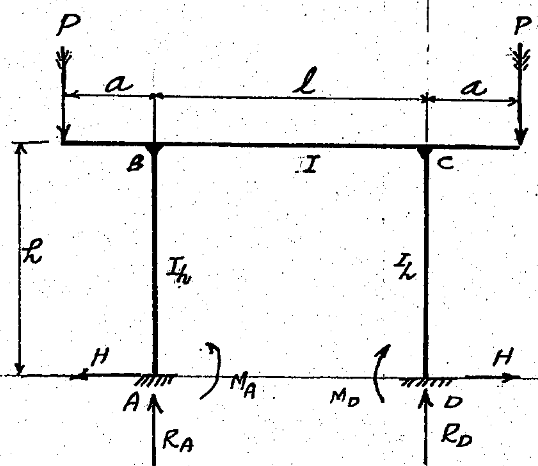
$$M_{max} = \frac{(3+2v)^2}{8(4+5v)^2} ql^2$$ max (+) moment in end span.

— o —

One span Rahmen with cantilever arms on both sides.







$$v = \frac{I \cdot h}{I_h \cdot l}$$

$$R_A = P\frac{a+l}{l} + \frac{M_D - M_A}{l}, \quad R_D = -P\frac{a}{l} + \frac{M_A - M_D}{l}.$$

$$H = \frac{Pa}{2h}\cdot\frac{3}{v+2}, \quad M_{B_1} = +\frac{Pa}{2}\cdot\frac{13v+4}{(6v+1)(v+2)}.$$

$$M_A = -\frac{Pa}{2}\cdot\frac{5v-1}{(6v+1)(v+2)}, \quad M_{B_2} = -\frac{Pa}{2}\cdot\frac{v(12v+13)}{(6v+1)(v+2)}$$

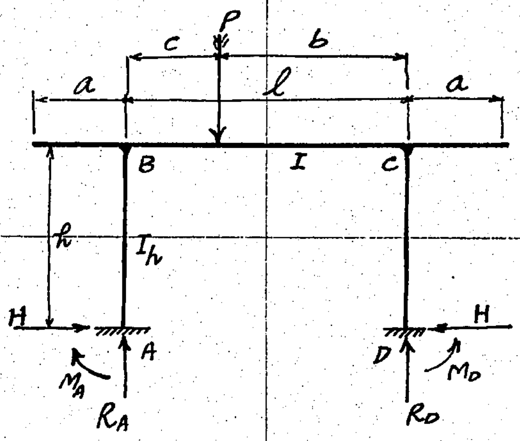
$$M_D = -\frac{Pa}{2}\cdot\frac{7v+3}{(6v+1)(v+2)}. \quad M_C = +\frac{Pa}{2}\cdot\frac{11v}{(6v+1)(v+2)}.$$

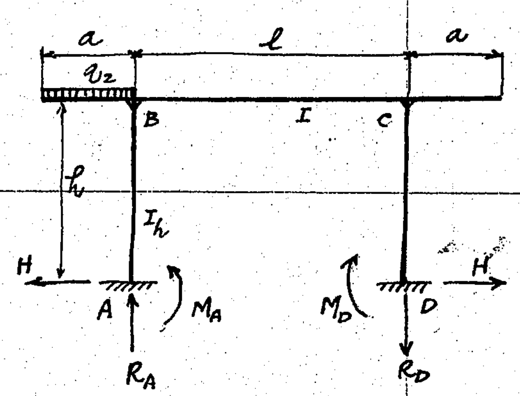
$$R_A = R_D = P, \quad H = \frac{Pa}{h}\cdot\frac{3}{v+2}.$$

$$M_A = M_D = -Pa\cdot\frac{6v+1}{(6v+1)(v+2)} = -\frac{Pa}{v+2},$$

$$M_{B1} = +\frac{2Pa}{v+2},$$

$$M_{B2} = -Pa\frac{v}{v+2}.$$





$$v = \frac{I h}{I_h l}, \quad \delta = \frac{c}{l}$$

$$R_A = \frac{Pb}{l}\cdot\frac{6v+1+\delta-2\delta^2}{6v+1}, \quad R_D = \frac{Pc}{l}\cdot\frac{6v+3\delta-2\delta^2}{6v+1}.$$

$$H = \frac{3Pcb}{2hl(v+2)},$$

$$M_A = +\frac{Pcb}{2l}\cdot\frac{5v-1+2\delta(v+2)}{(v+2)(6v+1)},$$

$$M_D = +\frac{Pcb}{2l}\cdot\frac{3+7v-2\delta(v+2)}{(v+2)(6v+1)},$$

$$M_B = M_A - Hh, \quad M_C = M_D - Hh.$$

$$M_P = M_A - Hh + R_A c$$

$$v = \frac{I h}{I_h l}$$

$$R_A = q_2 a\cdot\frac{a+2l}{2l} + \frac{M_D - M_A}{l}.$$

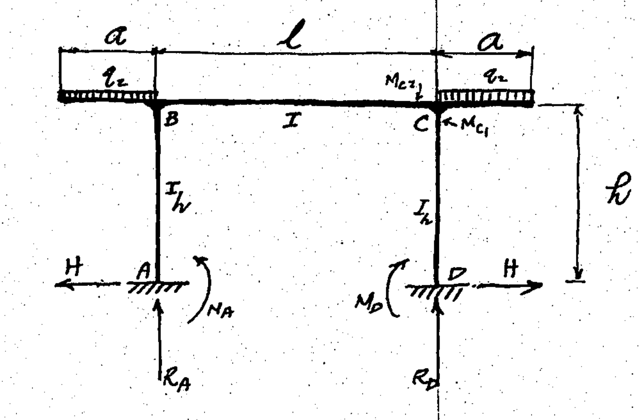
$$R_D = -q_2\frac{a^2}{2l} + \frac{M_A - M_D}{l}.$$

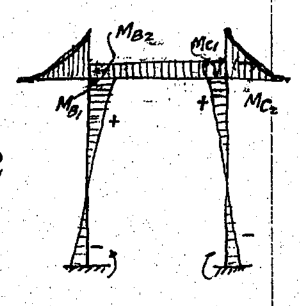
$$H = \frac{q_2 a^2}{4h}\cdot\frac{3}{v+2}, \quad M_{B_1} = +\frac{q_2 a^2}{4}\cdot\frac{13v+4}{(6v+1)(v+2)}.$$

$$M_A = -\frac{q_2 a^2}{4}\cdot\frac{5v-1}{(6v+1)(v+2)}, \quad M_{B_2} = -\frac{q_2 a^2}{4}\cdot\frac{v(12v+13)}{(6v+1)(v+2)}$$

$$M_D = -\frac{q_2 a^2}{4}\cdot\frac{7v+3}{(6v+1)(v+2)}, \quad M_C = +\frac{q_2 a^2}{4}\cdot\frac{11v}{(6v+1)(v+2)}$$

One span Rahmen with cantilever arms on both sides.



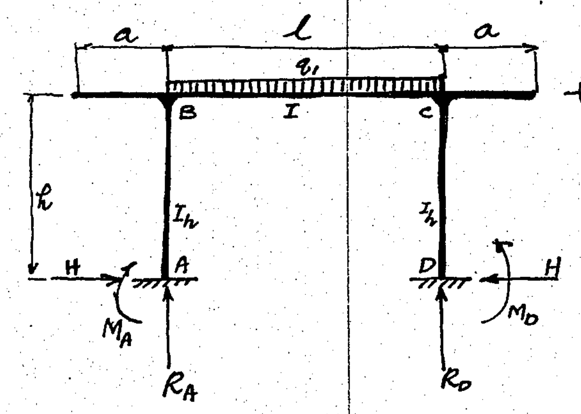


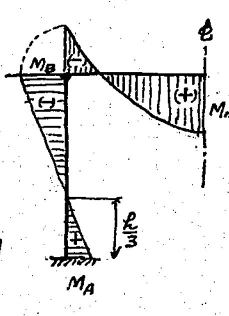
$v = \frac{I \cdot h}{I_h \cdot l}$

$R_A = R_D = q_2 a$. $H = \frac{3 q_2 a^2}{2h(v+2)}$

$M_A = M_D = -\frac{q_2 a^2}{2(v+2)}$,

$M_{B1} = M_{C1} = \frac{q_2 a^2}{v+2}$ $M_{B2} = M_{C2} = -\frac{q_2 a^2 v}{2(v+2)}$



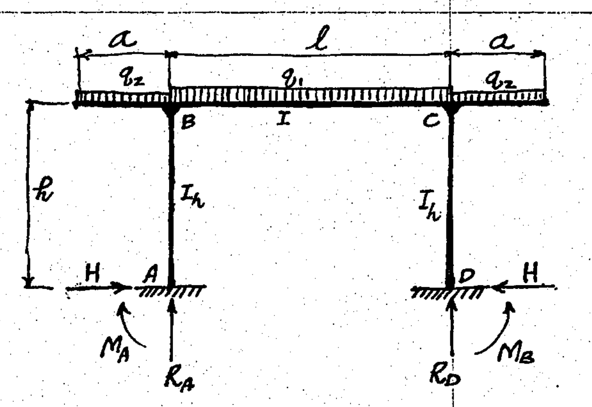


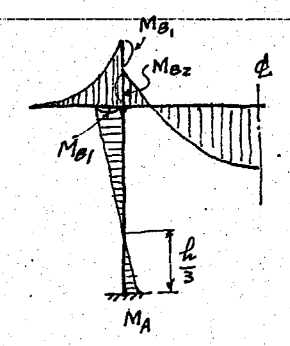
$v = \frac{I \cdot h}{I_h \cdot l}$

$R_A = R_D = \frac{q_1 l}{2}$, $H = \frac{q_1 l^2}{4h(v+2)}$,

$M_A = M_D = +\frac{q_1 l^2}{12(v+2)}$, $M_B = M_C = -\frac{q_1 l^2}{6(v+2)}$.

$M_{max.} = +\frac{q_1 l^2}{8} - \frac{q_1 l^2}{6(v+2)} = \frac{q_1 l^2}{24} \cdot \frac{2+3v}{v+2}$,





$v = \frac{I \cdot h}{I_h \cdot l}$

$R_A = R_D = q_2 a + \frac{q_1 l}{2}$. $H = \frac{q_1 l^2 - 6 q_2 a^2}{4h(v+2)}$,

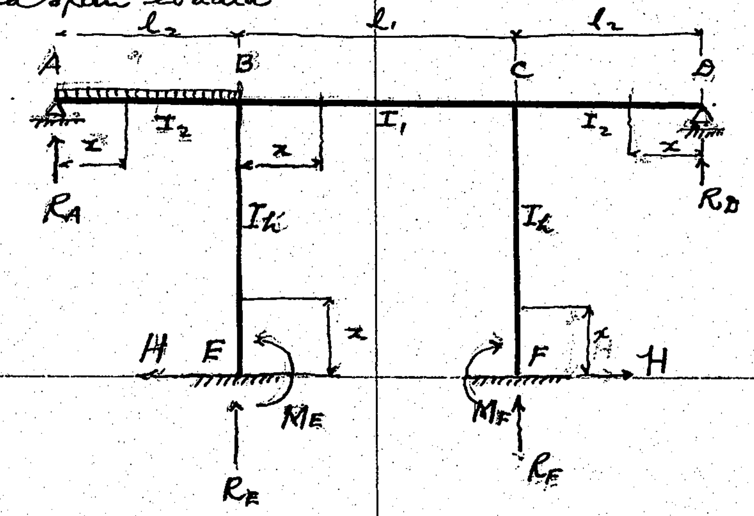
$M_A = M_D = \frac{q_1 l^2 - 6 q_2 a^2}{12(v+2)}$,

$M_{B1} = M_{C1} = \frac{6 q_2 a^2 - q_1 l^2}{6(v+2)}$,

$M_{B2} = M_{C2} = -\frac{3 q_2 a^2 v + q_1 l^2}{6(v+2)}$.

$M_{max.} = \frac{q_1 l^2 (2+3v) - 12 q_2 a^2 v}{24(v+2)}$

3 span Rahmen of a symmetrical construction
end span loaded



Redundancies
R_A
H
R_E
M_E
M_F

To find R_D $\quad R_D = -R_F - R_A - R_E + q_2 l_2$ ---------A

Taking moment at E

$$R_D = \frac{R_A l_2 - \frac{1}{2} q_2 l_2^2 + M_E - R_F l_1 - M_F}{l_1 + l_2} \quad \text{-------B}$$

Equations of moments in several members

Beam AB $\quad M_x = R_A x - \frac{q_2 x^2}{2}$ ---------- (1)

Column B-E $\quad M_x = Hx + M_E$ ---------- (2)

beam B-C $\quad M_x = R_A x - q_2 l_2 (x - \frac{l_2}{2}) + Hh + M_E + R_E(x - l_2)$

$\quad = x(R_A - q_2 l_2 + R_E) + q_2 \frac{l_2^2}{2} + Hh + M_E - R_E l_2$ ---- (3)

column C-F $\quad M_x = Hx + M_F$ ---------- (4)

beam C-D $\quad M_x = R_D x = (-R_F - R_A - R_E - q_2 l_2) x$ ---------- (5)

Partial differentiations of above moments

		$\frac{\partial M_x}{\partial R_A}$	$\frac{\partial M_x}{\partial R_E}$	$\frac{\partial M_x}{\partial H}$	$\frac{\partial M_x}{\partial M_E}$	$\frac{\partial M_x}{\partial M_F}$
Beam	A-B	x	0	0	0	0
Column	B-E	0	0	x	+1	0
Beam	B-C	x	$(x-l_2)$	h	+1	0
Column	C-F	0	0	x	0	+1
Beam	C-D	$-x$	$-x$	0	0	0

Equations for internal work

$$\frac{1}{EI_2}\int_0^{l_2}\left(R_A x - \frac{q_2 x^2}{2}\right) x\,dx + \frac{1}{EI_1}\int_{l_2}^{l_2+l_1}\left\{(R_A - q_2 l_2 + R_E)x^2 + \left(q_2\frac{l_2^2}{2} + Hh + M_E - R_E l_2\right)x\right\}dx$$

$$- \frac{1}{EI_2}\int_0^{l_2}(-R_F - R_A - R_E + q_2 l_2)x^2 dx = 0 \quad \text{-------- (6)}$$

$$\frac{1}{EI_1}\int_{l_2}^{l_2+l_1}\left\{(R_A - q_2 l_2 + R_E)x^2 - (R_A - q_2 l_2 + R_E)l_2 x + \left(q_2\frac{l_2^2}{2} + Hh + M_E - R_E l_2\right)x - \left(q_2\frac{l_2^2}{2} + Hh + M_E - R_E l_2\right)l_2\right\}dx$$

$$- \frac{1}{EI_2}\int_0^{l_2}(-R_F - R_A - R_E + q_2 l_2)x^2 dx = 0 \quad \text{--------(7)}$$

$$\frac{1}{EI_h}\int_0^h (Hx + M_E)x\,dx + \frac{1}{EI_1}\int_{l_2}^{l_2+l_1}\left\{x(R_A - q_2 l_2 + R_E) + \left(q_2\frac{l_2^2}{2} + Hh + M_E - R_E l_2\right)\right\}h\,dx + \frac{1}{EI_h}\int_0^h (Hx + M_F)x\,dx = 0 \quad \text{----(8)}$$

$$\frac{1}{EI_h}\int_0^h (Hx + M_E)dx + \frac{1}{EI_1}\int_{l_2}^{l_2+l_1}\left\{(R_A - q_2 l_2 + R_E)x + \left(q_2\frac{l_2^2}{2} + Hh + M_E - R_E l_2\right)\right\}dx = 0 \quad \text{-------(9)}$$

$$\frac{1}{EI_h}\int_0^h (Hx + M_F)dx = 0 \quad \text{----------(10)}$$

From above equations 5 unknown reactions and moments can be figured by solving determinants or the above unknowns can be determined by putting real value of span length, height of columns and respective moments of inertia.

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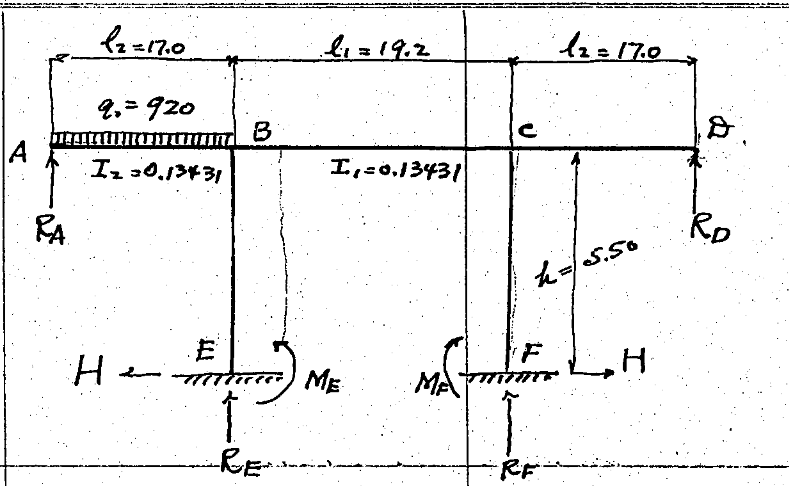
CHECKED BY________ DATE________ **PAGE NO** 8

CALCULATIONS FOR



$l_2 = 17.0$	$l_2^2 = 289$	$l_2^3 = 4913$	$l_2^4 = 83520$
$l_1+l_2 = 36.2$	$(\ )^2$ 1310	$(\ )^3$ 47440	$(\ )^4$ 1717300
$h = 5.5$	h^2 30.25	h^3 166.4	
		$\frac{h^3}{3}$ 55.46	

Putting above values in Equation (6)

$$\left[R_A\frac{x^3}{3}-\frac{qx^4}{8}\right]_0^{17}+\left[(R_A-17q+R_E)\frac{x^3}{3}\right]_{17}^{36.2}+\left[(144.5q+5.5H+M_E-17R_E)\frac{x^2}{2}\right]_{17}^{36.2}-\left[(-R_F-R_A-R_E+17q)\frac{x^3}{3}\right]_0^{17}=0$$

or $1638R_A-10.440q+14.170R_A-240.800q+14170R_E+737.50q+2807H+510.5M_E-8680R_E$
$+1638R_F+1638R_A+1638R_E-27.850q=0$

$17450R_A+7130R_E+2.807H+510.5M_E=-1638R_F+205.300$ ——————(11)

from Equation (7)

$$\left[(R_A-17q+R_E)\frac{x^3}{3}-(17R_A-289q+17R_E-144.5q-5.5H-M_E+17R_E)\frac{x^2}{2}-(2457q+93.5H+17M_E-289R_E)x\right]_{17}^{36.2}-\left[(-R_F-R_A-R_E+17q)\frac{x^3}{3}\right]_0^{17}=0$$

or $14172R_A-240800q+14172R_E-8680R_A+147500q-8680R_E+73800q+2807H+510.5M_E-8680R_E$
$-47.500q-1795H-326M_E+5550R_E+1638R_F+1638R_A+1638R_E-27.850q=0$

$7130R_A+4000R_E+1012H+184.5M_E=-1638R_F+94850q$ ——————(12)

from equation (8)

$$8.6\left[H\frac{x^3}{3}+M_E\frac{x^2}{2}\right]_0^{5.5}+7.45\left[5.5(R_A-17q+R_E)\frac{x^2}{2}+5.5(144.5q+5.5H+M_E-17R_E)x\right]_{17}^{36.2}+8.6\left[H\frac{x^3}{3}+M_F\frac{x^2}{2}\right]_0^{5.5}=0$$

or $477H+130.M_E+20.910R_A-35.5500q+20910R_E+113.700q+4325H+787M_E-13375R_E+477H+131M_F=0$

$20910R_A+7535R_E+5279H+917M_E+131M_F=241800q$ ——————(13)

from equation (9)

$$8.6\left[H\frac{x^2}{2}+M_Ex\right]_0^{5.5}+7.45\left[(R_A-17q+R_E)\frac{x^2}{2}+(144.5q+5.5H+M_E-17R_E)x\right]_{17}^{36.2}=0$$

or $130.2H+47.3M_E+3802R_A-64600q+3802R_E+20660q+786.5H+143M_E-2432R_E=0$

$3802R_A+1370R_E+916.7H+190.3M_E=43940q$ ——————(14)

From Equation (10)

$\left[H\frac{x^2}{2}+M_Fx\right]_0^{5.5}=0$ or $15.13H+5.5M_F=0$ ——————(15)

or $M_F=-\frac{15.13}{5.5}H=2.75H$

From equation 13 substituting $M_F=2.75H$

$20910R_A+7535R_E+4919H+917M_E=241.800q$ ——————(13A)

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Summarizing numerical equations

$$17450 R_A + 7130 R_E + 2807 H + 5105 M_E = -1638 R_F + 205300 q \quad \text{--- 11}$$
$$7130 R_A + 4000 R_E + 1012 H + 184.5 M_E = -1638 R_F + 94850 q \quad \text{--- 12}$$
$$20910 R_A + 7535 R_E + 4919 H + 917.0 M_E = 241800 q \quad \text{--- 13A}$$
$$3802 R_A + 1370 R_E + 916.7 H + 190.3 M_E = 43940 q \quad \text{--- 14}$$
$$15.13 H + 5.5 M_F = 0 \quad \text{--- 15}$$

from (11) $R_A + 0.409 R_E + 0.161 H + .0293 M_E = -0.094 R_F + 11.77 q$ ---- 16

(12) $R_A + 0.561 R_E + 0.142 H + .0259 M_E = -0.230 R_F + 13.31 q$ ---- 17

(13A) $R_A + 0.360 R_E + 0.2352 H + .04385 M_E = 11.560 q$ ---- 18

(14) $R_A + 0.360 R_E + 0.2411 H + .05006 M_E = 11.555 q$ ---- 19

(17)-(16) $0.152 R_E - 0.019 H - .0034 M_E = -0.136 R_F + 1.54 q$ ---- 20

(19)-(18) $0.0059 H + .00621 M_E = -0.005 q$ ---- 21

(16)-(18) $0.049 R_E - 0.0742 H - .01455 M_E = -0.094 R_F + 0.21 q$ ---- 22

(20) $R_E - 0.125 H - .0224 M_E = -0.895 R_F + 10.13 q$ ---- 23

(22) $R_E - 1.515 H - .2970 M_E = -1.919 R_F + 4.285 q$ ---- 24

(23)-(24) $1.390 H + .2746 M_E = +1.024 R_F + 5.845 q$ ---- 25

(21)-(25) $H + 1.053 M_E = -0.847 q$ ---- 26

$H + 0.1975 M_E = +0.737 R_F + 4.206 q$ ---- 27

(26) (27) $0.8555 M_E = -0.737 R_F - 5.053 q$

$M_E = -0.862 R_F - 5.905 q$ ---- 28

(26) $H - 0.908 R_F - 6.220 q = -0.847 q$

or $H = +0.908 R_F + 5.373$ ---- 29

(24) $R_E - 1.515(+0.908 R_F + 5.373 q) - 0.2970(-0.862 R_F - 5.905 q) = -1.919 R_F + 4.285 q$

$R_E = +1.375 R_F + 8.140 q - 0.256 R_F - 1.755 q - 1.919 R_F + 4.285 q$

or $R_E = -0.800 R_F + 10.670 q$ ---- 30

(19) $R_A + 0.360(-0.800 R_F + 10.67 q) + 0.2411(+0.908 R_F + 5.373 q) + 0.05006(-0.862 R_F - 5.905 q) = 11.555 q$

$R_A = +0.288 R_F - 3.838 q - 0.2190 R_F - 1.297 q + 0.04315 R_F + 0.2957 q + 11.555 q$

or $R_A = +0.1122 R_F + 6.7157 q$ ---- 31

Then

$$\left.\begin{aligned} R_A &= +0.112 R_F + 6.716 q \\ R_E &= -0.800 R_F + 10.670 q \\ H &= +0.908 R_F + 5.373 q \\ M_E &= -0.862 R_F - 5.905 q \\ M_F &= -2.500 R_F - 14.780 q \end{aligned}\right\} \quad \text{--- 32}$$

from Equation A page 7 $R_D = q l_2 - R_A - R_E - R_F$

$= 17.0 q - R_F + 0.800 R_F - 10.67 q - 0.112 R_F - 6.716 q$

$= -0.312 R_F - 0.386 q$ ---- 33

Equation B (page 7) $R_D = \dfrac{R_A l_2 - q\frac{l_2^2}{2} + M_E - R_F l_1 - M_F}{l_1 + l_2}$

$= \dfrac{17.0(0.112 R_F + 6.716 q) - 144.5 q - 0.862 R_F - 5.905 q - 19.2 R_F + 2.50 R_F + 14.780 q}{36.2}$

$$R_D = \frac{-15.658R_F - 21.425q}{36.2} = -0.433\,R_F - 0.592q \quad (34)$$

Equating 33 and 34

$$0 = -0.121\,R_F - 0.206q$$

$$R_F = -\frac{0.206q}{0.121} = -1.702q \quad (35)$$

$$R_D = +0.312 \times 1.702q - 0.386q = +0.145q \quad (36)$$

(32)	R_A = +0.112 (−1.702q)	+ 6.716q	=	+ 6.525q
	R_E = − 0.800 (−1.702q)	+ 10.670q	=	+ 12.031q
	H = + 0.908 (−1.702q)	+ 5.373q	=	+ 3.828q
	M_E = − 0.862 (−1.702q)	− 5.905q	=	− 4.438q
	M_F = − 2.500 (−1.702q)	− 14.780q	=	− 10.525q
(35)	R_F =		=	− 1.702q
(36)	R_D =		=	+ 0.145q