5. GATES AND OTHER METAL WORKS

5.1 General

The following metal equipment are proposed to provide at the each sluiceway in the Project.

a) Slide gate

2.3m width × 2.3m height
1.5m width × 1.3m height
1.3m width × 1.3m height
1.2m width × 1.2m height
1.1m width × 1.1m height
1.0m width × 1.0m height
0.9m width × 0.9m height
0.8m width × 0.8m height
0.7m width × 0.7m height

b) Flap gate

0.4m width × 0.4m height

c) Stoplog

2.3m width × 2.7m height
2.3m width × 3.4m height
1.5m width × 1.3m height
1.3m width × 1.3m height
1.2m width × 1.2m height
1.1m width × 1.1m height
1.0m width × 1.0m height
0.9m width × 0.9m height
0.8m width × 0.8m height
0.7m width × 0.7m height
0.4m width × 0.4m height

d) Trashrack

10.0m width × 2.403m height

c) Mesh cover

10.0m width × 378.4m length

5.2 Standard to be applied

The design and fabrication of gates, in principle, conform to the applicable provisions of the Technical Standards for Gates and Penstocks published by the Hydraulic Gate and Penstock Association of Japan. The Japanese Industrial Standards (JIS) and the American Society for Testing and Materials (ASTM) are mainly adopted for the materials to be used and workmanship of the works. In addition, the Indonesian National Standards are applied as much as possible

5.3 Gate

Nine (9) sizes of steel-made slide gates and one (1) size of steel-made flap gate are designed at the drain inlet or outlets for draining the water from inland area and for preventing the adverse flow of flood water from the river or main drain.

(1) Slide gates

Type of gate shall be determined from the view points of the required purpose, functions, frequency of operation, safety, convenience of operation and maintenance, installed location and circumstances, civil structure, etc., and also from the economical view point. Slide gate or roller (fixed wheel) gate is generally adopted for the drain inlet or outlet gates in vertical lift type gate. The slide gate is of plate girder construction and is simple structure compared with the roller gate because no rollers exist. While, the operating load is larger than that of roller gate due to the friction force of bearing plates. Thus, the slide gate in drain is used for small span gate and small operating head as described hereunder, but shall not be limited to.

Standard for Selection of Slide Gate and Roller Gate

Item	Slide Gate	Roller Gate
Clear span	less than 2.50 m	more than 2.50 m

Operating load	less than 6.0 tf	more than 6.0 tf

The vertical lift slide gate is selected as the drain inlet or outlet gate in due consideration of :

① The gate size is relatively small, i.e., the largest one is 2.30 m width × 2.30 m height
② The gate is operated under the water head difference of 1.0 m i.e, the gate is operated with small operating load.
③ The gate cost is cheaper due to simple structure.
④ The maintenance is easy, i.e., the lubrication is not required for the gate.
⑤ The gate is kept at fully opened position in dry season and the gate is operated to close at the time of flood, i.e., the frequency of operation is a relatively low.

Each gate consists of skin plate, main horizontal beams, vertical beams, bearing cum seal clamp plates, rubber seals, side guides, front wedges, lifting lug and all other necessary components, and the gate is capable of overcoming all loads at any water level up to H.W.L..

The skin plate and rubber seals are provided at the land side (anti-pressure side) of gate leaf because of requirement of perfect water tightness at flood.

The guide frame consists of the sealing frames, linter beam, sill beam, track frames, front frames, side guide frames and all other components necessary for the complete and satisfactory installation of the guide frame. The corrosion - resisting steel plates are attached to the sealing frame surfaces to avoid excessive wear of rubber seals.
The loads on the guide frame are the bearing load and all other loads due to the most adverse operation of the gate by the hoist. The guide frame and anchors are capable of transferring all the loads of bearing plate, side guides and rubber seals of the gate to the concrete structure.

The power source will not be supplied for the gate operation in principle. Accordingly, the gate should be operated by the man power within the limited operating force which a operator can operate the hoist continuously.

A manually driven single stem screwed spindle hoist is selected for each slide gate operation device because of:

① small lifting load,
② limited space,
③ availability of forcible lowering force by the hoist,
④ enough lead time for gate operation,
⑤ simple and compact construction,
⑥ easy maintenance and operation,
⑦ reliability and durability of the hoist,
⑧ small span (Normally two stem spindle hoist is used for the gate having a span of 2.5 m or more),
⑨ a few time operation of gate throughout a year and
⑩ low cost.

Each hoist consists of screwed spindle with its supports , gear reducer unit with gear cover, bearings manual operating device, position indicator and other necessary components for safe, proper and efficient operation. The hoist should be established on the structural steel base frame works. The spindle is made of corrosion-resisting steel.

If necessary the spindle supports are provided at proper positions with a interval to avoid the buckling of spindle due to over-lowering force when the gate is jammed or closed. The operation force on the manual operating device is less than 10 kgf force under normal design condition. The operation force is given by the 300 to 600 mm in diameter handle which is located at approximately 800 mm in height from the operation deck.

The design data of the slide gates are summarized as follows:

type	: Square steel made slide gate
clear span	: 700, 800, 900, 1000, 1100, 1200, 1300, 1500 and 2300 mm
clear height	: 700, 800, 900, 1000, 1100, 1200, 1300, 1300 and 2300 mm
design head	: Hydrostatic pressure of H.W.L. + 1.0m - Sill EL.
operation head	: Water head difference of 1.0 m
sealing method	: 4 edges rubber seal at land side

maximum deflection of main beams	: 1/800 of supporting span
corrosion allowance	: 0.5 mm for water contact face members
type of hoist	: Manually driven single stem screwed spindle hoist
hoisting height	: Clear height + 5 cm in normal operation
maximum operation force of handle	: less than 10 kgf

Note: The design water level (H.W.L. + 1.0m) is determined in account of ground subsidence which is caused in the future.

(2) Flap gates

The flap gates are provided at the drain outlets having the small size culverts (0.4 m width by 0.4 m height) which are located at arban areas in tributary. The flap gate can be operated automatically by a water head difference between upstream and downstream sides of the gate without operator. The circular type flap gate is normally provided for the circular type culvert, but the square type flap gate is provided for the circular type culvert because of easy manufacturing and water tightness thereof. The circular type flap gate is normally made in one piece by the mould with gray iron or spheroidal graphite iron casting or other alloy castings. The guide is also made in one piece as well as the gate. After moulding the gate and guide, the precise manufacturing, for example mechanical processing is required to get enough water tightness of the gate.

While, the square type flap gate is made of steel plates and sections . The guide frame is also made of steel plates and sections as well as gate. Therefore steel-made gate can be comparatively easily reformed, so the manufacturing is very easy compared with the circular type gate. The metal seal or rubber seal is generally used for the sealing method of the flap gate. The former water tightness of the gate is seriously affected by accuracy of manufacturing while, the latter elasticity of the rubber can absorb the distortion of manufacture. Flap gate is sometimes made from aluminum alloy. The comparison of the steel flap gate and aluminum ally flap gate is as follows:

Item	Steel flap gate	Aluminum alloy flap gate

Manufacturing	Easy	There are few factory which have facilities for aluminum welding in the Republic of Indonesia in comparison with steel gate.
Durability	Good Repainting is required 3 to 5 years	Poor Body of flap gate has enough durability as well steel flap gate. However stainless steel is used at the part of hinge by reason of strength. As a result, the part of aluminum alloy which is closed to the stainless steel is concentratively damaged by the Galvanic corrosion. Therefore, total durability should be poor.

As a result, the square type steel made flap gate having rubber seal is:

- supplied by the low cost,
- expected for perfect water tightness
- high durability, and
- easily manufactured

compared with the circular type flap gate.

The rectangular type flap gate is sometimes made of timber with combination steel plates and bolts. The comparison of steel flap gate and timber flap gate is as follows:

Item	Steel flap gate	Timber flap gate
Structure	Simple Welded steel girder construction with seal	Complication First class teak wood reinforced by steel plates, bolts and nuts
Water tightness	Good	Poor due to uneven con-

		tact between timber block and seating frame, the timber warps in dry condion.
Construction cost	- Same level -	
Reliability of operation by head difference	- Same level -	
Durability	Good Repainting is required every 3 to 5 years.	Poor Replacement of timber is required. Repainting is required for steel portions.
Garbage problem	- Same level -	
Installation	- Same level -	
Manufacturing difficulty	- Same level -	

It is recommended from the above comparison that the steel made flap gate with rubber seal shall be used for the Project.

The flap gate consists of skin plate, main beams, edge beams, side hinges, supporting arms and other necessary components and the gate is capable of overcoming all loads at any water level up to H.W.L.. The skin plate is provided at the river side (pressure side) of gate leaf, but the rubber seal is provided at the land side of gate leaf for the complete water tightness at flood. The hinge and liftting lug are provided on upper part of gate to support the gate and to turn the gate to outward or inward. The material of the pin is corrosion-resisting steel.

The guide frame consists of upper, bottom and side frames, hinge brackets and other components necessary for the complete and satisfactory installation of the guide frame. The corrosion-resisting steel plates are attached to four edge frames to avoid excessive wear thereof. The guide frame and anchors are capable of transferring the load of the metal seals of the gate to the concrete structure. The hinge brackets are rigidly fixed by the anchors to perfectly support the gate and no binding occurs when the gate is opened and closed.

The design data of the flap gates are summarized as follows:

Type	: square steel made flap gate
Clear span	: 400 mm
Clear height	: 400 mm
Design head	: hydrostatic pressure of H.W.L. + 1.0m - bottom seal EL.
Inclined angle	: 4 °
Operation	: automatically operated by water pressure difference
Sealing method	: 4 edges rubber seal at land side
Maximum deflection of main beam	: 1/800 of supporting span
Corrosion allowance	: 1.0 mm for water contact face members

5.4 Design of stoplog

To maintain the gate leaf, guide slots and piers, stoplogs are installed at the outlet or inlet of each sluiceway The slide gate is provided at the same sluiceway. Since the H.W.L. should be taken same value in the structural calculation.

(a) Gate type selection

The timber stoplog is selected because of:

① The span and water head is comparatively small,
② The stoplog is dealt by man power, therefore light material is profitable,
③ and low cost

(b) Gate details

The stoplog shall consist of wooden timber of class I (pkk-1), lifting lugs and all other necessary components. The guide frames shall consist of slot corner frames and all other components necessary for the complete and satisfactory installation of the guide frame.

(c) Portable hanger

The stoplog having 2.3m in clear span shall be handled by the portable hanger. The portable hanger shall be provided on the slab of drain for easy handling the timber stoplogs. The portable hanger shall consist of a hanger support, required number of stands and a handling tools with slings and hooks. The hanger support shall be of a steel pipe construction with a U-hook for suspending a handling tool. The stand for hanger shall be adequate for removing the hanger. The handling tool shall be of manually operated chain block type.

5.5 Design of Trashrack

To prevent the garbage which shall obstruct the smooth flow in the drain, fixed type tashrack is installed at the entrance of the open culvert of Saluran Cengkaren sluiceway, two (2) inlet points of the tributary drain which flow into the outlet part of the Saluran Cengkareng sluiceway and the one (1) spot of Meruya area. Each trashrack is inclined at an angle of 16.7 ° to the vertical plane. The above inclination is decided so as considering convenience of cleaning on their surface by manual. Each trashrack comprises screen panels, top and bottom embedded beams etc. The screen panels consist of rectangular bar elements, tie rods with nuts and spacing pipes, and they are fixed to the embedded beams.

The trashracks are designed to have a sufficient strength and suitable structure against the impact force, static and all other loads, and vibration phenomena which would likely occur due to the inflow of water.

The design head of the trashracks shall be determined to consider the head loss at the trashracks and the head difference between upstream side and downstream side. The flow velocity in this drain is small, therefore the head loss which is obtained by the calculation is very small. The quantity of the garbage in this drain is large, so head loss is mainly affected with obstruction caused by the trash at the screen. However it is very difficult to estimate the amount of the debris in this drain, since it is owe to the maintenance frequency and its interval. Therefore at the upper stream side design water level of trashrack shall be adopted to be H.W.L. and at the down stream side it shall adopted bottom elevation of the drain.

Consequently the design head of the trashrafck of this project is determined to be 2.0m of water head difference.

The pitch of bar elements is decided as 75mm to prevent flowing down and accumulating the dumped plastic goods, thrown empty juice cans and many dumped trash which maybe obstruct the smooth flow in the drain.

The design data of the typical trashrack is summarized as follows:

Type	:	Slant type fixed trashracks
Quantity	:	Two (2) sets, One (1) set
Clear span	:	3.333 m , 3.334 m
Concrete deck elevation	:	EL. +1.735
Sill elevation	:	EL. -0.668
Vertical height	:	2.403 m
Gradient	:	1 : 0.3
Slant length	:	2.867 m
Bar pitch	:	75 mm (Center to Center)
Design head	:	Water head of 2.0 m
Corrosion allowance	:	1.0 mm for water contact face members

5.6 Design of Mesh Cover

The Mesh Cover is provided at the part of the open culvert of Saluran Cenkareng drain to prevent thrown away the garbage. Expanded Metals (JIS G 3351 XS-type) should be used as the the mesh cover because of lightness and comparative strength. The mesh size is determined to be 50 mm square so as the relatively large garbage not to be dumped. The panel size of mesh cover is determined to be 2.0 m width × 3.5 m length for easy handling . The edge of mesh cover should be fixed with angle steel by welding. The angle steel is designed to consider the self weight of mesh cover panel and the garbage load of 10 kg/m^2. The mesh cover panel should be fixed with anchor bolts on the concrete of the drain.

5.7 Calculation of Slide gate (2.3m×2.3m)

5.7.1 General

Slide gates having 2.3 m wide by 2.3 m high is provided at the following sluiceway. The main design data for slide gate is as follows:

Main Design Data for Slide Gate

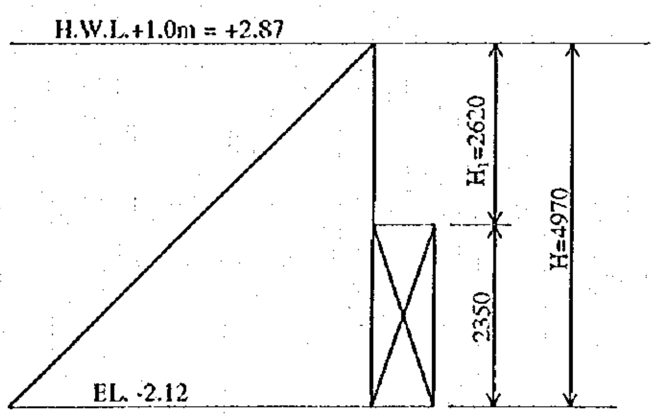
No.	Gate No.	H.W.L.+1.0m	(Sill El.).	Design Head (m)	Quantity (set)
1.	SKE-3R	+3.328	+1.452	1.876	1

5.7.2 Design Conditions

Type	: Steel made slide gate
Quantity	
Gate leaf	: 1 set
Guide frame	: 1 set
Hoist	: 1 set
Clear span	: 2.3 m
Clear height	: 2.3 m
Design head	: 4.97m (H.W.L.1.87+1.0m-Sill EL.-2.10m)
Sealing method	:4 edges rubber seal at downstream face of gate
Maximum deflection of main horizontal beams	:1/800 of supporting span
Corrosion allowance	: 0.5mm(One face)
Type of hoist	: Manual driven screwed spindle hoist
Operation head	: 1.0m
Hoisting height	: 2.75m(EL 0.65m-EL -2.10m)
Operation method	: Local

5.7.3 Design Load

(1) Hydraulic load



$$Pt = 0.5 \times (H^2 - H_1^2) \times B \times GW$$

where,

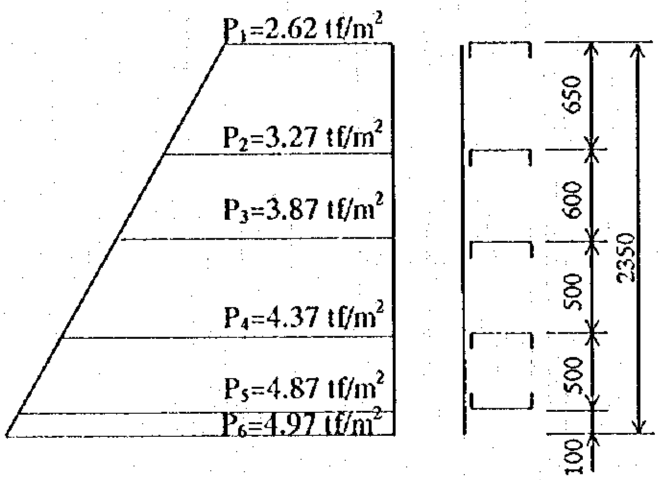
Pt	:Hydraulic load		(tf)
H	:Water head at gate bottom	4.970	m
H_1	:Water head at upper seal	2.61	m
B	:Sealing span	2.48	m
GW	:Specific gravity of water	1.0	tf/m³

Thus,

$$Pt = 0.5 \times (4.97^2 - 2.620^2) \times 2.48 \times 1.0$$
$$= 22.117\, tf$$

5.7.4 Main Horizontal beams

(1) Arrangement of main horizontal beams
Five (5) number of main horizontal beams are arranged follows:



Charging load on each beam

Charging load acting on each beam is calculated by following equation:

$$Beam\ A = \frac{(2 \times 2.620 + 3.270)}{6} \times 0.650$$
$$= 0.922\, tf/m$$

$$Beam\ B = \frac{(2.620 + 2 \times 3.270)}{6} \times 0.650 + \frac{(2 \times 3.270 + 3.870)}{6} \times 0.600$$
$$= 2.033\, tf/m$$

$$Beam\ C = \frac{(3.270 + 2 \times 3.870)}{6} \times 0.600 + \frac{(2 \times 3.870 + 4.370)}{6} \times 0.500$$
$$= 2.110\, tf/m$$

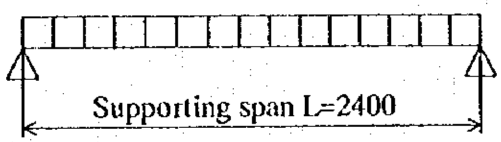
$$Beam\ D = \frac{(3.870 + 2 \times 4.370)}{6} \times 0.500 + \frac{(2 \times 4.370 + 4.870)}{6} \times 0.500$$
$$= 2.185\, tf/m$$

$$Beam\ E = \frac{(4.370 + 2 \times 4.870)}{6} \times 0.500 + \frac{(4.870 + 4.970)}{2} \times 0.100$$
$$= 1.668\ tf\ /m$$

(3) Bending moment and shearing force

(a) Bending moment

Maximum bending moment is calculated by the following equation:



$$M\max = W \times L / 8$$

where,			
	$M\max$	:Maximum bending moment	(tf-m)
	W	:Design load acting on the beam	(tf)
	L	:Supporting span	2.40m

(b) Max Shearing force is calculated by the following equation:

$$S\max = W / 2$$

where,			
	$S\max$	:Maximum shearing force	(tf)
	W	:Design load acting on beam	(tf)

(c) Calculation result

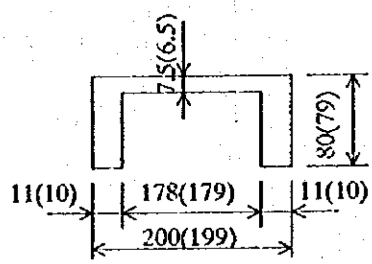
The calculation result is as follows:

		Beam D
W	(tf)	5.419
M max	(tf-m)	1.626
S max	(tf)	2.710

As maximum design load acts on beam D , bending moment and shearing force are calculated only on beam D.

(4) Sectional property of beams

	Beam D
Sectional dimension	



$I(cm^4)$	1723
$Z(cm^3)$	173
$A(cm^2)$	27.43

(5) Bending and shearing stress

Bending and shearing stress are calculated by the following equations:

$$\sigma \max = \frac{M \max \times 10^5}{Z}$$

$$\tau \max = \frac{S \max \times 10^3}{A_W}$$

where,			
	σ max	: Maximum bending stress	(kgf/cm^2)
	M max	: Maximum bending moment	(tf-m)
	Z	: Modulus of section	(cm^2)
	τ max	: Maximum shearing stress	(kgf/cm^2)
	S max	: maximum shearing	(tf)
	A_W	: Area of web at both ends	(cm^2)

	Beam D
M max	1.626
Z	173
σ max	940
S max	2.710
A_W	11.63
τ max	233
Allowable bending stress(kgf/cm^2)	1,200 (Material 40kgf/mm^{2}class mild steel)
Allowable scaring stress(kgf/cm^2)	700 (-ditto-)

(6) Deflection

Maximum deflection of each beams is calculated by the following equation:

$$\delta \max = \frac{5WL^3}{384EI}$$

where,			
	δ max	: Maximum deflection of each beam	(cm)
	W	: Design load on each beam	(kgf)
	L	: Supporting span	240cm
	E	: Elastic Modulus of steel	$2.1 \times 10^6 kgf / cm^2$
	I	: Geometrical moment of inertia (cm^4)	

Thus,

	Beam D

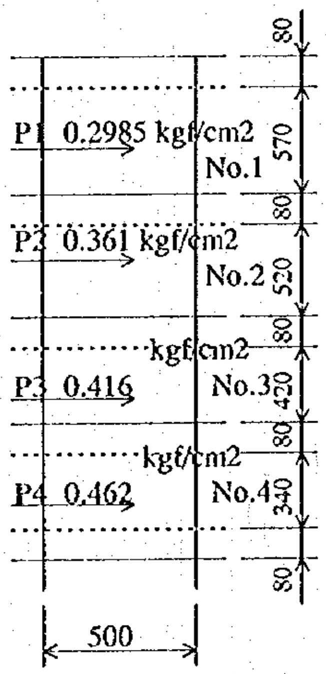
$W\ (kgf)$	5419
$I\ (cm^4)$	1723
$\delta\ (cm)$	0.270
$\delta / L\ (cm)$	1/889
Allowable deflection	< 1/800

5.7.5 Skin Plate

Bending stress of skin plate is calculated in accordance with the following Timoshenko's formula:

$$\sigma = \frac{k \cdot a^2 \cdot p}{100(t - \varepsilon)^2}$$

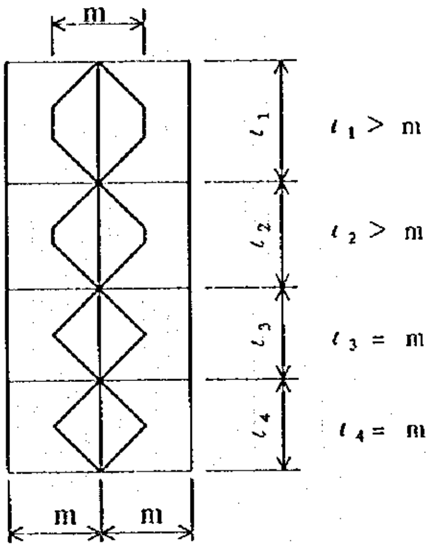
where,			
	σ	: Bending stress	(kgf/cm^2)
	k	: Coefficient by "b/a"	
	a	: Short span of plate	(cm)
	b	: Long span of plate	(cm)
	p	: Mean design pressure	(kgf/cm^2)
	t	: Thickness of plate	(cm)
	ε	: Corrosion allowance	0.1cm

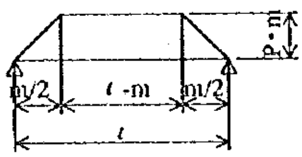


	No.1	No.2	No.3	No.4
a(cm)	50.0	50.0	42.0	34.0
b(cm)	57.0	52.0	50.0	50.0
b/a	1.14	1.04	1.19	1.47
k	36.16	32.40	38.06	44.89
p (kgf/cm^2)	0.2985	0.3610	0.4160	0.4620
t(cm)	0.5	0.5	0.5	0.5
σ (kgf/cm^2)	1079	1170	1117	959
σ a(kgf/cm^2)	1200	1200	1200	1200

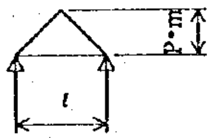
5.7.6 Vertical Girders

(1) Bending moment and shearing force are calculated by the following formula.





(a) $\ell > m$



(b) $\ell \leqq m$

(a) $\ell > m$

Bending moment

$$M = P \times m \times (3\ell^2 - m^2)/24$$

Shearing force

$$S = P \times m \times (\ell - m/2)/2$$

(b) $\ell \leqq m$

Bending moment

$$M = P \times m \times \ell^2 /12$$

Shearing force

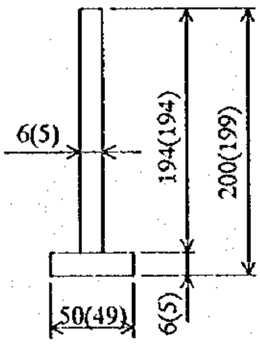
$$S = P \times m \times \ell /4$$

where, M : Maximum bending moment (kgf-cm)
P : Mean water pressure (kgf/cm^2)
m : Pitch of vertical girder 50.0 cm
ℓ : Distance between horizontal beams (cm)
S : Maximum shearing force (kgf)

Portion	m	ℓ	P	M	S
1	50.0	65.0	0.2945	6243	295
2	50.0	60.0	0.357	6173	312
3	50.0	50.0	0.412	4292	258
4	50.0	50.0	0.462	4813	289

(2) Sectional property

Following section is used.



Moment of inertia I $=498\ cm^4$
Modulus of section Z $=43\ cm^3$
Area of web Aw$=9.7\ cm^2$

Bending and shearing stresses

$\sigma = M / Z$

where, σ : Maximum bending stress (kgf/cm^2)
M : Maximum bending moment 6243 kgf-cm
Z : Modulus of section 43 cm^3

Thus,

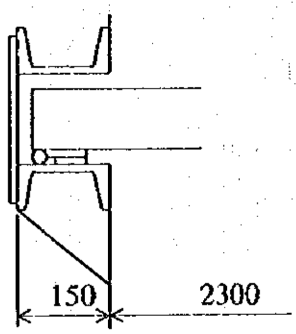
$\sigma = 6243 / 43$
$= 145\ kgf\ / cm^2 < 1.200\ kgf\ / cm^2 =$ *Allowable bending stress*
$\tau = S / Aw$

where, σ : Maximum shearing stress (kgf/cm^2)
S : maximum shearing force 312 kgf
Aw : Area of web 9.7 cm^2

Thus,

$\tau = 362 / 9.7$
$= 32\ kgf\ / cm^2 < 700\ kgf\ / cm^2 =$ *Allowable shearing stress*

5.7.7 Guide frame



Bearing stress of concrete

$$\sigma c = Pt / 2 \times b \times l$$

where,			
	σc	: Concrete bearing stress	(kgf/cm^2)
	Pt	: Hydraulic load	22117(kgf)
	b	: Flange width of track frame	15.0 (cm)
	l	: Sealing height	235.0(cm)

Thus,

$$\sigma c = \frac{22117}{2 \times 15.0 \times 235.0} = 3.1\, kgf / cm^2 < \sigma ca = 60\, kgf / cm^2$$

(2) Shearing stress of concrete

$$\tau c = Pt / 2 \times ls \times \ell$$

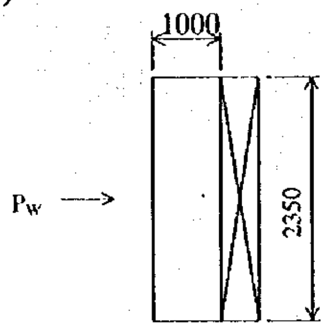
$$ls = 15.0 \times \sqrt{2} = 21.2\, cm$$

$$\tau c = \frac{22117}{2 \times 21.2 \times 235} = 2.22\, kgf / cm^2 < \tau ca = 3.6\, kgf / cm^2$$

5.7.8 Operation Load

(1) Operation Conditions
The slide gate is operated under the water head difference of 1.0m .

(2) Water Pressure Load at Operating.



$$Pw = H \times Hs \times B \times Gw$$

where,			
	Pw	: Water pressure load at operating (tf)	
	H	: Operating head	1.0m
	Hs	: Sealing height	2.35m
	B	: Sealing span	2.48m
	Gw	: Specific gravity of water	1.0 tf/m^3

Thus,

$$Pw = 1.0 \times 2.35 \times 2.48 \times 1.0$$
$$= 5.828\, tf$$

(3) Operating Load

(a) Own weight of gate leaf and spindle

$$Wg = 1.05\,tf$$

(b) Friction force of seal rubber

$$FrR = \mu \times (q \times p \times b) \times \Sigma_1$$

where,

FrR	: Friction force of seal rubber (tf)	
μ	: Friction coefficient of seal rubber	
	at starting 1.5	
	at sliding 0.7	
q	: Initial compression load on seal rubber	0.1 tf/m
p	: Mean design pressure	1.0 tf/m^2
b	: Contact width of seal rubber	0.03 m
Σ_1	: Total sliding length of seal rubber	7.18 m

Thus,

(i) at Raising

$$FrR = 1.5 \times (0.10 + 1.0 \times 0.03) \times 7.18$$
$$= 1.40\,tf$$

(ii) at Lowering

$$FrL = 0.7 \times (0.10 + 0.0 \times 0.03) \times 7.18$$
$$= 0.503\,tf$$

(c) Friction force of bearing plate

$$Fb = Pwr \times \mu b$$

where,

Fb	: Friction force of bearing plate (tf)	
Pwr	: Water pressure load	5.828 tf
μb	: Frictional coefficient of bearing plate	0.45

Thus,

$$Fb = 5.828 \times 0.45 = 2.623\,tf$$

(d) Buoyancy

$$Fb = \frac{G}{jo}$$

where,

F	: Buoyancy	(tf)
G	: Weight gate leaf	1.05 tf
jo	: Specific gravity	7.85 tf/m^3

Thus,

$$Fb = \frac{1.05}{7.85} = 0.134tf$$

(c) Total operation load

	Raising load (tf)	Lowering load (tf)
Gate weight(Wg)	+1.05	+1.05
Friction force due to seal rubber(Fr)	+1.40	-0.503
Friction force of bearing plate	+2.623	
Buoyancy(Fb)		-0.134
Total	+5.073	+0.413

where,
Operation load at
Raising : 5.1 tf(including allowance)
Lowering : 0.5 tf

5.7.9 Hoist

5.1 tf capacity manual hoist × 1 set

5.8 Calculation of Slide gate (1.5m × 1.3m)

5.8.1 General

Slide gates having 1.5 m wide by 1.3 m high are provided at the each sluiceways. The main design data for each slide gate are as follows:

Main Design Data for Slide Gates

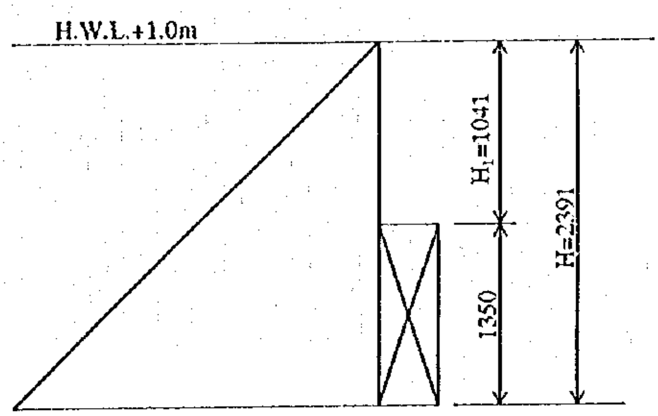
No.	Gate No.	H.W.L.+1.0m	(Sill El.).	Design Head(m)	Quantity(set)
1.	SKM-3L	+1.850	-0.541	2.391	1

5.8.2 Design Conditions

Type	: Steel made slide gate
Quantity	
Gate leaf	: 1 set
Guide frame	: 1 set
Hoist	: 1 set
Clear span	: 1.5 m
Clear height	: 1.3 m
Design head (H.W.L.+1.0m-Sill EL.)	: 2.391 m
Sealing method	:4 edges rubber seal at anti-pressure side(land side)
Maximum deflection of main horizontal beams	:1/800 of supporting span
Corrosion allowance	: 0.5mm for water contact face members)
Type of hoist	: Manual driven screwed spindle hoist
Operation head	: Water difference of 1.0m
Hoisting height	: Clear height + 5 cm in normal operation
Operation method	: Local

5.8.3 Design Load

(1) Hydraulic load



$$Pt = 0.5 \times (H^2 - H_1^2) \times B \times GW$$

where,		
	Pt :Hydraulic load	(tf)
	H :Water head at gate bottom	2.391 m
	H_1 :Water head at upper seal	1.041 m
	B :Sealing span	1.68 m
	GW :Specific gravity of water	1.0 tf/m^3

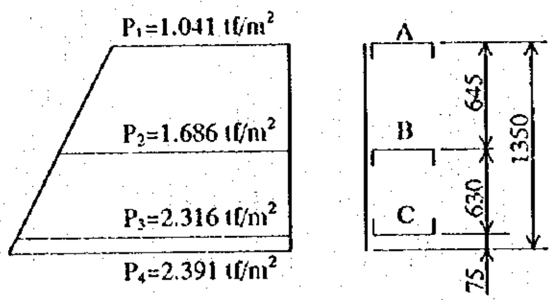
Thus,

$$Pt = 0.5 \times (2.391^2 - 1.041^2) \times 1.68 \times 1.0$$
$$= 3.892\ tf$$

5.8.4 Main Horizontal beams

(1) Arrangement of main horizontal beams

Three (3) number of main horizontal beams are arranged follows:



Charging load on each beam

Charging load acting on each beam is calculated by following equation:

$$Beam\ A = \frac{(2 \times 1.041 + 1.686)}{6} \times 0.645$$
$$= 0.405\ tf\ /m$$

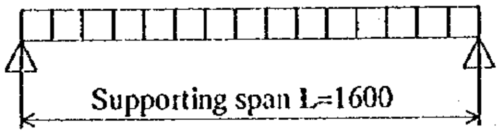
$$Beam\ B = \frac{(1.041 + 2 \times 1.686)}{6} \times 0.645 + \frac{(2 \times 1.686 + 2.316)}{6} \times 0.630$$
$$= 1.072\ tf\ /m$$

$$Beam\ C = \frac{(1.686 + 2 \times 2.316)}{6} \times 0.630 + \frac{(2.316 + 2.391)}{2} \times 0.075$$
$$= 0.840\ tf\ /m$$

(3) Bending moment and shearing force

(a) Bending moment

Maximum bending moment is calculated by the following equation:



$$M\max = W \times L / 8$$

where,

$M\max$	:Maximum bending moment	(tf-m)
W	:Design load acting on the beam	(tf)
L	:Supporting span	1.60m

(b) Max Shearing force is calculated by the following equation:

$$S\max = W / 2$$

where,

$S\max$	:Maximum shearing force	(tf)
W	:Design load acting on beam	(tf)

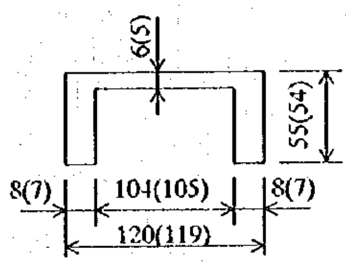
(c) Calculation result

The calculation result is as follows:

		Beam B
W	(tf)	1.801
M max	(tf-m)	0.360
S max	(tf)	0.901

As maximum design load acts on beam B , bending moment and shearing force are calculated only on beam B.

(4) Sectional property of beams

	Beam B
Sectional dimension	
$I(cm^4)$	286
$Z(cm^3)$	48
$A(cm^2)$	12.81

(5) Bending and shearing stress

Bending and shearing stress are calculated by the following equations:

$$\sigma\max = \frac{M\max\times 10^5}{Z}$$

$$\tau\max = \frac{S\max\times 10^3}{A_W}$$

where,			
	σ max	: Maximum bending stress	(kgf/cm^2)
	M max	: Maximum bending moment	(tf-m)
	Z	: Modulus of section	(cm^2)
	τ max	: Maximum shearing stress	(kgf/cm^2)
	S max	: maximum shearing	(tf)
	A_W	: Area of web at both ends	(cm^2)

	Beam B
M max	0.360
Z	48
σ max	750
S max	0.901
A_W	5.25
τ max	172
Allowable bending stress(kgf/cm^2)	1,200 (Material 40kgf/mm^{2}class mild steel)
Allowable searing stress(kgf/cm^2)	700 (-ditto-)

(6) Deflection

Maximum deflection of each beams is calculated by the following equation:

$$\delta\max = \frac{5WL^3}{384EI}$$

where,			
	δ max	: Maximum deflection of each beam	(cm)
	W	: Design load on each beam	(kgf)
	L	: Supporting span	160 cm
	E	: Elastic Modulus of steel	$2.1\times10^6 kgf\ /cm^2$
	I	: Geometrical moment of inertia (cm^4)	

Thus,

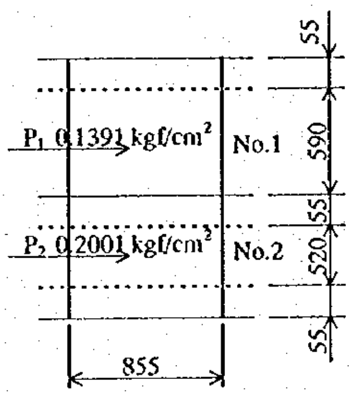
	Beam B
$W\ (kgf)$	1801
$I\ (cm^4)$	286
$\delta\ (cm)$	0.160
$\delta\ /\ L\ (cm)$	1/1000
Allowable deflection	< 1/800

5.8.5 Skin Plate

Bending stress of skin plate is calculated in accordance with the following Timoshenko's formula:

$$\sigma = \frac{k \cdot a^2 \cdot p}{100(t-\varepsilon)^2}$$

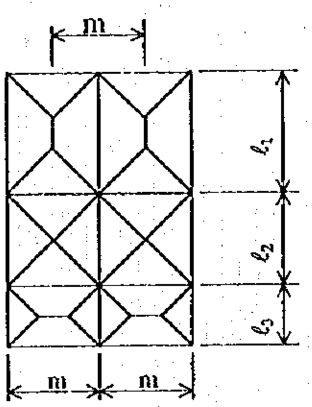
where,			
	σ	: Bending stress	(kgf/cm²)
	k	: Coefficient by "b/a"	
	a	: Short span of plate	(cm)
	b	: Long span of plate	(cm)
	p	: Mean design pressure	(kgf/cm²)
	t	: Thickness of plate	(cm)
	ε	: Corrosion allowance	0.1cm

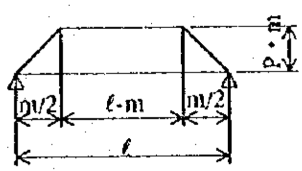


	No.1	No.2
a(cm)	59.0	52.0
b(cm)	85.5	85.5
b/a	1.449	1.644
k	44.44	47.17
p (kgf/cm²)	0.1391	0.2001
t(cm)	0.5	0.5
σ (kgf/cm²)	861	1021
σ a(kgf/cm²)	1200	1200

5.8.6 Vertical Girders

(1) Bending moment and shearing force are calculated by the following formula.





(a) $\ell > m$

(b) $\ell \leq m$

(a) $\ell > m$

Bending moment

$$M = P \times m \times (3\ell^2 - m^2) / 24$$

Shearing force

$$S = P \times m \times (\ell - m/2) / 2$$

(b) $\ell \leqq m$

Bending moment

$$M = P \times \ell^3 / 12$$

Shearing force

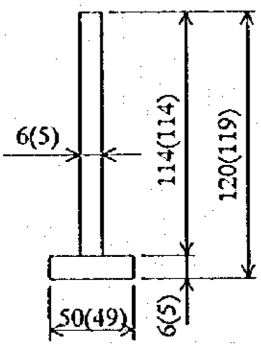
$$S = P \times \ell^2 / 4$$

where, M : Maximum bending moment (kgf-cm)
P : Mean water pressure (kgf/cm^2)
m : Pitch of vertical girder 85.5 cm
ℓ : Distance between horizontal beams (cm)
S : Maximum shearing force (kgf)

Portion	m	ℓ	P	M	S
1	85.5	64.5	0.1364	4043	188
2	85.5	63.0	0.2001	5659	269

(2) Sectional property

Following section is used.



Moment of inertia I =122 cm^4
Modulus of section Z = 16 cm^3
Area of web Aw=5.7 cm^2

Bending and shearing stresses

$$\sigma = M / Z$$

where, σ : Maximum bending stress (kgf/cm^2)
M : Maximum bending moment 5659 kgf-cm
Z : Modulus of section 16 cm^3

Thus,

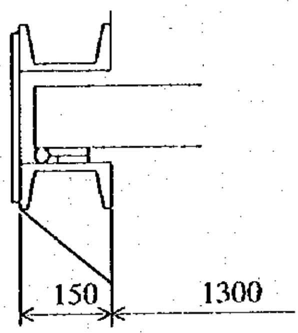
$$\sigma = 5659 / 16$$
$$= 354\, kgf / cm^2 < 1.200\, kgf / cm^2 = Allowable\ bending\ stress$$
$$\tau = S / Aw$$

where,	σ	: Maximum shearing stress	(kgf/cm^2)
	S	: maximum shearing force	269 kgf
	Aw	: Area of web	5.7 cm^2

Thus,

$$\tau = 269 / 5.7$$
$$= 47\, kgf / cm^2 < 700\, kgf / cm^2 = Allowable\ shearing\ stress$$

5.8.7 Guide frame



Bearing stress of concrete

$$\sigma c = Pt / 2 \times b \times l$$

where,	σc	: Concrete bearing stress	(kgf/cm^2)
	Pt	: Hydraulic load	3892 (kgf)
	b	: Flange width of track frame	15.0 (cm)
	l	: Sealing height	135.0 (cm)

Thus,

$$\sigma c = \frac{3892}{2 \times 15.0 \times 135.0} = 0.97\, kgf / cm^2 < \sigma ca = 60\, kgf / cm^2$$

(2) Shearing stress of concrete

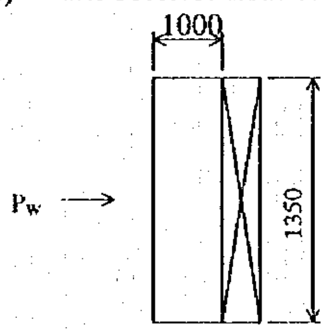
$$\tau c = Pt / 2 \times ls \times \ell$$
$$ls = 15.0 \times \sqrt{2} = 21.2\, cm$$
$$\tau c = \frac{3892}{2 \times 21.2 \times 135} = 0.68\, kgf / cm^2 < \tau ca = 3.6\, kgf / cm^2$$

5.8.8 Operation Load

(1) Operation Conditions

The slide gate is operated under the water head difference of 1.0m .

(2) Water Pressure Load at Operating.



$$Pw = H \times Hs \times B \times Gw$$

where,

Pw	: Water pressure load at operating (tf)	
H	: Operating head	1.0m
Hs	: Sealing height	1.35m
B	: Sealing span	1.68m
Gw	: Specific gravity of water	1.0 tf/m^3

Thus,

$$Pw = 1.0 \times 1.35 \times 1.68 \times 1.0$$
$$= 2.268\,tf$$

(3) Operating Load

(a) Own weight of gate leaf and spindle

$$Wg = 0.32\,tf$$

(b) Friction force of seal rubber

$$FrR = \mu \times (q \times p \times b) \times \Sigma_1$$

where,

FrR	: Friction force of seal rubber (tf)	
μ	: Friction coefficient of seal rubber at starting 1.5 at sliding 0.7	
q	: Initial compression load on seal rubber	0.1 tf/m
p	: Mean design pressure	1.0 tf/m^2
b	: Contact width of seal rubber	0.03 m
Σ_1	: Total sliding length of seal rubber	4.38 m

Thus,

(i) at Raising

$$FrR = 1.5 \times (0.10 + 1.0 \times 0.03) \times 4.38$$
$$= 0.854\ tf$$

(ii) at Lowering

$$FrL = 0.7 \times (0.10 + 0.0 \times 0.03) \times 4.38$$
$$= 0.307\ tf$$

(c) Friction force of bearing plate

$$Fb = Pwr \times \mu b$$

where,

Fb	: Friction force of bearing plate (tf)	
Pwr	: Water pressure load	2.268 tf
μb	: Frictional coefficient of bearing plate	0.45

Thus,

$$Fb = 2.268 \times 0.45 = 1.021\ tf$$

(d) Buoyancy

$$Fb = \frac{G}{jo}$$

where,

F	: Buoyancy	(tf)
G	: Weight gate leaf	0.32 tf
jo	: Specific gravity	7.85 tf/m^3

Thus,

$$Fb = \frac{0.32}{7.85} = 0.041 tf$$

(e) Total operation load

	Raising load (tf)	Lowering load (tf)
Gate weight(Wg)	+0.32	+0.32
Friction force due to seal rubber(Fr)	+0.854	-0.307
Friction force of bearing plate	+1.021	
Buoyancy(Fb)		-0.041
Total	+2.195	-0.028

where,

Operation load at

Raising : 2.2 tf(including allowance)

Lowering : 0.1 tf

5.8.9 Hoist

2.2 tf capacity manual hoist × 1 set

5.9 Calculation of Slide gate (1.3m×1.3m)

5.9.1 General

Slide gates having 1.3 m wide by 1.3 m high are provided at the each sluiceways. The main design data for each slide gate are as follows:

Main Design Data for Slide Gates

No.	Gate No.	H.W.L.+1.0m	(Sill El.).	Design Head (m)	Quantity (set)
1.	SKM-3R	+1.907	-0.492	2.399	1
2.	SCM-1L	+2.381	-0.177	2.558	1

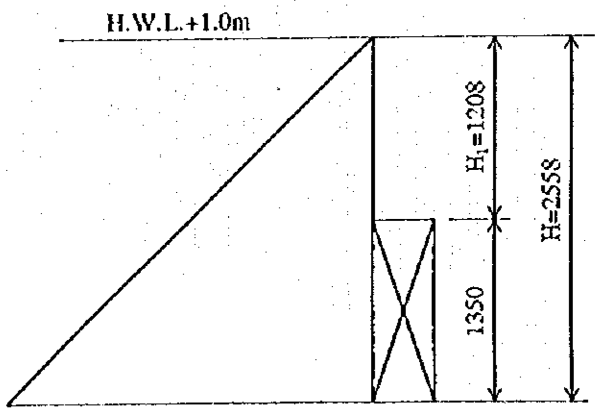
Since the design head varies from 2.399 m to 2.558 m , the design head of slide gate is taken at 2.558 m in the structural calculations.

5.9.2 Design Conditions

Type	: Steel made slide gate
Quantity	
Gate leaf	: 2 sets
Guide frame	: 2 sets
Hoist	: 2 sets
Clear span	: 1.3 m
Clear height	: 1.3 m
Design head (H.W.L.+1.0m-Sill EL.)	: 2.558 m
Sealing method	:4 edges rubber seal at anti-pressure side (land side)
Maximum deflection of main horizontal beams	:1/800 of supporting span
Corrosion allowance	: 0.5mm for water contact face members)
Type of hoist	: Manual driven screwed spindle hoist
Operation head	: Water difference of 1.0m
Hoisting height	: Clear height + 5 cm in normal operation
Operation method	: Local

5.9.3 Design Load

(1) Hydraulic load



$$Pt = 0.5 \times (H^2 - H_1^2) \times B \times GW$$

where,		
	Pt :Hydraulic load	(tf)
	H :Water head at gate bottom	2.558 m
	H_1 :Water head at upper seal	1.208 m
	B :Sealing span	1.48 m
	GW :Specific gravity of water	1.0 tf/m^3

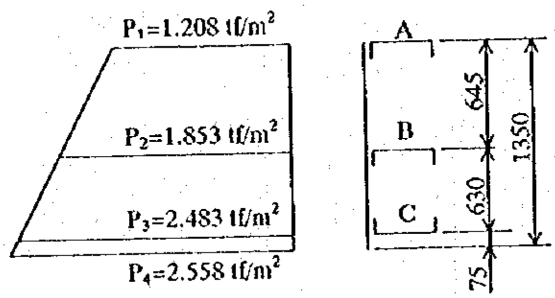
Thus,

$$Pt = 0.5 \times (2.558^2 - 1.208^2) \times 1.48 \times 1.0$$
$$= 3.762\ tf$$

5.9.4 Main Horizontal beams

(1) Arrangement of main horizontal beams

Three (3) number of main horizontal beams are arranged follows:



Charging load on each beam

Charging load acting on each beam is calculated by following equation:

$$Beam\ A = \frac{(2 \times 1.208 + 1.853)}{6} \times 0.645$$
$$= 0.459\ tf\ /m$$

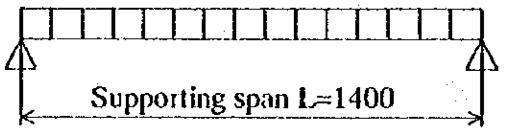
$$Beam\ B = \frac{(1.208 + 2 \times 1.853)}{6} \times 0.645 + \frac{(2 \times 1.853 + 2.483)}{6} \times 0.630$$
$$= 1.178\ tf\ /m$$

$$Beam\ C = \frac{(1.853 + 2 \times 2.483)}{6} \times 0.630 + \frac{(2.483 + 2.558)}{2} \times 0.075$$
$$= 0.905\ tf\ /m$$

(3) Bending moment and shearing force

(a) Bending moment

Maximum bending moment is calculated by the following equation:



$M\max = W \times L / 8$

where,	$M\max$	:Maximum bending moment	(tf-m)
	W	:Design load acting on the beam	(tf)
	L	:Supporting span	1.40m

(b) Max Shearing force is calculated by the following equation:

$S\max = W / 2$

where,	$S\max$	:Maximum shearing force	(tf)
	W	:Design load acting on beam	(tf)

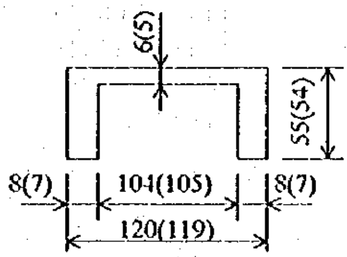
(c) Calculation result

The calculation result is as follows:

		Beam B
W	(tf)	1.743
M max	(tf-m)	0.305
S max	(tf)	0.872

As maximum design load acts on beam B , bending moment and shearing force are calculated only on beam B.

(4) Sectional property of beams

	Beam B
Sectional dimension	
$I(cm^4)$	286
$Z(cm^3)$	48
$A(cm^2)$	12.81

(5) Bending and shearing stress

Bending and shearing stress are calculated by the following equations:

$$\sigma \max = \frac{M \max \times 10^5}{Z}$$

$$\tau \max = \frac{S \max \times 10^3}{A_W}$$

where,			
	σ max	: Maximum bending stress	(kgf/cm^2)
	M max	: Maximum bending moment	(tf-m)
	Z	: Modulus of section	(cm^2)
	τ max	: Maximum shearing stress	(kgf/cm^2)
	S max	: maximum shearing	(tf)
	A_W	: Area of web at both ends	(cm^2)

	Beam B
M max	0.305
Z	48
σ max	635
S max	0.872
A_W	5.25
τ max	166
Allowable bending stress(kgf/cm^2)	1,200 (Material 40kgf/mm^{2}class mild steel)
Allowable searing stress(kgf/cm^2)	700 (-ditto-)

(6) Deflection

Maximum deflection of each beams is calculated by the following equation:

$$\delta \max = \frac{5WL^3}{384EI}$$

where,			
	δ max	: Maximum deflection of each beam	(cm)
	W	: Design load on each beam	(kgf)
	L	: Supporting span	140cm
	E	: Elastic Modulus of steel	$2.1 \times 10^6 kgf / cm^2$
	I	: Geometrical moment of inertia (cm^4)	

Thus,

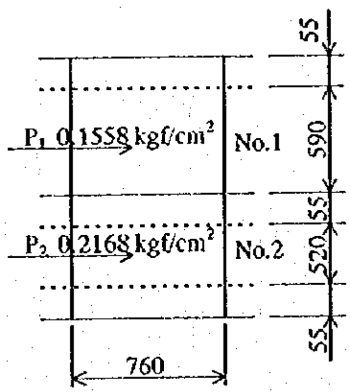
	Beam B
$W (kgf)$	1743
$I (cm^4)$	286
$\delta (cm)$	0.104
$\delta / L (cm)$	1/1346
Allowable deflection	< 1/800

5.9.5 Skin Plate

Bending stress of skin plate is calculated in accordance with the following Timoshenko's formula:

$$\sigma = \frac{k \cdot a^2 \cdot p}{100(t - \varepsilon)^2}$$

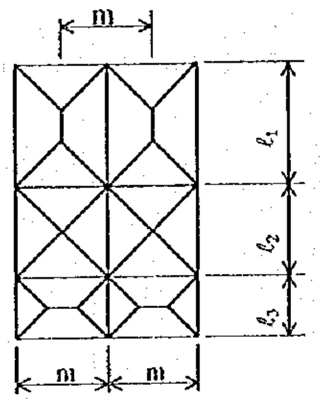
where,			
	σ	: Bending stress	(kgf/cm^2)
	k	: Coefficient by "b/a"	
	a	: Short span of plate	(cm)
	b	: Long span of plate	(cm)
	p	: Mean design pressure	(kgf/cm^2)
	t	: Thickness of plate	(cm)
	ε	: Corrosion allowance	0.1cm

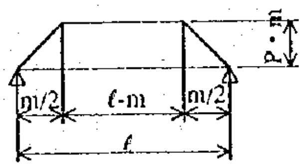


	No.1	No.2
a(cm)	59.0	52.0
b(cm)	76.0	76.0
b/a	1.288	1.462
k	41.09	44.70
p (kgf/cm^2)	0.1558	0.2168
t(cm)	0.5	0.5
σ (kgf/cm^2)	891	1048
σ a(kgf/cm^2)	1200	1200

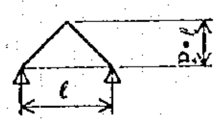
5.9.6 Vertical Girders

(1) Bending moment and shearing force are calculated by the following formula.





(a) $\ell > m$



(b) $\ell \leq m$

(a) $\ell > m$

Bending moment

$$M = P \times m \times (3\ell^2 - m^2) / 24$$

Shearing force

$$S = P \times m \times (\ell - m / 2) / 2$$

(b) $\ell \leqq m$

Bending moment

$$M = P \times \ell^3 / 12$$

Shearing force

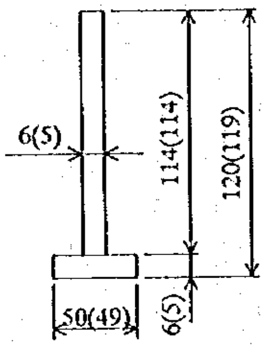
$$S = P \times \ell^2 / 4$$

where, M : Maximum bending moment (kgf-cm)
P : Mean water pressure (kgf/cm^2)
m : Pitch of vertical girder 76.0 cm
ℓ : Distance between horizontal beams (cm)
S : Maximum shearing force (kgf)

Portion	m	ℓ	P	M	S
1	76.0	64.5	0.1531	4034	188
2	76.0	63.0	0.2168	5450	260

(2) Sectional property

Following section is used.



Moment of inertia I =122 cm^4
Modulus of section Z = 16 cm^3
Area of web Aw=5.7 cm^2

Bending and shearing stresses

$$\sigma = M / Z$$

where, σ : Maximum bending stress (kgf/cm^2)
M : Maximum bending moment 5450 kgf-cm
Z : Modulus of section 16 cm^3

Thus,

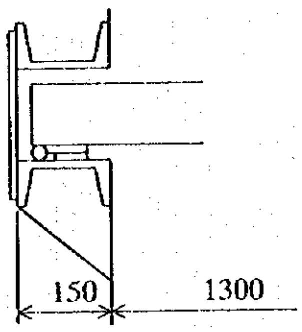
$$\sigma = 5450/16$$
$$= 341\, kgf/cm^2 < 1{,}200\, kgf/cm^2 = Allowable\ bending\ stress$$
$$\tau = S / Aw$$

where,	σ	: Maximum shearing stress	(kgf/cm^2)
	S	: maximum shearing force	260 kgf
	Aw	: Area of web	5.7 cm^2

Thus,

$$\tau = 260/5.7$$
$$= 46\, kgf/cm^2 < 700\, kgf/cm^2 = Allowable\ shearing\ stress$$

5.9.7 Guide frame



Bearing stress of concrete

$$\sigma c = Pt / 2 \times b \times l$$

where,	σc	: Concrete bearing stress	(kgf/cm^2)
	Pt	: Hydraulic load	3762 (kgf)
	b	: Flange width of track frame	15.0 (cm)
	l	: Sealing height	135.0(cm)

Thus,

$$\sigma c = \frac{3762}{2 \times 15.0 \times 135.0} = 0.93\, kgf/cm^2 < \sigma ca = 60\, kgf/cm^2$$

(2) Shearing stress of concrete

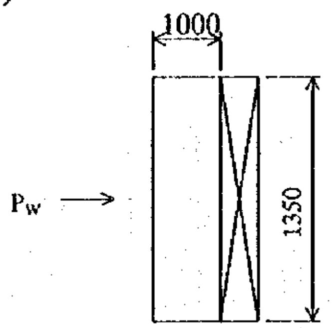
$$\tau c = Pt / 2 \times ls \times \ell$$
$$ls = 15.0 \times \sqrt{2} = 21.2\, cm$$
$$\tau c = \frac{3762}{2 \times 21.2 \times 135} = 0.66\, kgf/cm^2 < \tau ca = 3.6\, kgf/cm^2$$

5.9.8 Operation Load

(1) Operation Conditions

The slide gate is operated under the water head difference of 1.0m .

(2) Water Pressure Load at Operating.



$$Pw = H \times Hs \times B \times Gw$$

where,

Pw	: Water pressure load at operating (tf)	
H	: Operating head	1.0m
Hs	: Sealing height	1.35m
B	: Sealing span	1.48m
Gw	: Specific gravity of water	1.0 tf/m^3

Thus,

$$Pw = 1.0 \times 1.35 \times 1.48 \times 1.0$$
$$= 1.998\,tf$$

(3) Operating Load

(a) Own weight of gate leaf and spindle

$$Wg = 0.31\,tf$$

(b) Friction force of seal rubber

$$FrR = \mu \times (q \times p \times b) \times \Sigma_1$$

where,

FrR	: Friction force of seal rubber (tf)	
μ	: Friction coefficient of seal rubber	
	at starting 1.5	
	at sliding 0.7	
q	: Initial compression load on seal rubber	0.1 tf/m
p	: Mean design pressure	1.0 tf/m^2
b	: Contact width of seal rubber	0.03 m
Σ_1	: Total sliding length of seal rubber	4.18 m

Thus,

(i) at Raising

$$FrR = 1.5 \times (0.10 + 1.0 \times 0.03) \times 4.18$$
$$= 0.815\,tf$$

(ii) at Lowering

$$FrL = 0.7 \times (0.10 + 0.0 \times 0.03) \times 4.18$$
$$= 0.293\,tf$$

(c) Friction force of bearing plate

$$Fb = Pwr \times \mu b$$

where,

Fb	: Friction force of bearing plate (tf)	
Pwr	: Water pressure load	1.998 tf
μb	: Frictional coefficient of bearing plate	0.45

Thus,

$$Fb = 1.998 \times 0.45 = 0.889\,tf$$

(d) Buoyancy

$$Fb = \frac{G}{jo}$$

where,

F	: Buoyancy	(tf)
G	: Weight gate leaf	0.31 tf
jo	: Specific gravity	7.85 tf/m³

Thus,

$$Fb = \frac{0.31}{7.85} = 0.039\,tf$$

(e) Total operation load

	Raising load (tf)	Lowering load (tf)
Gate weight(Wg)	+0.31	+0.31
Friction force due to seal rubber(Fr)	+0.815	-0.293
Friction force of bearing plate	+0.899	
Buoyancy(Fb)		-0.039
Total	+2.024	-0.021

where,

Operation load at

Raising	: 2.1 tf(including allowance)
Lowering	: 0.1 tf

5.9.9 Hoist

2.1 tf capacity manual hoist × 1 set

5.10 Calculation of Slide gate (1.2m×1.2m)

5.10.1 General

Slide gates having 1.2 m wide by 1.2 m high are provided at the each sluiceways. The main design data for each slide gate are as follows:

Main Design Data for Slide Gates

No.	Gate No.	H.W.L.+1.0m	(Sill El.).	Design Head (m)	Quantity (set)
1.	SKM-1L	+1.688	-0.682	2.370	1
2.	SKM-2R	+1.695	-0.676	2.371	1
3.	SCM-2L	+2.675	-0.064	2.739	2
4.	SCM-2R	+2.632	+0.204	2.428	1
5.	SCM-3R	+2.669	-0.069	2.738	1

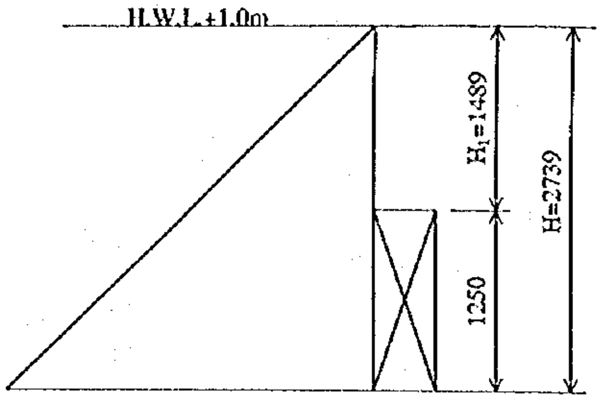
Since the design head varies from 2.370 m to 2.739 m , the design head of slide gate is taken at 2.739 m in the structural calculations.

5.10.2 Design Conditions

Type	: Steel made slide gate
Quantity	
Gate leaf	: 6 sets
Guide frame	: 6 sets
Hoist	: 6 sets
Clear span	: 1.2 m
Clear height	: 1.2 m
Design head (H.W.L.+1.0m-Sill EL.)	: 2.739 m
Sealing method	:4 edges rubber seal at anti-pressure side (land side)
Maximum deflection of main horizontal beams	:1/800 of supporting span
Corrosion allowance	: 0.5mm for water contact face members)
Type of hoist	: Manual driven screwed spindle hoist
Operation head	: Water difference of 1.0m
Hoisting height	: Clear height + 5 cm in normal operation
Operation method	: Local

5.10.3 Design Load

(1) Hydraulic load



$$Pt = 0.5 \times (H^2 - H_1^2) \times B \times GW$$

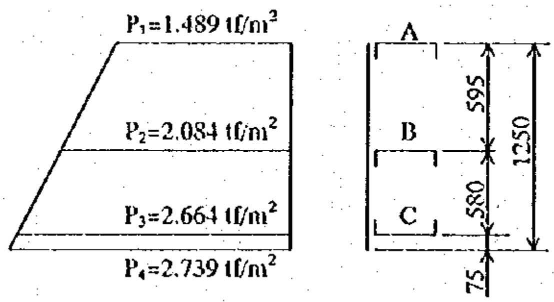
where,			
	Pt :Hydraulic load		(tf)
	H :Water head at gate bottom	2.739	m
	H_1 :Water head at upper seal	1.489	m
	B :Sealing span	1.38	m
	GW :Specific gravity of water	1.0	tf/m^3

Thus,

$$Pt = 0.5 \times (2.739^2 - 1.489^2) \times 1.38 \times 1.0$$
$$= 3.647\ tf$$

5.10.4 Main Horizontal beams

(1) Arrangement of main horizontal beams
Three (3) number of main horizontal beams are arranged follows:



Charging load on each beam

Charging load acting on each beam is calculated by following equation:

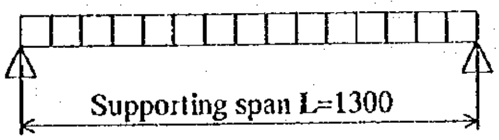
$$Beam\ A = \frac{(2 \times 1.489 + 2.084)}{6} \times 0.595$$
$$= 0.502\ tf\ /\ m$$

$$Beam\ B = \frac{(1.489 + 2 \times 2.084)}{6} \times 0.595 + \frac{(2 \times 2.084 + 2.664)}{6} \times 0.580$$
$$= 1.221\ tf\ /m$$

$$Beam\ C = \frac{(2.084 + 2 \times 2.664)}{6} \times 0.580 + \frac{(2.664 + 2.739)}{2} \times 0.075$$
$$= 0.919\ tf\ /m$$

(3) Bending moment and shearing force

(a) Bending moment
Maximum bending moment is calculated by the following equation:



$M\max = W \times L / 8$

where,			
	$M\max$	:Maximum bending moment	(tf-m)
	W	:Design load acting on the beam	(tf)
	L	:Supporting span	1.30m

(b) Max Shearing force is calculated by the following equation:

$S\max = W / 2$

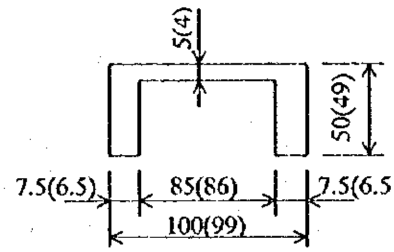
where,			
	$S\max$	:Maximum shearing force	(tf)
	W	:Design load acting on beam	(tf)

(c) Calculation result
The calculation result is as follows:

		Beam B
W	(tf)	1.685
M max	(tf-m)	0.274
S max	(tf)	0.843

As maximum design load acts on beam B , bending moment and shearing force are calculated only on beam B.

(4) Sectional property of beams

	Beam B
Sectional dimension	
$I(cm^4)$	158
$Z(cm^3)$	32
$A(cm^2)$	9.81

(5) Bending and shearing stress

Bending and shearing stress are calculated by the following equations:

$$\sigma \max = \frac{M \max \times 10^5}{Z}$$

$$\tau \max = \frac{S \max \times 10^3}{A_W}$$

where, σ max : Maximum bending stress (kgf/cm^2)
M max : Maximum bending moment (tf-m)
Z : Modulus of section (cm^2)
τ max : Maximum shearing stress (kgf/cm^2)
S max : maximum shearing (tf)
A_W : Area of web at both ends (cm^2)

	Beam B	
M max	0.274	
Z	32	
σ max	856	
S max	0.843	
A_W	3.44	
τ max	245	
Allowable bending stress(kgf/cm^2)	1,200	(Material 40kgf/mm^{2}class mild steel)
Allowable searing stress(kgf/cm^2)	700	(-ditto-)

(6) Deflection

Maximum deflection of each beams is calculated by the following equation:

$$\delta \max = \frac{5WL^3}{384EI}$$

where,			
	$\delta\max$	: Maximum deflection of each beam	(cm)
	W	: Design load on each beam	(kgf)
	L	: Supporting span	130cm
	E	: Elastic Modulus of steel	$2.1\times10^{6}\,kgf/cm^{2}$
	I	: Geometrical moment of inertia (cm^4)	

Thus,

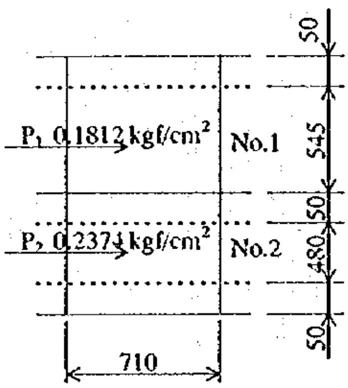
	Beam B
$W\ (kgf)$	1685
$I\ (cm^4)$	158
$\delta\ (cm)$	0.145
$\delta / L\ (cm)$	1/897
Allowable deflection	< 1/800

5.10.5 Skin Plate

Bending stress of skin plate is calculated in accordance with the following Timoshenko's formula:

$$\sigma = \frac{k \cdot a^2 \cdot p}{100(t-\varepsilon)^2}$$

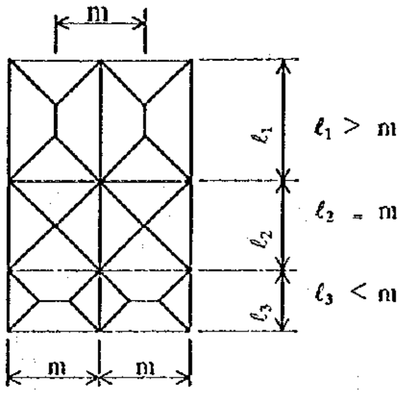
where,			
	σ	: Bending stress	(kgf/cm^2)
	k	: Coefficient by "b/a"	
	a	: Short span of plate	(cm)
	b	: Long span of plate	(cm)
	p	: Mean design pressure	(kgf/cm^2)
	t	: Thickness of plate	(cm)
	ε	: Corrosion allowance	0.1cm

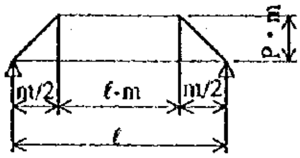


	No.1	No.2
a(cm)	54.5	48.0
b(cm)	71.0	71.0
b/a	1.303	1.479
k	41.40	45.07
p (kgf/cm^2)	0.1812	0.2374
t(cm)	0.5	0.5
σ (kgf/cm^2)	891	986
σa(kgf/cm^2)	1200	1200

5.10.6 Vertical Girders

(1) Bending moment and shearing force are calculated by the following formula.





(a) $\ell > m$

(b) $\ell \leq m$

(a) $\ell > m$

Bending moment

$$M = P \times m \times (3\ell^2 - m^2)/24$$

Shearing force

$$S = P \times m \times (\ell - m/2)/2$$

(b) $\ell \leqq m$

Bending moment

$$M = P \times \ell^3 / 12$$

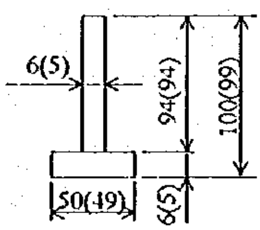
Shearing force

$$S = P \times \ell^2 / 4$$

where, M : Maximum bending moment (kgf-cm)
P : Mean water pressure (kgf/cm²)
m : Pitch of vertical girder 71.0 cm
ℓ : Distance between horizontal beams (cm)
S : Maximum shearing force (kgf)

Portion	m	ℓ	P	M	S
1	71.0	59.5	0.1787	3137	158
2	71.0	58.0	0.2374	3860	200

Sectional property
Following section is used.



Moment of inertia $I = 74\ cm^4$
Modulus of section $Z = 12\ cm^3$
Area of web $Aw = 4.7\ cm^2$

Bending and shearing stresses

$$\sigma = M / Z$$

where, σ : Maximum bending stress (kgf/cm²)
M : Maximum bending moment 3860 kgf-cm
Z : Modulus of section 12 cm³

Thus,

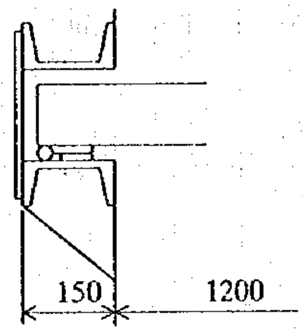
$$\sigma = 3860 / 12$$
$$= 322\,kgf\ /\ cm^2 < 1200\,kgf\ /\ cm^2 = Allowable\ bending\ stress$$
$$\tau = S / Aw$$

where, σ : Maximum shearing stress (kgf/cm²)
S : maximum shearing force 200 kgf
Aw : Area of web 4.7 cm²

Thus,

$$\tau = 200 / 4.7$$
$$= 43\,kgf\ /\ cm^2 < 700\,kgf\ /\ cm^2 = Allowable\ shearing\ stress$$

5.10.7 Guide frame



Bearing stress of concrete
$$\sigma c = Pt / 2 \times b \times l$$

where, σc : Concrete bearing stress (kgf/cm²)
Pt : Hydraulic load 3647 (kgf)
b : Flange width of track frame 15.0 (cm)
l : Sealing height 125.0(cm)

Thus,

$$\sigma c = \frac{3647}{2 \times 15.0 \times 125.0} = 0.97\,kgf\ /\ cm^2 < \sigma ca = 60\,kgf\ /\ cm^2$$

(2) Shearing stress of concrete

$$\tau c = Pt / 2 \times ls \times \ell$$

$$ls = 15.0 \times \sqrt{2} = 21.2\ cm$$

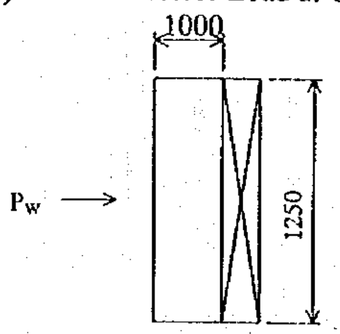
$$\tau c = \frac{3647}{2 \times 21.2 \times 125} = 0.69\ kgf / cm^2 < \tau ca = 3.6\ kgf / cm^2$$

5.10.8 Operation Load

(1) Operation Conditions

The slide gate is operated under the water head difference of 1.0m .

(2) Water Pressure Load at Operating.



$$Pw = H \times Hs \times B \times Gw$$

where,			
	Pw	: Water pressure load at operating (tf)	
	H	: Operating head	1.0m
	Hs	: Sealing height	1.25m
	B	: Sealing span	1.38m
	Gw	: Specific gravity of water	1.0 tf/m^3

Thus,

$$Pw = 1.0 \times 1.25 \times 1.38 \times 1.0$$
$$= 1.725\ tf$$

(3) Operating Load

(a) Own weight of gate leaf and spindle

$$Wg = 0.27\ tf$$

(b) Friction force of seal rubber

$$FrR = \mu \times (q \times p \times b) \times \Sigma_1$$

where,

FrR : Friction force of seal rubber (tf)

μ	: Friction coefficient of seal rubber	
	at starting 1.5	
	at sliding 0.7	
q	: Initial compression load on seal rubber	0.1 tf/m
p	: Mean design pressure	1.0 tf/m^2
b	: Contact width of seal rubber	0.03 m
Σ_1	: Total sliding length of seal rubber	3.88 m

Thus,

(i) at Raising

$$FrR = 1.5 \times (0.10 + 1.0 \times 0.03) \times 3.88$$
$$= 0.757\ tf$$

(ii) at Lowering

$$FrL = 0.7 \times (0.10 + 0.0 \times 0.03) \times 3.88$$
$$= 0.272\ tf$$

(c) Friction force of bearing plate

$$Fb = Pwr \times \mu b$$

where,

Fb	: Friction force of bearing plate (tf)	
Pwr	: Water pressure load	1.725 tf
μb	: Frictional coefficient of bearing plate	0.45

Thus,

$$Fb = 1.725 \times 0.45 = 0.776\ tf$$

(d) Buoyancy

$$Fb = \frac{G}{jo}$$

where,

F	: Buoyancy	(tf)
G	: Weight gate leaf	0.27 tf
jo	: Specific gravity	7.85 tf/m^3

Thus,

$$Fb = \frac{0.27}{7.85} = 0.034 tf$$

(c) Total operation load

	Raising load (tf)	Lowering load (tf)
Gate weight(Wg)	+0.27	+0.27
Friction force due to seal rubber(Fr)	+0.757	-0.272
Friction force of bearing plate	+0.776	
Buoyancy(Fb)		-0.036
Total	+1.803	-0.036

where,
Operation load at
Raising : 1.9 tf (including allowance)
Lowering : 0.1 tf

5.10.9 Hoist
1.9 tf capacity manual hoist × 1 set

5.11 SLIDE GATE (1.1m×1.1m)

5.11.1 General

Slide gates having 1.1 m wide by 1.1 m high are provided at the each sluiceways. The main design data for each slide gate are as follows:

Main Design Data for Slide Gates

No.	Gate No.	H.W.L.+1.0m	(Sill El.).	Design Head (m)	Quantity (set)
1.	SKM-2L	+1.798	-0.587	2.385	1
2.	SKM-1R	+1.592	-0.762	2.354	2
3.	SNM-1R	+2.973	+0.608	2.365	1
4.	SCM-4L	+2.948	+0.304	2.644	1
5.	SCM-6L	+3.142	+0.578	2.564	1
6.	SCM-7L	+3.192	+0.680	2.512	1
7.	SCM-7R	+3.206	+0.744	2.462	1

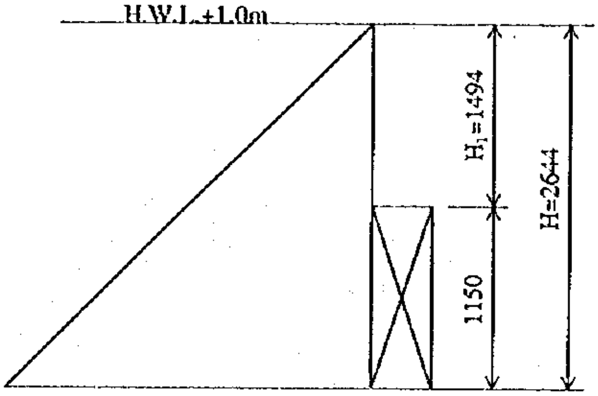
Since the design head varies from 2.354 m to 2.644 m , the design head of slide gate is taken at 2.644 m in the structural calculations.

5.11.2 Design Conditions

Type	: Steel made slide gate
Quantity	
Gate leaf	: 8 sets
Guide frame	: 8 sets
Hoist	: 8 sets
Clear span	: 1.1 m
Clear height	: 1.1 m
Design head (H.W.L.+1.0m-Sill EL.)	: 2.644 m
Sealing method	:4 edges rubber seal at anti-pressure side (land side)
Maximum deflection of main horizontal beams	:1/800 of supporting span
Corrosion allowance	: 0.5mm for water contact face members)
Type of hoist	: Manual driven screwed spindle hoist
Operation head	: Water difference of 1.0m
Hoisting height	: Clear height + 5 cm in normal operation
Operation method	: Local

5.11.3 Design Load

(1) Hydraulic load



$$Pt = 0.5 \times (H^2 - H_1^2) \times B \times GW$$

where,

Pt	:Hydraulic load	(tf)
H	:Water head at gate bottom	2.644 m
H_1	:Water head at upper seal	1.494 m
B	:Sealing span	1.28 m
GW	:Specific gravity of water	1.0 tf/m^3

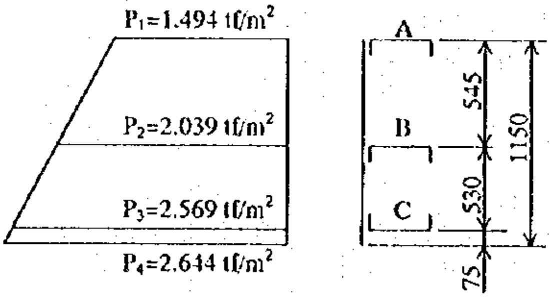
Thus,

$$Pt = 0.5 \times (2.644^2 - 1.494^2) \times 1.28 \times 1.0$$
$$= 3.046\, tf$$

5.11.4 Main Horizontal beams

(1) Arrangement of main horizontal beams

Three (3) number of main horizontal beams are arranged follows:



Charging load on each beam

Charging load acting on each beam is calculated by following equation:

$$Beam\ A = \frac{(2 \times 1.494 + 2.039)}{6} \times 0.545$$
$$= 0.457\, tf\ /m$$

$$Beam\ B = \frac{(1.494 + 2 \times 2.039)}{6} \times 0.545 + \frac{(2 \times 2.039 + 2.569)}{6} \times 0.530$$

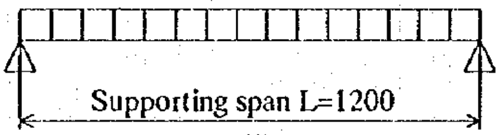
$$= 1.093\, tf\ /m$$

$$Beam\ C = \frac{(2.039 + 2 \times 2.569)}{6} \times 0.530 + \frac{(2.569 + 2.644)}{2} \times 0.075$$
$$= 0.829\, tf\ /m$$

(3) Bending moment and shearing force

(a) Bending moment

Maximum bending moment is calculated by the following equation:



$$M\max = W \times L / 8$$

where,			
	M max	:Maximum bending moment	(tf-m)
	W	:Design load acting on the beam	(tf)
	L	:Supporting span	1.20m

(b) Max Shearing force is calculated by the following equation:

$$S\max = W / 2$$

where,			
	S max	:Maximum shearing force	(tf)
	W	:Design load acting on beam	(tf)

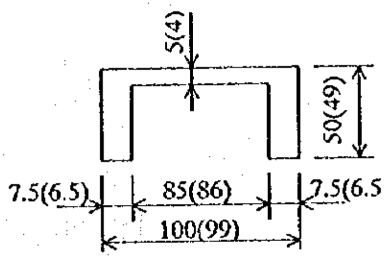
(c) Calculation result

The calculation result is as follows:

		Beam B
W	(tf)	1.399
M max	(tf-m)	0.210
S max	(tf)	0.700

As maximum design load acts on beam B , bending moment and shearing force are calculated only on beam B.

(4) Sectional property of beams

	Beam B
Sectional dimension	
$I(cm^4)$	158
$Z(cm^3)$	32
$A(cm^2)$	9.81

(5) Bending and shearing stress

Bending and shearing stress are calculated by the following equations:

$$\sigma \max = \frac{M \max \times 10^5}{Z}$$

$$\tau \max = \frac{S \max \times 10^3}{A_W}$$

where,			
	$\sigma \max$	: Maximum bending stress	(kgf/cm^2)
	$M \max$	: Maximum bending moment	(tf-m)
	Z	: Modulus of section	(cm^2)
	$\tau \max$	: Maximum shearing stress	(kgf/cm^2)
	$S \max$	: maximum shearing	(tf)
	A_W	: Area of web at both ends	(cm^2)

	Beam B
$M \max$	0.210
Z	32
$\sigma \max$	656
$S \max$	0.700
A_W	3.44
$\tau \max$	203
Allowable bending stress(kgf/cm^2)	1,200 (Material 40kgf/mm^{2}class mild steel)
Allowable searing stress(kgf/cm^2)	700 (-ditto-)

(6) Deflection

Maximum deflection of each beams is calculated by the following equation:

$$\delta \max = \frac{5WL^3}{384EI}$$

where,	δ max	: Maximum deflection of each beam	(cm)
	W	: Design load on each beam	(kgf)
	L	: Supporting span	120cm
	E	: Elastic Modulus of steel	$2.1 \times 10^6 kgf / cm^2$
	I	: Geometrical moment of inertia (cm^4)	

Thus,

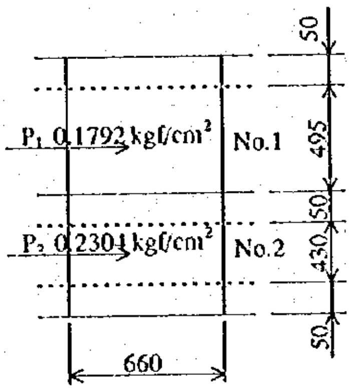
	Beam B
$W\ (kgf)$	1399
$I\ (cm^4)$	158
$\delta\ (cm)$	0.095
$\delta / L\ (cm)$	1/1263
Allowable deflection	< 1/800

5.11.5 Skin Plate

Bending stress of skin plate is calculated in accordance with the following Timoshenko's formula:

$$\sigma = \frac{k \cdot a^2 \cdot p}{100(t - \varepsilon)^2}$$

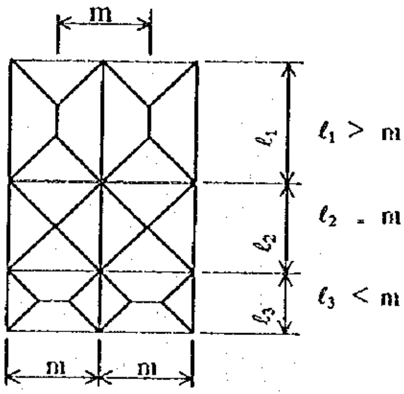
where,	σ	: Bending stress	(kgf/cm^2)
	k	: Coefficient by "b/a"	
	a	: Short span of plate	(cm)
	b	: Long span of plate	(cm)
	p	: Mean design pressure	(kgf/cm^2)
	t	: Thickness of plate	(cm)
	ε	: Corrosion allowance	0.1cm

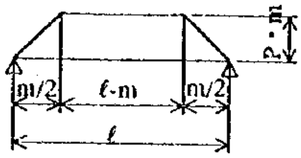


	No.1	No.2
a(cm)	49.5	43.0
b(cm)	66.0	66.0
b/a	1.333	1.535
k	42.03	45.90
p (kgf/cm^2)	0.1792	0.2304
t(cm)	0.5	0.5
σ (kgf/cm^2)	738	782
σ a(kgf/cm^2)	1200	1200

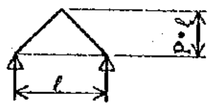
5.11.6 Vertical Girders

(1) Bending moment and shearing force are calculated by the following formula.





(a) $\ell > m$



(b) $\ell \leqq m$

(a) $\ell > m$

Bending moment

$$M = P \times m \times (3\ell^2 - m^2) / 24$$

Shearing force

$$S = P \times m \times (\ell - m/2) / 2$$

(b) $\ell \leqq m$

Bending moment

$$M = P \times \ell^3 / 12$$

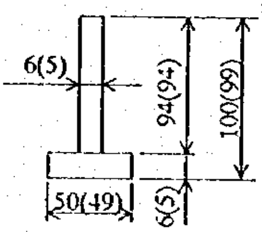
Shearing force

$$S = P \times \ell^2 / 4$$

where, M : Maximum bending moment (kgf-cm)
P : Mean water pressure (kgf/cm^2)
m : Pitch of vertical girder 66.0 cm
ℓ : Distance between horizontal beams (cm)
S : Maximum shearing force (kgf)

Portion	m	ℓ	P	M	S
1	66.0	54.5	0.1766	2382	131
2	66.0	53.0	0.2304	2858	162

Sectional property
Following section is used.



Moment of inertia $I = 74\ cm^4$
Modulus of section $Z = 12\ cm^3$
Area of web $Aw = 4.7\ cm^2$

Bending and shearing stresses

$\sigma = M / Z$

where, σ	: Maximum bending stress		(kgf/cm^2)
M	: Maximum bending moment		2858 kgf-cm
Z	: Modulus of section		12 cm^3

Thus,

$\sigma = 2858 / 12$

$= 238\ kgf\ /\ cm^2 < 1200\ kgf\ /\ cm^2 = Allowable\ bending\ stress$

$\tau = S / Aw$

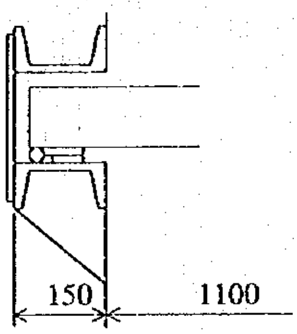
where, σ	: Maximum shearing stress	(kgf/cm^2)
S	: maximum shearing force	200 kgf
Aw	: Area of web	4.7 cm^2

Thus,

$\tau = 162 / 4.7$

$= 34\ kgf\ /\ cm^2 < 700\ kgf\ /\ cm^2 = Allowable\ shearing\ stress$

5.11.7 Guide frame



Bearing stress of concrete

$\sigma c = Pt / 2 \times b \times l$

where, σc	: Concrete bearing stress	(kgf/cm^2)
Pt	: Hydraulic load	3046 (kgf)
b	: Flange width of track frame	15.0 (cm)
l	: Sealing height	115.0(cm)

Thus,

$$\sigma c = \frac{3046}{2 \times 15.0 \times 115.0} = 0.88\ kgf\ /\ cm^2 < \sigma ca = 60\ kgf\ /\ cm^2$$

(2) Shearing stress of concrete

$$\tau c = Pt / 2 \times ls \times \ell$$

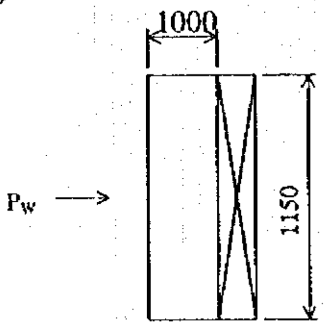
$$ls = 15.0 \times \sqrt{2} = 21.2\ cm$$

$$\tau c = \frac{3046}{2 \times 21.2 \times 115} = 0.62\ kgf / cm^2 < \tau ca = 3.6\ kgf / cm^2$$

5.11.8 Operation Load

(1) Operation Conditions
The slide gate is operated under the water head difference of 1.0m .

(2) Water Pressure Load at Operating.



$$Pw = H \times Hs \times B \times Gw$$

where,

Pw	: Water pressure load at operating (tf)	
H	: Operating head	1.0m
Hs	: Sealing height	1.15m
B	: Sealing span	1.28m
Gw	: Specific gravity of water	1.0 tf/m^3

Thus,

$$Pw = 1.0 \times 1.15 \times 1.28 \times 1.0$$
$$= 1.472\ tf$$

(3) Operating Load

(a) Own weight of gate leaf and spindle

$$Wg = 0.24\ tf$$

(b) Friction force of seal rubber

$$FrR = \mu \times (q \times p \times b) \times \Sigma_1$$

where,

FrR : Friction force of seal rubber (tf)

μ	: Friction coefficient of seal rubber		
	at starting	1.5	
	at sliding	0.7	
q	: Initial compression load on seal rubber		0.1 tf/m
p	: Mean design pressure		1.0 tf/m^2
b	: Contact width of seal rubber		0.03 m
Σ_1	: Total sliding length of seal rubber		3.58 m

Thus,

(i) at Raising

$$FrR = 1.5 \times (0.10 + 1.0 \times 0.03) \times 3.58$$
$$= 0.698\ tf$$

(ii) at Lowering

$$FrL = 0.7 \times (0.10 + 0.0 \times 0.03) \times 3.58$$
$$= 0.251\ tf$$

(c) Friction force of bearing plate

$$Fb = Pwr \times \mu b$$

where,

Fb	: Friction force of bearing plate (tf)	
Pwr	: Water pressure load	1.472 tf
μb	: Frictional coefficient of bearing plate	0.45

Thus,

$$Fb = 1.472 \times 0.45 = 0.662\ tf$$

(d) Buoyancy

$$Fb = \frac{G}{jo}$$

where,

F	: Buoyancy	(tf)
G	: Weight gate leaf	0.24 tf
jo	: Specific gravity	7.85 tf/m^3

Thus,

$$Fb = \frac{0.24}{7.85} = 0.031tf$$

(c) Total operation load

	Raising load (tf)	Lowering load (tf)
Gate weight(Wg)	+0.24	+0.24
Friction force due to seal rubber(Fr)	+0.698	-0.251
Friction force of bearing plate	+0.662	
Buoyancy(Fb)		-0.031
Total	+1.600	-0.042

where,
Operation load at
Raising : 1.7 tf (including allowance)
Lowering : 0.1 tf

5.11.9 Hoist
1.7 tf capacity manual hoist × 1 set

5.12 Calculation of Slide gate (1.0m × 1.0m)

5.12.1 General

Slide gates having 1.0 m wide by 1.0 m high are provided at the each sluiceways. The main design data for each slide gate are as follows:

Main Design Data for Slide Gates

No.	Gate No.	H.W.L.+1.0m	(Sill El.).	Design Head (m)	Quantity (set)
1.	SKM-5L	+1.974	-0.378	2.352	1
2.	SKM-6L	+2.097	-0.151	2.248	1
3.	SKM-8L	+2.323	+0.159	2.164	1
4.	SKM-7R	+2.565	+0.453	2.112	1
5.	STM-2L	+1.496	-0.593	2.089	2
6.	STM-4L	+1.544	-0.561	2.105	1
7.	SCM-3L	+2.799	+0.078	2.721	1
8.	SCM-5L	+3.030	+0.594	2.436	1
9.	SCM-4R	+2.920	+0.263	2.657	1
10.	SCM-5R	+3.030	+0.394	2.636	1
11.	SCM-6R	+3.137	+0.568	2.569	1
12.	SGM-5L	+4.039	+1.204	2.835	2

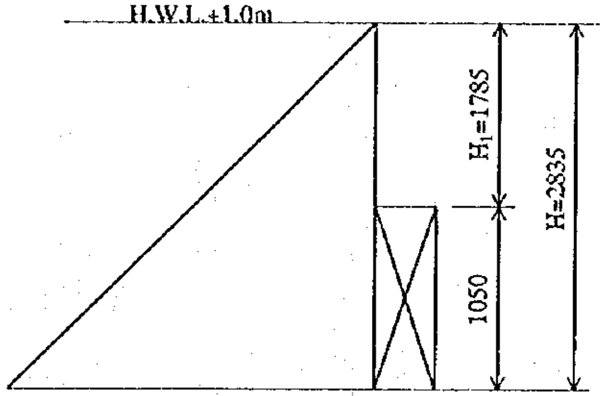
Since the design head varies from 2.089 m to 2.835 m , the design head of slide gate is taken at 2.835 m in the structural calculations.

5.12.2 Design Conditions

Type	: Steel made slide gate
Quantity	
Gate leaf	: 14 sets
Guide frame	: 14 sets
Hoist	: 14 sets
Clear span	: 1.1 m
Clear height	: 1.1 m
Design head (H.W.L.+1.0m-Sill EL.)	: 2.835 m
Sealing method	:4 edges rubber seal at anti-pressure side (land side)
Maximum deflection of main horizontal beams	:1/800 of supporting span
Corrosion allowance	: 0.5mm for water contact face members)
Type of hoist	: Manual driven screwed spindle hoist
Operation head	: Water difference of 1.0m
Hoisting height	: Clear height + 5 cm in normal operation
Operation method	: Local

5.12.3 Design Load

(1) Hydraulic load



$$Pt = 0.5 \times (H^2 - H_1^2) \times B \times GW$$

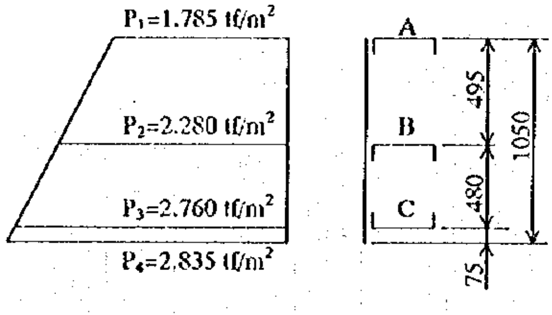
where,		
	Pt :Hydraulic load	(tf)
	H :Water head at gate bottom	2.835 m
	H_1 :Water head at upper seal	1.785 m
	B :Sealing span	1.18 m
	GW :Specific gravity of water	1.0 tf/m^3

Thus,

$$Pt = 0.5 \times (2.835^2 - 1.785^2) \times 1.18 \times 1.0$$
$$= 2.862\ tf$$

5.12.4 Main Horizontal beams

(1) Arrangement of main horizontal beams
Three (3) number of main horizontal beams are arranged follows:



Charging load on each beam

Charging load acting on each beam is calculated by following equation:

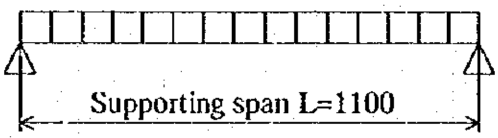
$$Beam\ A = \frac{(2 \times 1.785 + 2.280)}{6} \times 0.495$$
$$= 0.483\, tf\ /m$$

$$Beam\ B = \frac{(1.785 + 2 \times 2.280)}{6} \times 0.495 + \frac{(2 \times 2.280 + 2.760)}{6} \times 0.480$$
$$= 1.109\, tf\ /m$$

$$Beam\ C = \frac{(2.280 + 2 \times 2.760)}{6} \times 0.480 + \frac{(2.760 + 2.835)}{2} \times 0.075$$
$$= 0.834\, tf\ /m$$

(3) Bending moment and shearing force

(a) Bending moment
Maximum bending moment is calculated by the following equation:



$$M\max = W \times L / 8$$

where,			
	M max	:Maximum bending moment	(tf-m)
	W	:Design load acting on the beam	(tf)
	L	:Supporting span	1.10m

(b) Max Shearing force is calculated by the following equation:

$$S\max = W / 2$$

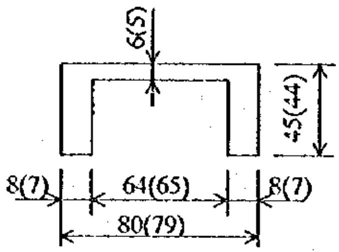
where,			
	S max	:Maximum shearing force	(tf)
	W	:Design load acting on beam	(tf)

(c) Calculation result
The calculation result is as follows:

		Beam B
W	(tf)	1.309
M max	(tf-m)	0.180
S max	(tf)	0.655

As maximum design load acts on beam B , bending moment and shearing force are calculated only on beam B.

(4) Sectional property of beams

	Beam B
Sectional dimension	
$I(cm^4)$	92
$Z(cm^3)$	23
$A(cm^2)$	9.41

(5) Bending and shearing stress

Bending and shearing stress are calculated by the following equations:

$$\sigma \max = \frac{M \max \times 10^5}{Z}$$

$$\tau \max = \frac{S \max \times 10^3}{A_w}$$

where,

σ max	: Maximum bending stress	(kgf/cm^2)
M max	: Maximum bending moment	(tf-m)
Z	: Modulus of section	(cm^2)
τ max	: Maximum shearing stress	(kgf/cm^2)
S max	: maximum shearing	(tf)
A_w	: Area of web at both ends	(cm^2)

	Beam B
M max	0.180
Z	23
σ max	783
S max	0.655
A_w	3.25
τ max	202
Allowable bending stress(kgf/cm^2)	994 (Material 40kgf/mm^{2}class mild steel)
Allowable scaring stress(kgf/cm^2)	700 (-ditto-)

(6) Deflection

Maximum deflection of each beams is calculated by the following equation:

$$\delta \max = \frac{5WL^3}{384EI}$$

where,	δ max	: Maximum deflection of each beam	(cm)
	W	: Design load on each beam	(kgf)
	L	: Supporting span	110cm
	E	: Elastic Modulus of steel	$2.1 \times 10^6 kgf\ / cm^2$
	I	: Geometrical moment of inertia (cm^4)	

Thus,

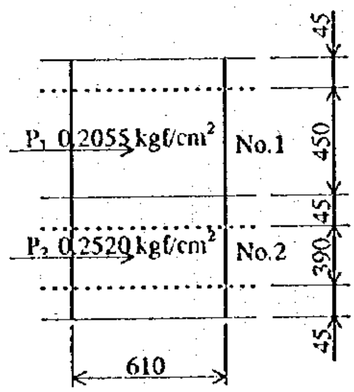
	Beam B
$W\ (kgf)$	1309
$I\ (cm^4)$	92
$\delta\ (cm)$	0.117
$\delta\ /\ L\ (cm)$	1/940
Allowable deflection	< 1/800

5.12.5 Skin Plate

Bending stress of skin plate is calculated in accordance with the following Timoshenko's formula:

$$\sigma = \frac{k \cdot a^2 \cdot p}{100(t - \varepsilon)^2}$$

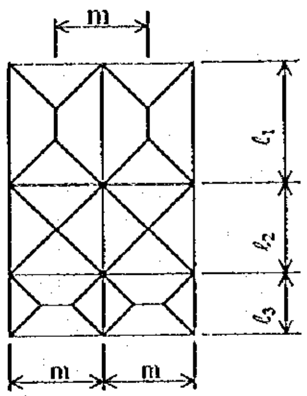
where,	σ	: Bending stress	(kgf/cm^2)
	k	: Coefficient by "b/a"	
	a	: Short span of plate	(cm)
	b	: Long span of plate	(cm)
	p	: Mean design pressure	(kgf/cm^2)
	t	: Thickness of plate	(cm)
	ε	: Corrosion allowance	0.1cm

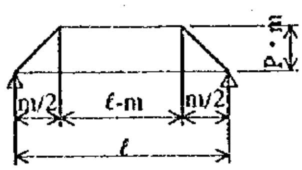


	No.1	No.2
a(cm)	45.0	39.0
b(cm)	61.0	61.0
b/a	1.356	1.564
k	42.50	46.24
p (kgf/cm^2)	0.2055	0.2520
t(cm)	0.5	0.5
σ (kgf/cm^2)	707	709
σ a(kgf/cm^2)	1200	1200

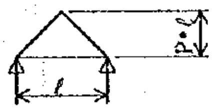
5.12.6 Vertical Girders

(1) Bending moment and shearing force are calculated by the following formula.





(a) ℓ > m



(b) ℓ ≤ m

(a) $\ell > m$

Bending moment

$$M = P \times m \times (3\ell^2 - m^2) / 24$$

Shearing force

$$S = P \times m \times (\ell - m/2) / 2$$

(b) $\ell \leqq m$

Bending moment

$$M = P \times \ell^3 / 12$$

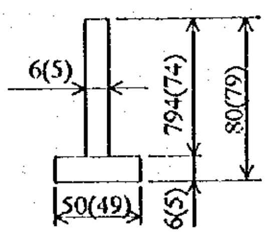
Shearing force

$$S = P \times \ell^2 / 4$$

where, M : Maximum bending moment (kgf-cm)
P : Mean water pressure (kgf/cm^2)
m : Pitch of vertical girder 61.0 cm
ℓ : Distance between horizontal beams (cm)
S : Maximum shearing force (kgf)

Portion	m	ℓ	P	M	S
1	61.0	49.5	0.2033	2055	125
2	61.0	48.0	0.2520	2322	145

Sectional property
Following section is used.



Moment of inertia I = 40 cm^4
Modulus of section Z = 8 cm^3
Area of web Aw = 3.7 cm^2

Bending and shearing stresses

$$\sigma = M / Z$$

where,	σ	: Maximum bending stress	(kgf/cm^2)
	M	: Maximum bending moment	2322 kgf-cm
	Z	: Modulus of section	8 cm^3

Thus,

$$\sigma = 2322 / 8$$

$$= 290\ kgf\ /\ cm^2 < 1.200\ kgf\ /\ cm^2 = Allowable\ bending\ stress$$

$$\tau = S / Aw$$

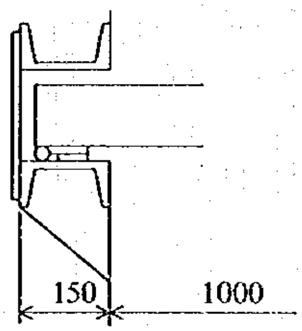
where,	σ	: Maximum shearing stress	(kgf/cm^2)
	S	: maximum shearing force	145 kgf
	Aw	: Area of web	3.7 cm^2

Thus,

$$\tau = 145 / 3.7$$

$$= 39\ kgf\ /\ cm^2 < 700\ kgf\ /\ cm^2 = Allowable\ shearing\ stress$$

5.12.7 Guide frame



Bearing stress of concrete

$$\sigma c = Pt / 2 \times b \times l$$

where,	σc	: Concrete bearing stress	(kgf/cm^2)
	Pt	: Hydraulic load	2862 (kgf)
	b	: Flange width of track frame	15.0 (cm)
	l	: Sealing height	105.0(cm)

Thus,

$$\sigma c = \frac{3046}{2 \times 15.0 \times 115.0} = 0.88\ kgf\ /\ cm^2 < \sigma ca = 60\ kgf\ /\ cm^2$$

(2) Shearing stress of concrete

$$\tau c = Pt / 2 \times ls \times \ell$$

$$ls = 15.0 \times \sqrt{2} = 21.2\ cm$$

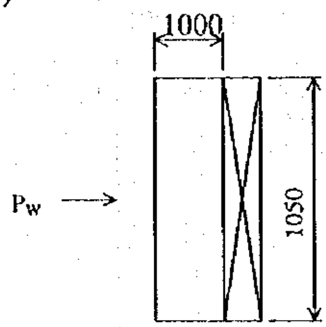
$$\tau c = \frac{2862}{2 \times 21.2 \times 105} = 0.64\ kgf / cm^2 < \tau ca = 3.6\ kgf / cm^2$$

5.12.8 Operation Load

(1) Operation Conditions

The slide gate is operated under the water head difference of 1.0m.

(2) Water Pressure Load at Operating.



$$Pw = H \times Hs \times B \times Gw$$

where,	Pw	: Water pressure load at operating (tf)	
	H	: Operating head	1.0m
	Hs	: Sealing height	1.05m
	B	: Sealing span	1.18m
	Gw	: Specific gravity of water	1.0 tf/m^3

Thus,

$$Pw = 1.0 \times 1.05 \times 1.18 \times 1.0$$
$$= 1.239\ tf$$

(3) Operating Load

(a) Own weight of gate leaf and spindle

$$Wg = 0.22\ tf$$

(b) Friction force of seal rubber

$$FrR = \mu \times (q \times p \times b) \times \Sigma_1$$

where,

FrR : Friction force of seal rubber (tf)

μ	: Friction coefficient of seal rubber at starting 1.5 at sliding 0.7	
q	: Initial compression load on seal rubber	0.1 tf/m
p	: Mean design pressure	1.0 tf/m^2
b	: Contact width of seal rubber	0.03 m
Σ_1	: Total sliding length of seal rubber	3.28 m

Thus,

(i) at Raising

$$FrR = 1.5 \times (0.10 + 1.0 \times 0.03) \times 3.28$$
$$= 0.640\ tf$$

(ii) at Lowering

$$FrL = 0.7 \times (0.10 + 0.0 \times 0.03) \times 3.28$$
$$= 0.230\ tf$$

(c) Friction force of bearing plate

$$Fb = Pwr \times \mu b$$

where,

Fb	: Friction force of bearing plate (tf)	
Pwr	: Water pressure load	1.239 tf
μb	: Frictional coefficient of bearing plate	0.45

Thus,

$$Fb = 1.239 \times 0.45 = 0.558\ tf$$

(d) Buoyancy

$$Fb = \frac{G}{jo}$$

where,

F	: Buoyancy	(tf)
G	: Weight gate leaf	0.22 tf
jo	: Specific gravity	7.85 tf/m^3

Thus,

$$Fb = \frac{0.22}{7.85} = 0.028\ tf$$

(c) Total operation load

	Raising load (tf)	Lowering load (tf)
Gate weight(Wg)	+0.22	+0.22
Friction force due to seal rubber(Fr)	+0.640	-0.230
Friction force of bearing plate	+0.558	
Buoyancy(Fb)		-0.028
Total	+1.418	-0.038

where,
Operation load at
Raising : 1.5 tf (including allowance)
Lowering : 0.1 tf

5.12.9 Hoist
1.5 tf capacity manual hoist × 1 set

5.13 Calculation of Slide gate (0.9m×0.9m)

5.13.1 General

Slide gates having 0.9 m wide by 0.9 m high are provided at the following sluiceway. The main design data for slide gate is as follows:

Main Design Data for Slide Gate

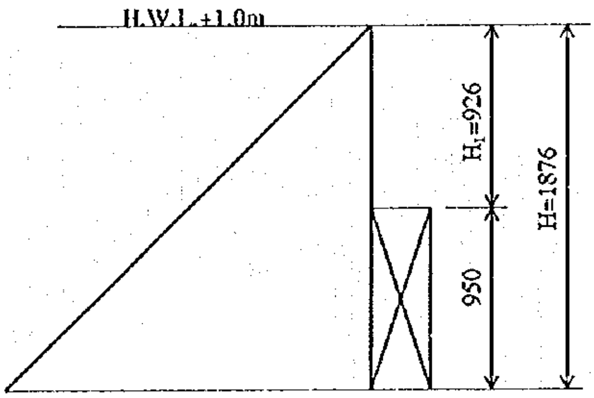
No.	Gate No.	H.W.L.+1.0m	(Sill El.).	Design Head (m)	Quantity (set)
1.	SKE-3R	+3.328	+1.452	1.876	1

5.13.2 Design Conditions

Type	: Steel made slide gate
Quantity	
Gate leaf	: 1 set
Guide frame	: 1 set
Hoist	: 1 set
Clear span	: 0.9 m
Clear height	: 0.9 m
Design head (H.W.L.+1.0m-Sill EL.)	: 1.876 m
Sealing method	:4 edges rubber seal at anti-pressure side (land side)
Maximum deflection of main horizontal beams	:1/800 of supporting span
Corrosion allowance	: 0.5mm for water contact face members)
Type of hoist	: Manual driven screwed spindle hoist
Operation head	: Water difference of 1.0m
Hoisting height	: Clear height + 5 cm in normal operation
Operation method	: Local

5.13.3 Design Load

(1) Hydraulic load



$$Pt = 0.5 \times (H^2 - H_1^2) \times B \times GW$$

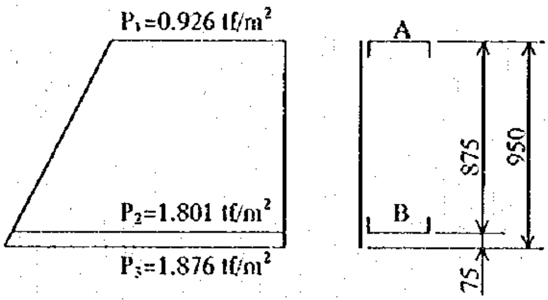
where, Pt :Hydraulic load (tf)
H :Water head at gate bottom 1.876 m
H_1 :Water head at upper seal 0.926 m
B :Sealing span 1.08 m
GW :Specific gravity of water 1.0 tf/m^3

Thus,

$$Pt = 0.5 \times (1.876^2 - 0.926^2) \times 1.08 \times 1.0$$
$$= 1.437\ tf$$

5.13.4 Main Horizontal beams

(1) Arrangement of main horizontal beams
Two (2) number of main horizontal beams are arranged follows:



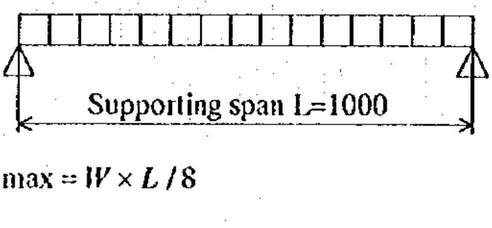
Charging load on each beam

Charging load acting on each beam is calculated by following equation:

$$Beam\ A = \frac{(2 \times 0.926 + 1.801)}{6} \times 0.875$$
$$= 0.533\ tf\ /m$$
$$Beam\ B = \frac{(0.926 + 2 \times 1.801)}{6} \times 0.875 + \frac{(1.801 + 1.876)}{2} \times 0.075$$
$$= 0.798\ tf\ /m$$

(3) Bending moment and shearing force

(a) Bending moment
Maximum bending moment is calculated by the following equation:



$$M\max = W \times L / 8$$

where,	$M\max$	:Maximum bending moment	(tf-m)
	W	:Design load acting on the beam	(tf)
	L	:Supporting span	1.00m

(b) Max Shearing force is calculated by the following equation:

$$S\max = W/2$$

where,	$S\max$	:Maximum shearing force	(tf)
	W	:Design load acting on beam	(tf)

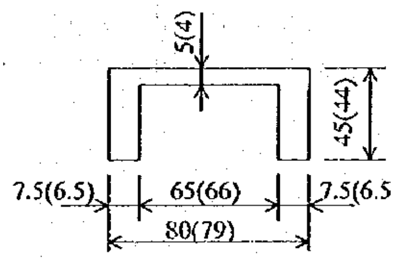
(c) Calculation result

The calculation result is as follows:

		Beam B
W	(tf)	0.862
M max	(tf-m)	0.108
S max	(tf)	0.431

As maximum design load acts on beam B , bending moment and shearing force are calculated only on beam B.

(4) Sectional property of beams

	Beam B
Sectional dimension	
$I(cm^4)$	85
$Z(cm^3)$	22
$A(cm^2)$	8.36

(5) Bending and shearing stress

Bending and shearing stress are calculated by the following equations:

$$\sigma\max = \frac{M\max\times 10^5}{Z}$$

$$\tau\max = \frac{S\max\times 10^3}{A_w}$$

where, σ max : Maximum bending stress (kgf/cm^2)
M max : Maximum bending moment (tf-m)
Z : Modulus of section (cm^3)
τ max : Maximum shearing stress (kgf/cm^2)
S max : maximum shearing (tf)
A_W : Area of web at both ends (cm^2)

	Beam B
M max	0.108
Z	22
σ max	491
S max	0.431
A_W	2.64
τ max	163
Allowable bending stress(kgf/cm^2)	1200 (Material 40kgf/mm^{2}class mild steel)
Allowable searing stress(kgf/cm^2)	700 (-ditto-)

(6) Deflection

Maximum deflection of each beams is calculated by the following equation:

$$\delta \max = \frac{5WL^3}{384EI}$$

where, δ max : Maximum deflection of each beam (cm)
W : Design load on each beam (kgf)
L : Supporting span 100cm
E : Elastic Modulus of steel $2.1 \times 10^6 kgf / cm^2$
I : Geometrical moment of inertia (cm^4)

Thus,

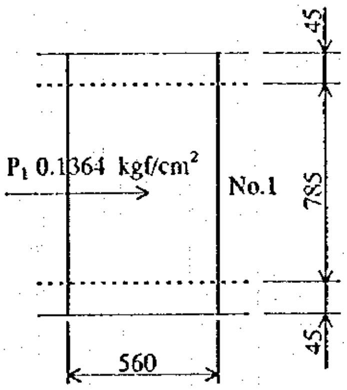
	Beam B
$W (kgf)$	862
$I (cm^4)$	85
$\delta (cm)$	0.063
$\delta / L (cm)$	1/1587
Allowable deflection	< 1/800

5.13.5 Skin Plate

Bending stress of skin plate is calculated in accordance with the following Timoshenko's formula:

$$\sigma = \frac{k \cdot a^2 \cdot p}{100(t - \varepsilon)^2}$$

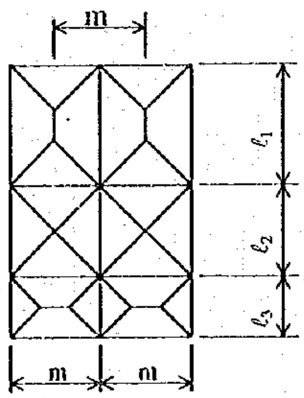
where,			
	σ	: Bending stress	(kgf/cm^2)
	k	: Coefficient by "b/a"	
	a	: Short span of plate	(cm)
	b	: Long span of plate	(cm)
	p	: Mean design pressure	(kgf/cm^2)
	t	: Thickness of plate	(cm)
	ε	: Corrosion allowance	0.1cm

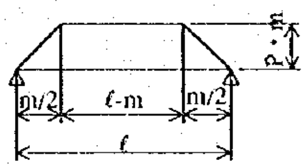


	No.1
a(cm)	56.0
b(cm)	78.5
b/a	1.402
k	43.46
p (kgf/cm^2)	0.1364
t(cm)	0.5
σ (kgf/cm^2)	743
σ a(kgf/cm^2)	1200

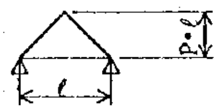
5.13.6 Vertical Girders

(1) Bending moment and shearing force are calculated by the following formula.





(a) $\ell > m$



(b) $\ell \leq m$

(a) $\ell > m$

Bending moment

$$M = P \times m \times (3\ell^2 - m^2) / 24$$

Shearing force

$$S = P \times m \times (\ell - m/2) / 2$$

(b) $\ell \leqq m$

Bending moment

$$M = P \times \ell^3 / 12$$

Shearing force

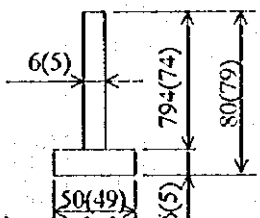
$$S = P \times \ell^2 / 4$$

where, M	: Maximum bending moment (kgf-cm)	
P	: Mean water pressure (kgf/cm^2)	
m	: Pitch of vertical girder	56.0 cm
ℓ	: Distance between horizontal beams (cm)	
S	: Maximum shearing force (kgf)	

Portion	m	ℓ	P	M	S
1	56.0	87.5	0.1363	6307	227

Sectional property

Following section is used.



Moment of inertia	I	= 40 cm^4
Modulus of section	Z	= 8 cm^3
Area of web	Aw	= 3.7 cm^2

Bending and shearing stresses

$$\sigma = M / Z$$

where, σ	: Maximum bending stress	(kgf/cm^2)
M	: Maximum bending moment	6307 kgf-cm
Z	: Modulus of section	8 cm^3

Thus,

$$\sigma = 6307 / 8$$

$$= 788\, kgf / cm^2 < 1.200\, kgf / cm^2 = \text{Allowable bending stress}$$

$$\tau = S / Aw$$

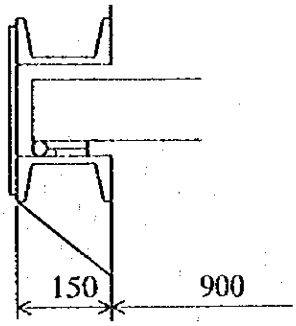
where, σ	: Maximum shearing stress	(kgf/cm^2)
S	: maximum shearing force	227 kgf
Aw	: Area of web	3.7 cm^2

Thus,

$$\tau = 227 / 3.7$$

$$= 61\, kgf / cm^2 < 700\, kgf / cm^2 = \text{Allowable shearing stress}$$

5.13.7 Guide frame



Bearing stress of concrete

$$\sigma c = Pt / 2 \times b \times l$$

where, σc	: Concrete bearing stress		(kgf/cm^2)
Pt	: Hydraulic load		1437 (kgf)
b	: Flange width of track frame		15.0 (cm)
l	: Sealing height		95.0 (cm)

Thus,

$$\sigma c = \frac{1437}{2 \times 15.0 \times 95.0} = 0.50\, kgf\ / cm^2 < \sigma ca = 60\, kgf\ / cm^2$$

(2) Shearing stress of concrete

$$\tau c = Pt / 2 \times ls \times \ell$$

$$ls = 15.0 \times \sqrt{2} = 21.2\ cm$$

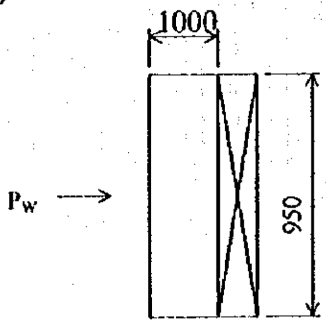
$$\tau c = \frac{1437}{2 \times 21.2 \times 95} = 0.36\, kgf\ / cm^2 < \tau ca = 3.6\, kgf\ / cm^2$$

5.13.8 Operation Load

(1) Operation Conditions

The slide gate is operated under the water head difference of 1.0m .

(2) Water Pressure Load at Operating.



$$Pw = H \times Hs \times B \times Gw$$

where,	Pw	: Water pressure load at operating (tf)	
	H	: Operating head	1.0m
	Hs	: Sealing height	0.95m
	B	: Sealing span	1.08m
	Gw	: Specific gravity of water	1.0 tf/m^3

Thus,

$$Pw = 1.0 \times 0.95 \times 1.08 \times 1.0$$
$$= 1.026\, tf$$

(3) Operating Load

(a) Own weight of gate leaf and spindle

$$Wg = 0.19\, tf$$

(b) Friction force of seal rubber

$$FrR = \mu \times (q \times p \times b) \times \Sigma_1$$

where,

FrR	: Friction force of seal rubber (tf)	
μ	: Friction coefficient of seal rubber	
	at starting 1.5	
	at sliding 0.7	
q	: Initial compression load on seal rubber	0.1 tf/m
p	: Mean design pressure	1.0 tf/m^2
b	: Contact width of seal rubber	0.03 m
Σ_1	: Total sliding length of seal rubber	2.98 m

Thus,

(i) at Raising

$$FrR = 1.5 \times (0.10 + 1.0 \times 0.03) \times 2.98$$
$$= 0.581\, tf$$

(ii) at Lowering

$$FrL = 0.7 \times (0.10 + 0.0 \times 0.03) \times 2.98$$
$$= 0.209\, tf$$

(c) Friction force of bearing plate

$$Fb = Pwr \times \mu b$$

where,

Fb	: Friction force of bearing plate (tf)	
Pwr	: Water pressure load	1.026 tf
μb	: Frictional coefficient of bearing plate	0.45

Thus,

$$Fb = 1.026 \times 0.45 = 0.462\ tf$$

(d) Buoyancy

$$Fb = \frac{G}{jo}$$

where,

F	: Buoyancy	(tf)
G	: Weight gate leaf	0.19 tf
jo	: Specific gravity	7.85 tf/m^3

Thus,

$$Fb = \frac{0.19}{7.85} = 0.024\ tf$$

(e) Total operation load

	Raising load (tf)	Lowering load (tf)
Gate weight(Wg)	+0.19	+0.19
Friction force due to seal rubber(Fr)	+0.581	-0.209
Friction force of bearing plate	+0.462	
Buoyancy(Fb)		-0.024
Total	+1.233	-0.043

where,
Operation load at
Raising : 1.3 tf (including allowance)
Lowering : 0.1 tf

5.13.9 Hoist

1.3 tf capacity manual hoist × 1 set

5.14 Calculation of Slide gate (0.8m×0.8m)

5.14.1 General

Slide gates having 0.8 m wide by 0.8 m high are provided at the each sluiceways. The main design data for each slide gate are as follows:

Main Design Data for Slide Gates

No.	Gate No.	H.W.L.+1.0m	(Sill EL).	Design Head (m)	Quantity (set)
1.	SKM-4L	+1.948	- 0.436	2.384	1
2.	SKE-1L	+2.425	+0.523	1.902	1
3.	SKE-7L	+3.328	+1.452	1.876	1
4.	STM-3L	+1.504	- 0.588	2.092	1
5.	STM-3R	+1.608	- 0.517	2.125	1
6.	SGM-6L	+4.115	+1.883	2.232	1
7.	SGM-2R	+3.609	+1.532	2.077	1

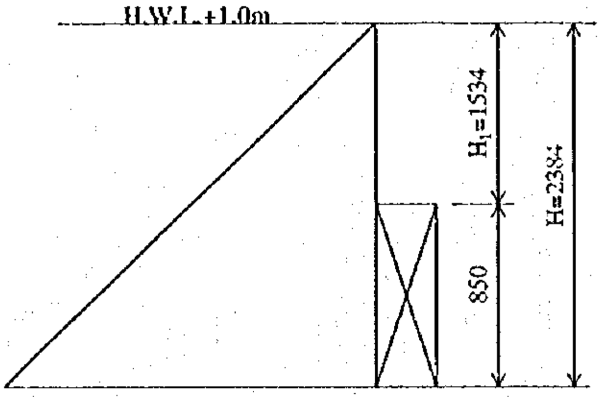
Since the design head varies from 1.876 m to 2.384 m , the design head of slide gate is taken at 2.384 m in the structural calculations.

5.14.2 Design Conditions

Type	: Steel made slide gate
Quantity	
Gate leaf	: 7 set
Guide frame	: 7 set
Hoist	: 7 set
Clear span	: 0.8 m
Clear height	: 0.8 m
Design head (H.W.L.+1.0m-Sill EL.)	: 2.384 m
Sealing method	:4 edges rubber seal at anti-pressure side (land side)
Maximum deflection of main horizontal beams	:1/800 of supporting span
Corrosion allowance	: 0.5mm for water contact face members)
Type of hoist	: Manual driven screwed spindle hoist
Operation head	: Water difference of 1.0m
Hoisting height	: Clear height + 5 cm in normal operation
Operation method	: Local

5.14.3 Design Load

(1) Hydraulic load



$$Pt = 05 \times (H^2 - H_1^2) \times B \times GW$$

where,

Pt :Hydraulic load		(tf)
H :Water head at gate bottom	2.384 m	
H_1 :Water head at upper seal	1.534 m	
B :Sealing span	0.98 m	
GW :Specific gravity of water	1.0 tf/m^3	

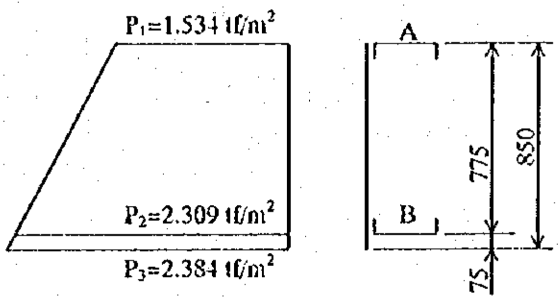
Thus,

$$Pt = 0.5 \times (2.384^2 - 1.534^2) \times 0.98 \times 1.0$$
$$= 1.632\ tf$$

5.14.4 Main Horizontal beams

(1) Arrangement of main horizontal beams

Two (2) number of main horizontal beams are arranged follows:



Charging load on each beam

Charging load acting on each beam is calculated by following equation:

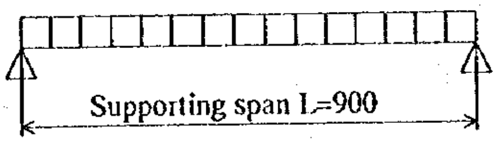
$$Beam\ A = \frac{(2 \times 1.534 + 2.309)}{6} \times 0.775$$
$$= 0.695\ tf\ /m$$

$$Beam\ B = \frac{(1.534 + 2 \times 2.309)}{6} \times 0.775 + \frac{(2.309 + 2.384)}{2} \times 0.075$$
$$= 0.971\ tf\ /m$$

(3) Bending moment and shearing force

(a) Bending moment

Maximum bending moment is calculated by the following equation:



$$M\max = W \times L/8$$

where,			
	$M\max$	:Maximum bending moment	(tf-m)
	W	:Design load acting on the beam	(tf)
	L	:Supporting span	0.90m

(b) Max Shearing force is calculated by the following equation:

$$S\max = W/2$$

where,			
	$S\max$	:Maximum shearing force	(tf)
	W	:Design load acting on beam	(tf)

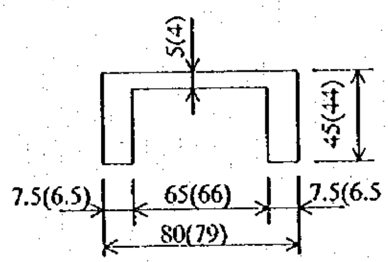
(c) Calculation result

The calculation result is as follows:

		Beam B
W	(tf)	0.952
M max	(tf-m)	0.107
S max	(tf)	0.476

As maximum design load acts on beam B , bending moment and shearing force are calculated only on beam B.

(4) Sectional property of beams

	Beam B
Sectional dimension	
$I(cm^4)$	85
$Z(cm^3)$	22
$A(cm^2)$	8.36

(5) Bending and shearing stress

Bending and shearing stress are calculated by the following equations:

$$\sigma \max = \frac{M \max \times 10^5}{Z}$$

$$\tau \max = \frac{S \max \times 10^3}{A_W}$$

where,			
	σ max	: Maximum bending stress	(kgf/cm^2)
	M max	: Maximum bending moment	(tf-m)
	Z	: Modulus of section	(cm^2)
	τ max	: Maximum shearing stress	(kgf/cm^2)
	S max	: maximum shearing	(tf)
	A_W	: Area of web at both ends	(cm^2)

	Beam B
M max	0.107
Z	22
σ max	486
S max	0.476
A_W	2.64
τ max	180
Allowable bending stress(kgf/cm^2)	1200 (Material 40kgf/mm^{2}class mild steel)
Allowable scaring stress(kgf/cm^2)	700 (-ditto-)

(6) Deflection

Maximum deflection of each beams is calculated by the following equation:

$$\delta \max = \frac{5WL^3}{384EI}$$

where,			
	δ max	: Maximum deflection of each beam	(cm)
	W	: Design load on each beam	(kgf)
	L	: Supporting span	90 cm
	E	: Elastic Modulus of steel	$2.1 \times 10^6 kgf / cm^2$
	I	: Geometrical moment of inertia (cm^4)	

Thus,

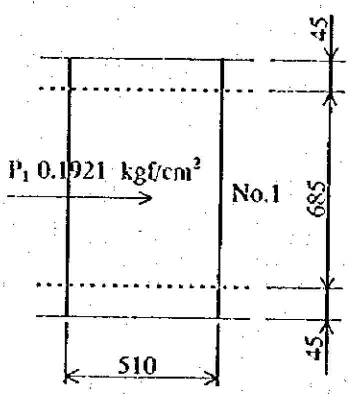
	Beam B
$W (kgf)$	952
$I (cm^4)$	85
$\delta (cm)$	0.051
$\delta / L (cm)$	1/1765
Allowable deflection	< 1/800

5.14.5 Skin Plate

Bending stress of skin plate is calculated in accordance with the following Timoshenko's formula:

$$\sigma = \frac{k \cdot a^2 \cdot p}{100(t - \varepsilon)^2}$$

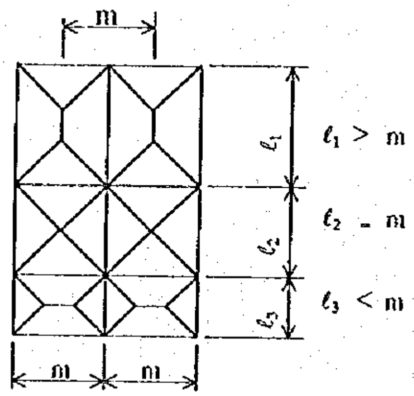
where,			
	σ	: Bending stress	(kgf/cm²)
	k	: Coefficient by "b/a"	
	a	: Short span of plate	(cm)
	b	: Long span of plate	(cm)
	p	: Mean design pressure	(kgf/cm²)
	t	: Thickness of plate	(cm)
	ε	: Corrosion allowance	0.1cm

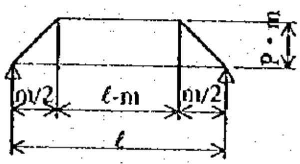


	No.1
a(cm)	51.0
b(cm)	68.5
b/a	1.343
k	42.24
p (kgf/cm²)	0.1921
t(cm)	0.5
σ (kgf/cm²)	844
σ a(kgf/cm²)	1200

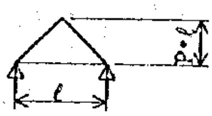
5.14.6 Vertical Girders

(1) Bending moment and shearing force are calculated by the following formula.





(a) $\ell > m$



(b) $\ell \leq m$

(a) $\ell > m$

Bending moment

$$M = P \times m \times (3\ell^2 - m^2) / 24$$

Shearing force

$$S = P \times m \times (\ell - m/2) / 2$$

(b) $\ell \leqq m$

Bending moment

$$M = P \times \ell^3 / 12$$

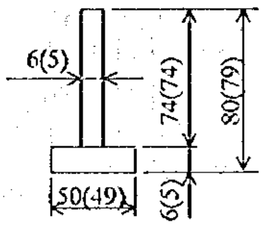
Shearing force

$$S = P \times \ell^2 / 4$$

where, M : Maximum bending moment (kgf-cm)
P : Mean water pressure (kgf/cm^2)
m : Pitch of vertical girder 51.0 cm
ℓ : Distance between horizontal beams (cm)
S : Maximum shearing force (kgf)

Portion	m	ℓ	P	M	S
1	51.0	77.5	0.1921	7452	288

Sectional property
Following section is used.



Moment of inertia $I = 40$ cm^4
Modulus of section $Z = 8$ cm^3
Area of web $Aw = 3.7$ cm^2

Bending and shearing stresses

$$\sigma = M / Z$$

where, σ : Maximum bending stress (kgf/cm^2)
M : Maximum bending moment 7452 kgf-cm
Z : Modulus of section 8 cm^3

Thus,

$\sigma = 7452 / 8$

$= 932\ kgf\ /\ cm^2 < 1.200\ kgf\ /\ cm^2 = Allowable\ bending\ stress$

$\tau = S\ /\ Aw$

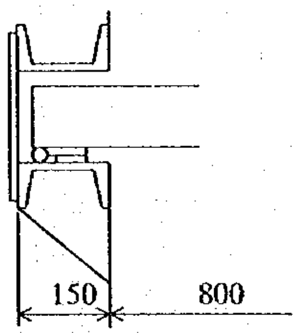
where, σ	: Maximum shearing stress		(kgf/cm^2)
S	: maximum shearing force		288 kgf
Aw	: Area of web		3.7 cm^2

Thus,

$\tau = 288 / 3.7$

$= 78\ kgf\ /\ cm^2 < 700\ kgf\ /\ cm^2 = Allowable\ shearing\ stress$

5.14.7 Guide frame



Bearing stress of concrete

$\sigma c = Pt / 2 \times b \times l$

where,	σc	: Concrete bearing stress	(kgf/cm^2)
	Pt	: Hydraulic load	1632 (kgf)
	b	: Flange width of track frame	15.0 (cm)
	l	: Sealing height	85.0 (cm)

Thus,

$$\sigma c = \frac{1632}{2 \times 15.0 \times 85.0} = 0.64\ kgf\ /\ cm^2 < \sigma ca = 60\ kgf\ /\ cm^2$$

(2) Shearing stress of concrete

$\tau c = Pt / 2 \times ls \times \ell$

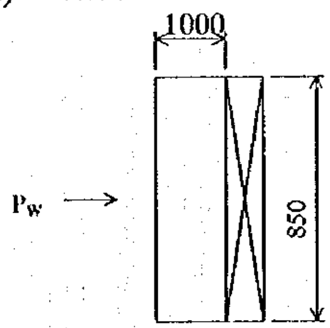
$ls = 15.0 \times \sqrt{2} = 21.2\ cm$

$$\tau c = \frac{1632}{2 \times 21.2 \times 85} = 0.45\ kgf\ /\ cm^2 < \tau ca = 3.6\ kgf\ /\ cm^2$$

5.14.8 Operation Load

(1) Operation Conditions
The slide gate is operated under the water head difference of 1.0m .

(2) Water Pressure Load at Operating.



$$Pw = H \times Hs \times B \times Gw$$

where,

Pw	: Water pressure load at operating (tf)		
H	: Operating head	1.0m	
Hs	: Sealing height	0.85m	
B	: Sealing span	0.98m	
Gw	: Specific gravity of water	1.0 tf/m^3	

Thus,

$$Pw = 1.0 \times 0.85 \times 0.98 \times 1.0$$
$$= 0.833\,tf$$

(3) Operating Load

(a) Own weight of gate leaf and spindle

$$Wg = 0.17\,tf$$

(b) Friction force of seal rubber

$$FrR = \mu \times (q \times p \times b) \times \Sigma_1$$

where,

FrR	: Friction force of seal rubber (tf)	
μ	: Friction coefficient of seal rubber	
	at starting 1.5	
	at sliding 0.7	
q	: Initial compression load on seal rubber	0.1 tf/m
p	: Mean design pressure	1.0 tf/m^2
b	: Contact width of seal rubber	0.03 m
Σ_1	: Total sliding length of seal rubber	2.68 m

Thus,

(i) at Raising

$$FrR = 15 \times (0.10 + 1.0 \times 0.03) \times 2.68$$
$$= 0.523\,tf$$

(ii) at Lowering

$$FrL = 0.7 \times (0.10 + 0.0 \times 0.03) \times 2.68$$
$$= 0.188\,tf$$

(c) Friction force of bearing plate

$$Fb = Pwr \times \mu b$$

where,

Fb	: Friction force of bearing plate (tf)	
Pwr	: Water pressure load	0.833 tf
μb	: Frictional coefficient of bearing plate	0.45

Thus,

$$Fb = 0.833 \times 0.45 = 0.375\,tf$$

(d) Buoyancy

$$Fb = \frac{G}{jo}$$

where,

F	: Buoyancy	(tf)
G	: Weight gate leaf	0.17 tf
jo	: Specific gravity	7.85 tf/m^3

Thus,

$$Fb = \frac{0.17}{7.85} = 0.022\,tf$$

(e) Total operation load

	Raising load (tf)	Lowering load (tf)
Gate weight(Wg)	+0.17	+0.17
Friction force due to seal rubber(Fr)	+0.523	-0.188
Friction force of bearing plate	+0.375	
Buoyancy(Fb)		-0.022
Total	+1.068	-0.040

where,
Operation load at
Raising : 1.1 tf (including allowance)
Lowering : 0.1 tf

5.14.9 Hoist

1.1 tf capacity manual hoist × 1 set

5.15 Calculation of Slide gate (0.7m×0.7m)

5.15.1 General

Slide gates having 0.7 m wide by 0.7 m high are provided at the following sluiceway. The main design data for slide gate is as follows:

Main Design Data for Slide Gate

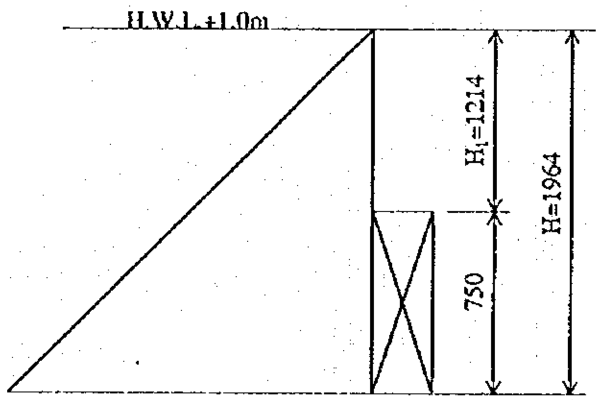
No.	Gate No.	H.W.L.+1.0m	(Sill EL).	Design Head (m)	Quantity (set)
1.	SKM-7L	+2.207	+0.243	1.964	1

5.15.2 Design Conditions

Type	: Steel made slide gate
Quantity	
Gate leaf	: 1 set
Guide frame	: 1 set
Hoist	: 1 set
Clear span	: 0.7 m
Clear height	: 0.7 m
Design head (H.W.L.+1.0m-Sill EL.)	: 1.964 m
Sealing method	:4 edges rubber seal at anti-pressure side (land side)
Maximum deflection of main horizontal beams	:1/800 of supporting span
Corrosion allowance	: 0.5mm for water contact face members)
Type of hoist	: Manual driven screwed spindle hoist
Operation head	: Water difference of 1.0m
Hoisting height	: Clear height + 5 cm in normal operation
Operation method	: Local

5.15.3 Design Load

(1) Hydraulic load



$$Pt = 0.5 \times (H^2 - H_1^2) \times B \times GW$$

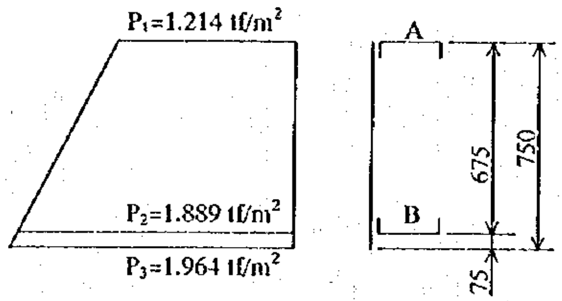
where,		
	Pt :Hydraulic load	(tf)
	H :Water head at gate bottom	1.964 m
	H_1 :Water head at upper seal	1.214 m
	B :Sealing span	0.88 m
	GW :Specific gravity of water	1.0 tf/m^3

Thus,

$$Pt = 0.5 \times (1.964^2 - 1.214^2) \times 0.88 \times 1.0$$
$$= 1.049\,tf$$

5.15.4 Main Horizontal beams

(1) Arrangement of main horizontal beams
Two (2) number of main horizontal beams are arranged follows:



Charging load on each beam

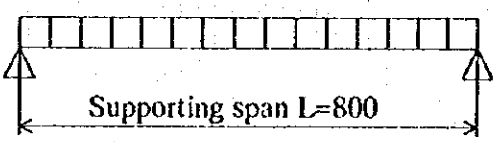
Charging load acting on each beam is calculated by following equation:

$$Beam\ A = \frac{(2 \times 1.214 + 1.889)}{6} \times 0.675$$
$$= 0.486\,tf\ /m$$

$$Beam\ B = \frac{(1.214 + 2 \times 1.889)}{6} \times 0.675 + \frac{(1.889 + 1.964)}{2} \times 0.075$$
$$= 0.706\,tf\ /m$$

(3) Bending moment and shearing force

(a) Bending moment
Maximum bending moment is calculated by the following equation:



$$M\max = W \times L / 8$$

where,	M max	:Maximum bending moment	(tf-m)
	W	:Design load acting on the beam	(tf)
	L	:Supporting span	0.80m

(b) Max Shearing force is calculated by the following equation:

$$S \max = W / 2$$

where,	S max	:Maximum shearing force	(tf)
	W	:Design load acting on beam	(tf)

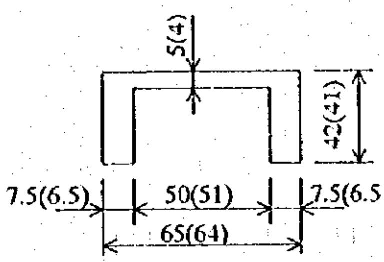
(c) Calculation result

The calculation result is as follows:

		Beam B
W	(tf)	0.621
M max	(tf-m)	0.062
S max	(tf)	0.311

As maximum design load acts on beam B , bending moment and shearing force are calculated only on beam B.

(4) Sectional property of beams

	Beam B
Sectional dimension	
$I(cm^4)$	49
$Z(cm^3)$	15
$A(cm^2)$	7.37

(5) Bending and shearing stress

Bending and shearing stress are calculated by the following equations:

$$\sigma \max = \frac{M \max \times 10^5}{Z}$$

$$\tau \max = \frac{S \max \times 10^3}{A_w}$$

where, σ max : Maximum bending stress (kgf/cm^2)

M max	: Maximum bending moment	(tf-m)
Z	: Modulus of section	(cm^2)
τ max	: Maximum shearing stress	(kgf/cm^2)
S max	: maximum shearing	(tf)
A_W	: Area of web at both ends	(cm^2)

	Beam B
M max	0.062
Z	15
σ max	413
S max	0.311
A_W	2.04
τ max	152
Allowable bending stress(kgf/cm^2)	1200 (Material 40kgf/mm^2class mild steel)
Allowable scaring stress(kgf/cm^2)	700 (-ditto-)

(6) Deflection

Maximum deflection of each beams is calculated by the following equation:

$$\delta \max = \frac{5WL^3}{384EI}$$

where,			
	δ max	: Maximum deflection of each beam	(cm)
	W	: Design load on each beam	(kgf)
	L	: Supporting span	80 cm
	E	: Elastic Modulus of steel	$2.1 \times 10^6 kgf/cm^2$
	I	: Geometrical moment of inertia (cm^4)	

Thus,

	Beam B
W (kgf)	621
I (cm^4)	49
δ (cm)	0.040
δ / L (cm)	1/2000
Allowable deflection	< 1/800

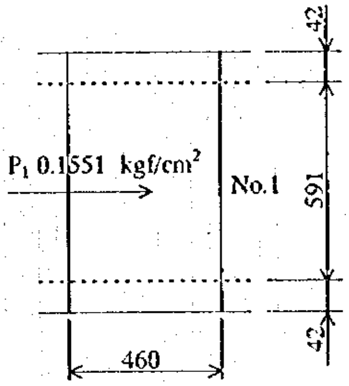
5.15.5 Skin Plate

Bending stress of skin plate is calculated in accordance with the following Timoshenko's formula:

$$\sigma = \frac{k \cdot a^2 \cdot p}{100(t - \varepsilon)^2}$$

where, σ : Bending stress (kgf/cm^2)

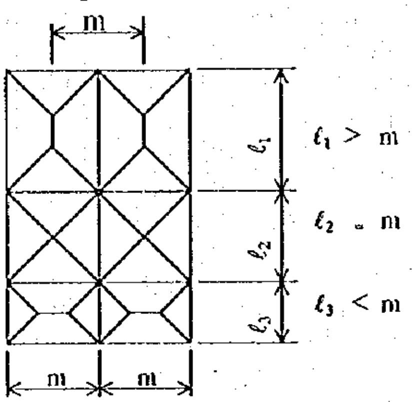
k	: Coefficient by "b/a"	
a	: Short span of plate	(cm)
b	: Long span of plate	(cm)
p	: Mean design pressure	(kgf/cm^2)
t	: Thickness of plate	(cm)
ε	: Corrosion allowance	0.1cm

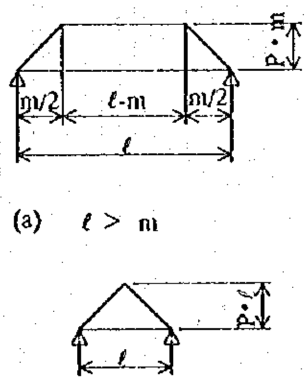


	No.1
a(cm)	46.0
b(cm)	59.1
b/a	1.285
k	41.02
p (kgf/cm^2)	0.1551
t(cm)	0.5
σ (kgf/cm^2)	539
σ a(kgf/cm^2)	1200

5.15.6 Vertical Girders

(1) Bending moment and shearing force are calculated by the following formula.





(a) $\ell > m$

Bending moment

$$M = P \times m \times (3\ell^2 - m^2)/24$$

Shearing force

$$S = P \times m \times (\ell - m/2)/2$$

(b) $\ell \leq m$

Bending moment

$M = P \times \ell^3 / 12$

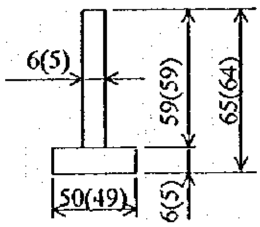
Shearing force

$S = P \times \ell^2 / 4$

where, M : Maximum bending moment (kgf-cm)
P : Mean water pressure (kgf/cm^2)
m : Pitch of vertical girder 51.0 cm
ℓ : Distance between horizontal beams (cm)
S : Maximum shearing force (kgf)

Portion	m	ℓ	P	M	S
1	46.0	67.5	0.1551	3434	159

Sectional property
Following section is used.



Moment of inertia I = 22 cm^4
Modulus of section Z = 5 cm^3
Area of web Aw = 2.95 cm^2

Bending and shearing stresses

$\sigma = M / Z$

where, σ : Maximum bending stress (kgf/cm^2)
M : Maximum bending moment 3434 kgf-cm
Z : Modulus of section 5 cm^3

Thus,

$\sigma = 3434 / 5$

$= 687\ kgf/cm^2 < 1.200\ kgf/cm^2 = Allowable\ bending\ stress$

$\tau = S / Aw$

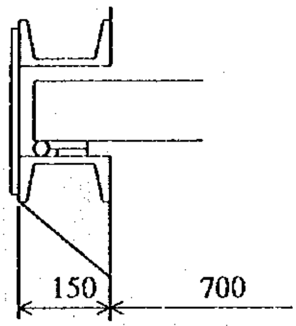
where, σ : Maximum shearing stress (kgf/cm^2)
S : maximum shearing force 159 kgf
Aw : Area of web 2.95 cm^2

Thus,

$\tau = 159 / 2.95$

$= 54\, kgf\ / cm^2 < 700\, kgf\ / cm^2 = Allowable\ shearing\ stress$

5.15.7 Guide frame



Bearing stress of concrete

$\sigma c = Pt / 2 \times b \times l$

where, σc	: Concrete bearing stress		(kgf/cm^2)
Pt	: Hydraulic load		1049 (kgf)
b	: Flange width of track frame		15.0 (cm)
l	: Sealing height		75.0 (cm)

Thus,

$$\sigma c = \frac{1049}{2 \times 15.0 \times 75.0} = 0.47\, kgf\ / cm^2 < \sigma ca = 60\, kgf\ / cm^2$$

(2) Shearing stress of concrete

$\tau c = Pt / 2 \times ls \times \ell$

$ls = 15.0 \times \sqrt{2} = 21.2\, cm$

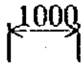
$$\tau c = \frac{1049}{2 \times 21.2 \times 75} = 0.33\, kgf\ / cm^2 < \tau ca = 3.6\, kgf\ / cm^2$$

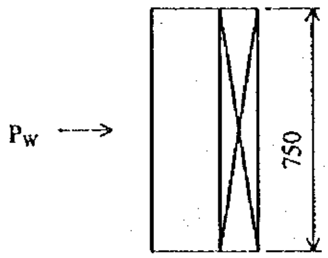
5.15.8 Operation Load

(1) Operation Conditions

The slide gate is operated under the water head difference of 1.0m .

(2) Water Pressure Load at Operating.





$$Pw = H \times Hs \times B \times Gw$$

where,

Pw	: Water pressure load at operating (tf)	
H	: Operating head	1.0m
Hs	: Sealing height	0.75m
B	: Sealing span	0.88m
Gw	: Specific gravity of water	1.0 tf/m^3

Thus,

$$Pw = 1.0 \times 0.75 \times 0.88 \times 1.0$$
$$= 0.660\, tf$$

(3) Operating Load

(a) Own weight of gate leaf and spindle

$$Wg = 0.15\, tf$$

(b) Friction force of seal rubber

$$FrR = \mu \times (q \times p \times b) \times \Sigma_1$$

where,

FrR	: Friction force of seal rubber (tf)	
μ	: Friction coefficient of seal rubber at starting 1.5 at sliding 0.7	
q	: Initial compression load on seal rubber	0.1 tf/m
p	: Mean design pressure	1.0 tf/m^2
b	: Contact width of seal rubber	0.03 m
Σ_1	: Total sliding length of seal rubber	2.38 m

Thus,

(i) at Raising

$$FrR = 1.5 \times (0.10 + 1.0 \times 0.03) \times 2.38$$
$$= 0.464\, tf$$

(ii) at Lowering

$$FrL = 0.7 \times (0.10 + 0.0 \times 0.03) \times 2.38$$
$$= 0.167\ tf$$

(c) Friction force of bearing plate

$$Fb = Pwr \times \mu b$$

where,

Fb	: Friction force of bearing plate (tf)	
Pwr	: Water pressure load	0.660 tf
μb	: Frictional coefficient of bearing plate	0.45

Thus,

$$Fb = 0.660 \times 0.45 = 0.297\ tf$$

(d) Buoyancy

$$Fb = \frac{G}{jo}$$

where,

F	: Buoyancy	(tf)
G	: Weight gate leaf	0.15 tf
jo	: Specific gravity	7.85 tf/m^3

Thus,

$$Fb = \frac{0.15}{7.85} = 0.019\ tf$$

(e) Total operation load

	Raising load (tf)	Lowering load (tf)
Gate weight(Wg)	+0.15	+0.15
Friction force due to seal rubber(Fr)	+0.464	-0.167
Friction force of bearing plate	+0.297	
Buoyancy(Fb)		-0.019
Total	+0.911	-0.036

where,
Operation load at

Raising : 1.0 tf (including allowance)
Lowering : 0.1 tf

5.15.9 Hoist

1.0 tf capacity manual hoist × 1 set

5.16 Calculation of Flap gate (0.4m×0.4m)

5.16.1 General

Flap gates having 0.4 m wide by 0.4 m high are provided at the following sluiceways. The main design data for each flap gate are as follows:

Main Design Data for Flap Gates

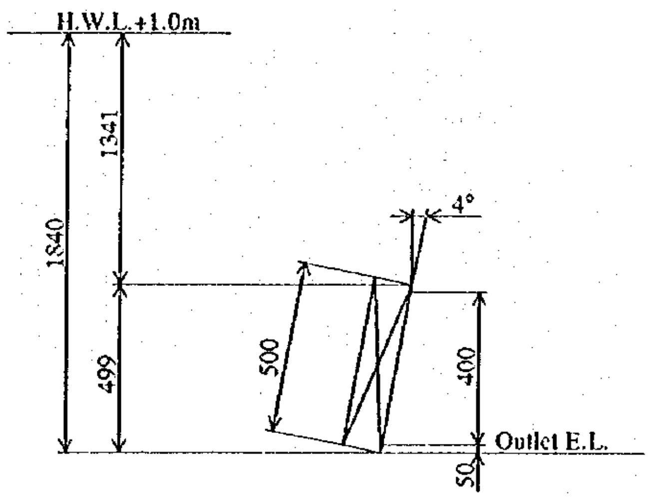
Gate No.	H.W.L + 1.0m.	Outlet EL.	Design Head (m)	Quantity (set)
SKE-2L	+2.836	+1.274	1.562	1
SKE-3L	+2.916	+1.342	1.574	1
SKE-9L	+3.645	+2.025	1.620	1
SKE-4R	+3.645	+2.025	1.624	1
STM-2R	+1.500	- 0.290	1.790	1

Since the design head varies from 1.562 m to 1.790 m, the design head of flap gate is taken at 1.790 m in the structural calculations.

5.16.2 Design Conditions

Type	: Steel made square flap gate
Clear span	: 0.4 m
Clear height	: 0.4 m
Design head	: 1.790 m
Inclined angle	: 4°
Operation	: Automatically operated by water head difference
Sealing method	: 4 edges metal seal anti - pressure side (land side)
Maximum deflection of main beam	: 1/800 of sealing span
Corrosion allowance	: 1.0 mm for water contact face members

5.16.3 Water Pressure Load



$$Pw = 0.5 \times (H_1^2 - H_2^2) \times B \times Gw / \cos\theta$$

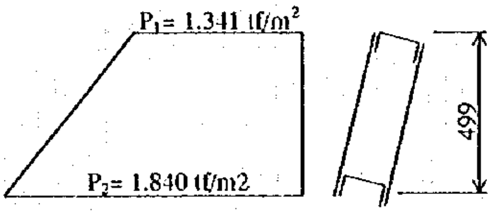
where,	Pw	: Water pressure load (tf)	
	H_1	: Water head at bottom seal	1.840 m
	H_2	: Water head at upper seal	1.341 m
	B	: Sealing span	0.50 m
	Gw	: Specific gravity of water	1.0 tf/m^3
	θ	: Inclined angle	4°

Thus,

$$Pw = 0.5 \times (1.840^2 - 1.341^2) \times 0.50 \times 1.0 / \cos 4^\circ = 0.398\, tf$$

5.16.4 Main Horizontal Beams

(1) Arrangement of main horizontal beams

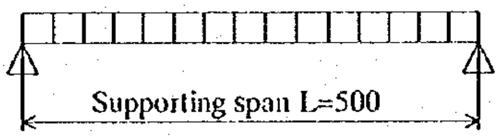


(2) Unit load on each beam

$$Beam\ A = 0.499 \times \frac{(2 \times 1.341 + 1.840)}{6} \times \frac{1}{\cos 4^\circ} = 0.377\, tf - m$$

$$Beam\ B = 0.499 \times \frac{(1.341 + 2 \times 1.840)}{6} \times \frac{1}{\cos 4^\circ} = 0.419\, tf - m$$

(3) Bending moment and shearing force



Maximum bending moment (Mmax)

$$M\max = \frac{WL^2}{8}$$

where,	W	: Unit load on each beam (tf/m)	
	L	: Supporting span	0.50 m

Maximum shearing force(Smax)

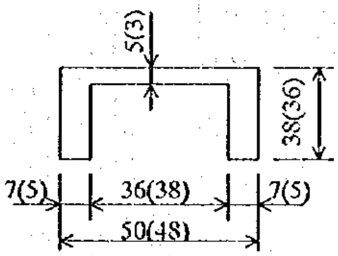
$$S\max = \frac{WL}{2}$$

The calculation results are as follows :

		Beam B
W	(tf/m)	0.419[*1]
M max	(tf-m)	0.013
S max	(tf)	0.105

[*1] Beam A and B have same section. As major unit load acts on Beam B , the bending moment and shearing force are calculated only Beam B.

(4) Sectional property of beams

	Beam B
Sectional dimension	
$I(cm^4)$	18
$Z(cm^3)$	8
$A(cm^2)$	4.74

(5) Bending and shearing stress

Bending and shearing stress are calculated by the following equations:

$$\sigma\max = \frac{M\max\times 10^5}{Z}$$

$$\tau\max = \frac{S\max\times 10^3}{A_W}$$

where,			
	σ max	: Maximum bending stress	(kgf/cm^2)
	M max	: Maximum bending moment	(tf-m)
	Z	: Modulus of section	(cm^2)
	τ max	: Maximum shearing stress	(kgf/cm^2)
	S max	: maximum shearing force	(tf)
	A_W	: Area of web at both ends	(cm^2)

	Beam B
M max	0.013
Z	8
σ max	163
S max	0.105
A_W	1.14
τ max	92
Allowable bending stress(kgf/cm^2)	1200 (Material 40kgf/mm^{2}class mild steel)
Allowable searing stress(kgf/cm^2)	700 (-ditto-)

(6) Deflection

Maximum deflection of each beam is calculated by the following equation.

$$\delta \max = \frac{5WL^4}{384EI}$$

where,
W : Unit load on each beam(kgf/cm)
L : Supporting span 50 cm
E : Elastic modulus of steel 2.1×10^6 kgf/cm^2
I : Moment of inertia(cm^4)

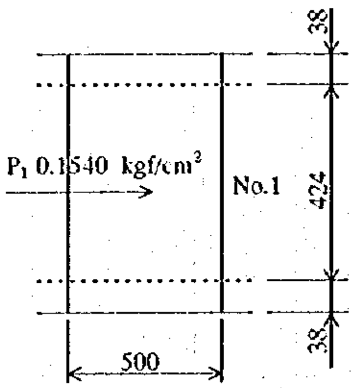
	Beam B
W (kgf/cm)	4.19
I (cm^4)	18
δ max (cm)	0.009
δ / L	1/5,556
Allowable deflection	< 1/800

5.16.5 Skin Plate

Bending stress of skin plate is calculated in accordance with the following Timoshenko's formula:

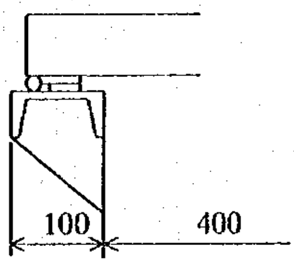
$$\sigma = \frac{k \cdot a^2 \cdot p}{100(t - \varepsilon)^2}$$

where,
σ : Bending stress (kgf/cm^2)
k : Coefficient by "b/a"
a : Short span of plate (cm)
b : Long span of plate (cm)
p : Mean design pressure (kgf/cm^2)
t : Thickness of plate (cm)
ε : Corrosion allowance 0.1cm



	No.1
a(cm)	42.4
b(cm)	50.0
b/a	1.180
k	37.65
p (kgf/cm²)	0.1540
t(cm)	0.4
σ (kgf/cm²)	651
σ a(kgf/cm²)	1200

5.16.6 Guide frame



Bearing stress of concrete

$$\sigma c = Pt / 2 \times b \times l$$

where,			
	σc	: Concrete bearing stress	(kgf/cm²)
	Pt	: Hydraulic load	398 (kgf)
	b	: Flange width of track frame	10.0 (cm)
	l	: Sealing height	50.0 (cm)

Thus,

$$\sigma c = \frac{398}{2 \times 10.0 \times 50.0} = 0.40\, kgf / cm^2 < \sigma ca = 60\, kgf / cm^2$$

(2) Shearing stress of concrete

$$\tau c = Pt / 2 \times ls \times \ell$$

$$ls = 10.0 \times \sqrt{2} = 14.1\, cm$$

$$\tau c = \frac{398}{2 \times 14.1 \times 50} = 0.28\, kgf / cm^2 < \tau ca = 3.6\, kgf / cm^2$$

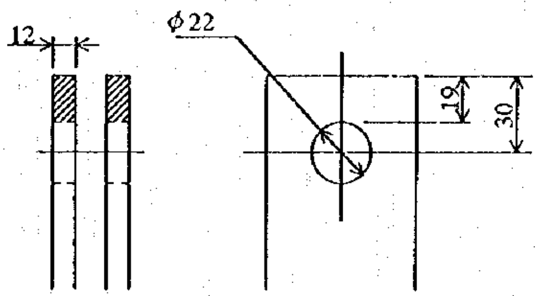
5.16.7 Hinge

(1) Pin

Weight of gate leaf : 50 kgf
Diameter of pin : 20 mm
Sectional area of pin : 3.142 cm^2
Shearing stress of pin : (S)

$$S = 50/(2 \times 3.142/\cos 4^\circ)$$
$$= 8.0\ kgf/cm^2 < 630\ kgf/cm^2 = Allowable\ shearing\ stress\ of\ SUS304$$

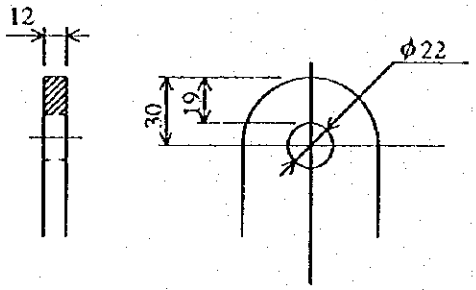
(2) Bracket



Thickness of bracket : 12 mm
Distance between top and pin : 3.0 mm
Shearing area of bracket : 4.56 cm^2
Shearing stress of bracket (S) :

$$S = 50/(4.56/\cos 4^\circ)$$
$$= 10.9\ kgf/cm^2 < 700\ kgf/cm^2 = Allowable\ shering\ stress$$

(3) Link plate



Thickness of link plate : 12 mm
Distance between top and pin : 30 mm
Shearing area of bracket : 2.28 cm^2
Shearing stress of bracket : (S)

$$S = 50/(2.28/\cos 4^\circ)$$
$$= 21.9\ kgf/cm^2 < 700\ kgf/cm^2 = Allowable\ shering\ stress$$

5.17 Calculation of Timber stoplog (2.3m×2.3m)

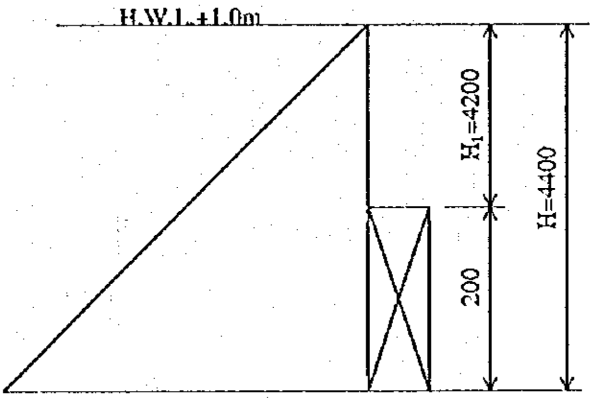
5.17.1 General

Timber stoplog having 2.3m wide by 2.3m high is provided at the Sulurang cengkareng drain outlet where the slide gate is provided at the outlet of same drain. Since the H.W.L. + 1.0m is EL. +2.30 and elevation of the drain is EL. -2.1, the design head of stoplog is taken at 4.4m in the structural calculation.

5.17.2 Design Conditions

Type	: Timber stoplog
Quantity	
Gate leaf	: 2 sets
Guide frame	: 10 set
Clear span	: 2.3m
Clear height	: 0.2m
Design head	: 4.4m
Sealing method	: 4 edges direct seal by wood and corner frame
Operation method	: By the man power using slings

(1) Hydraulic load



$$Pw = 0.5 \times \left(H_2^{\,2} - H_1^{\,2}\right) \times B \times Gw$$

where,			
Pw	: Total hydraulic load(tf)		
H_2	: Water head at stoplog bottom	4.4m
H_1	: Water head at stoplog clear height	4.2m
B	: Sealing span	2.3m
Gw	: Specific gravity of water	1.0 tf/m^3

Thus,

$$Pw = 0.5 \times \left(4.4^2 - 4.2^2\right) \times 2.3 \times 1.0$$
$$= 1.978\, tf$$

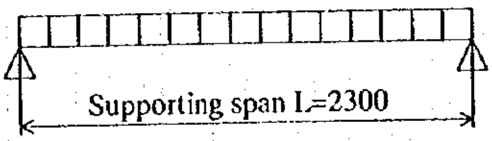
5.17.3 Charging Load on Bottom Piece

Charging load is calculated by the following equation:

$$W = 1.0 \times (4.2 + 4.4) / 2 \times 0.2$$
$$= 0.86 \, tf/m$$

(a) Bending moment and shearing force

Maximum bending moment is calculated by the following equation:



$$M \max = WL^2 / 8$$

where, $M \max$	:	Maximum bending moment	(tf-m)
W	:	Charging load	0.86tf/m
L	:	Supporting span	2.3m

Thus,

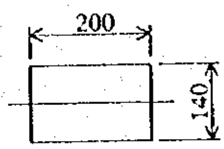
$$M \max = 0.86 \times 2.3^2 / 8$$
$$= 0.569 \, tf-m$$
$$S \max = WL / 2$$

where, $S \max$	:	Maximum bending moment	(tf)
W	:	Charging load	0.86tf/m
L	:	Supporting span	2.3m

Thus,

$$S \max = 0.86 \times 2.3 / 2$$
$$= 0.989 \, tf$$

5.17.4 Sectional Property



Moment of inertia	$I = 3{,}662 cm^4$
Modulus of section	$Z = 563 cm^3$
Area of section	$As = 260 cm^2$

5.17.5 Bending and shearing stress

$$\sigma \max = M \max \times 10^5 / Z$$

where,			
$\sigma \max$	: Maximum bending stress		(kgf/cm²)
$M \max$	: Maximum bending moment		0.5690tf-m
Z	: Modulus section		563cm³

Thus,

$$\sigma \max = 0.569 \times 10^5 / 563$$
$$= 101\, kgf / cm^2 < 110\, kgf / cm^2 = \textit{Allowable bending stress of teak wood}$$

$$\tau \max = S \max \times 10^3 / As$$

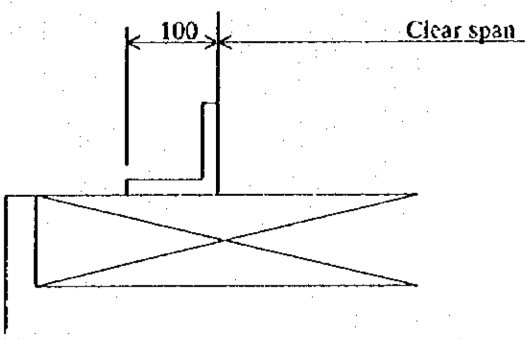
where,

$\tau \max$	: Maximum shearing stress	(kgf/cm²)
$S \max$	: Maximum shearing force	0.989tf
As	: Area of section	180cm²

Thus,

$$\tau \max = 0.989 \times 10^3 / 260$$
$$= 3.8\, kgf / cm^2 < 11\, kgf / cm^2 = \textit{Allowable shearing stress of teak wood}$$

5.17.6 Corner Frame



(1) Bearing stress

$$\sigma c = Pw / (2 \times L \times B)$$

where,			
σc	: Bearing stress of concrete	(kgf/cm²)
Pw	: Water pressure load	1978 kgf
L	: Length of bearing flange	20 cm
B	: Width of corner flame	10 cm

Thus,

$$\sigma c = 1978/(2 \times 20 \times 10)$$
$$= 4.95\,kgf\ /cm^2 < 60kgf\ /cm^2 = Allowable\ stress\ of\ concrete$$

(2) Shearing stress

$$\tau c = Pw/(2 \times Ac)$$

where, τc	:	Shearing stress of concrete	
Pw	:	Water pressure load	1978 kgf
Ac	:	Shearing area	283 cm^2
		$(10 \times \sqrt{2}) \times 20$	

Thus,

$$\tau c = 1078/(2 \times 283)$$
$$= 3.46\,kgf\ /cm^2 < 3.6\,kgf\ /cm^2 = Allowable\ shearing\ stress\ of\ cocrete$$

5.18 Calculation of Timber stoplog (0.4m×0.4m~1.5m ×1.3m)

5.18.1 General

Many size of stoplogs are provided at the sluiceway of this Project. Since the design size of stoplog is taken at 1.5m clear span × 1.3m clear height.

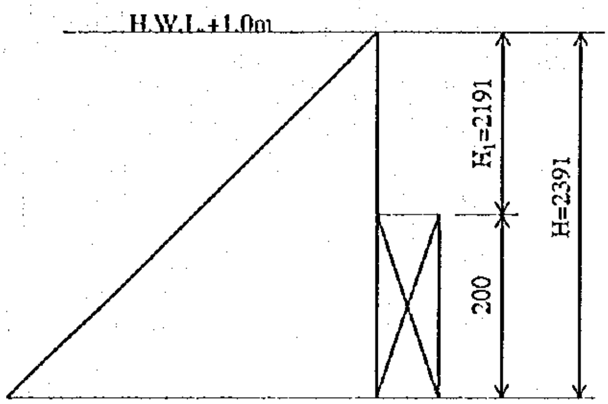
Main Design Data for Stoplog

No.	Gate No.	H.W.L.+1.0m	(Sill El.).	Design Head (m)
1.	SKM-3L	+1.850	- 0.541	2.391

5.18.2 Design Conditions

Type	: Timber stoplog
Clear span	: 1.5 m
Gate height	: 0.2 m
Design head	: 2.391 m
Sealing method	: 4 edges direct seal by wood and corner frame
Operation method	: By the man power using slings

(1) Hydraulic load



$$Pw = 0.5 \times \left(H_2^{\,2} - H_1^{\,2}\right) \times B \times Gw$$

where,	Pw	: Total hydraulic load(tf)	
	H_2	: Water head at stoplog bottom	2.391 m
	H_1	: Water head at stoplog clear height	2.191 m
	B	: Sealing span	1.5m
	Gw	: Specific gravity of water	1.0 tf/m^3

Thus,

$$Pw = 0.5 \times \left(2.391^2 - 2.191^2\right) \times 1.5 \times 1.0$$
$$= 0.687\, tf$$

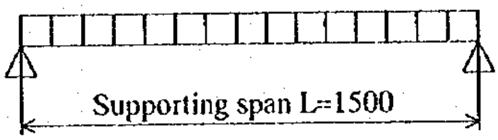
5.18.3 Charging Load on Bottom Piece

Charging load is calculated by the following equation:

$$W = 1.0 \times \left(2.191 + 2.391\right) / 2 \times 0.2$$
$$= 0.458\, tf/m$$

(a) Bending moment and shearing force

Maximum bending moment is calculated by the following equation:



$$M\max = WL^2/8$$

where, $M\max$	:	Maximum bending moment	(tf-m)
W	:	Charging load	0.458tf/m
L	:	Supporting span	1.5m

Thus,

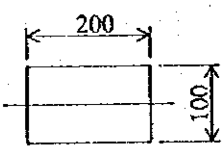
$$M\max = 0.458 \times 1.5^2/8$$
$$= 0.129\, tf-m$$
$$S\max = WL/2$$

where, $S\max$	:	Maximum bending moment	(tf)
W	:	Charging load	0.458 tf/m
L	:	Supporting span	1.5 m

Thus,

$$S\max = 0.458 \times 1.5/2$$
$$= 0.344\, tf$$

5.18.4 Sectional Property



Moment of inertia	I	= 1,667cm^4
Modulus of section	Z	= 333 cm^3
Area of section	As	= 200 cm^2

5.18.5 Bending and shearing stress

$$\sigma \max = M \max \times 10^5 / Z$$

where,			
	σ max	: Maximum bending stress	(kgf/cm^2)
	M max	: Maximum bending moment	0.129 tf-m
	Z	: Modulus section	333 cm^3

Thus,

$$\sigma \max = 0.129 \times 10^5 / 333$$

$$= 22.9\, kgf / cm^2 < 110\, kgf / cm^2 = \textit{Allowable bending stress of teak wood}$$

$$\tau \max = S \max \times 10^3 / As$$

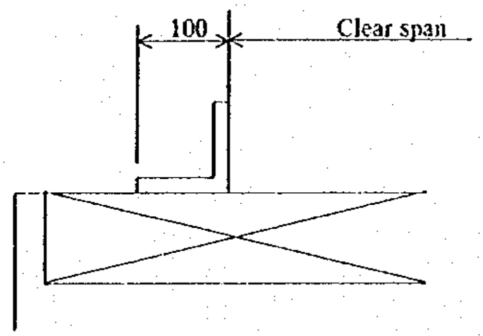
where,			
	τ max	: Maximum shearing stress	(kgf/cm^2)
	S max	: Maximum shearing force	0.344 tf
	As	: Area of section	200 cm^2

Thus,

$$\tau \max = 0.344 \times 10^3 / 200$$

$$= 1.72\, kgf / cm^2 < 11\, kgf / cm^2 = \textit{Allowable shearing stress of teak wood}$$

5.18.6 Corner Frame



(1) Bearing stress

$$\sigma c = Pw / (2 \times L \times B)$$

where,			
	σc	: Bearing stress of concrete	(kgf/cm^2)
	Pw	: Water pressure load	687 kgf
	L	: Length of bearing flange	20 cm

	B	: Width of corner flame	10 cm

Thus,

$$\sigma c = 687/(2 \times 20 \times 10)$$
$$= 1.72\ kgf/cm^2 < 60 kgf/cm^2 = Allowable\ stress\ of\ concrete$$

(2) Shearing stress

$$\tau c = Pw/(2 \times Ac)$$

where,	τc	: Shearing stress of concrete	
	Pw	: Water pressure load	687 kgf
	Ac	: Shearing area $(10 \times \sqrt{2}) \times 20$	283 cm^2

Thus,

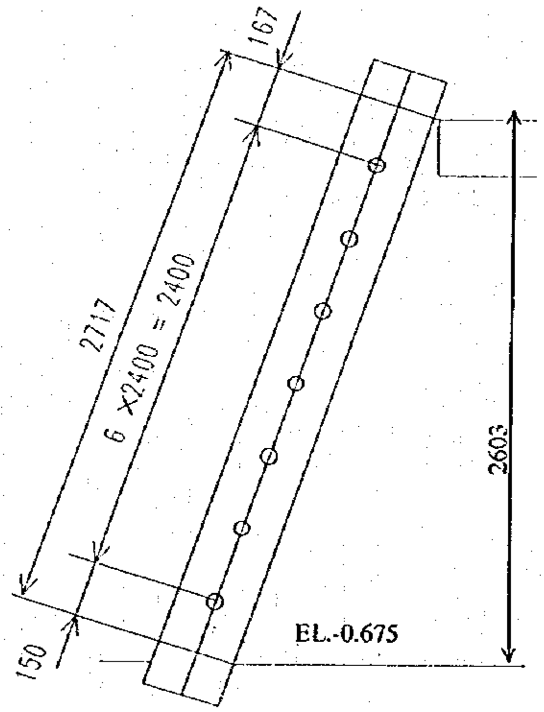
$$\tau c = 687/(2 \times 283)$$
$$= 1.21\ kgf/cm^2 < 3.6\ kgf/cm^2 = Allowable\ shearing\ stress\ of\ cocrete$$

5.19 Calculation of Fixed trashrack

5.19.1 Design Conditions

Type	: Slant type fixed trash rack	
Quantity	: 2 sets	1 set
Clear span	: 3.333m	3.334m
Vertical height	: 2.603m	
Design head	: 2.057m	
Bar pitch	: 75mm (center to center)	
Gradient	: 1:0.3	

5.19.2 Disposition



5.19.3 Capacity of trashrack bar

(1) The force due to water head : Pw

$$Pw = P \cdot b \cdot L_1$$
$$= 2.057 \times 0.075 \times 2.717$$
$$= 0.419\, tf$$

where P : Water head 2.057 tf/m^2
b : Distance of center to center of bar 0.075 m
L_1 : Supporting span 2.717 m

(2) The force due to own weight : P_G

$$P_G = G \cdot \cos\theta \cdot L_1$$
$$= 0.0094 \times \cos 73.3^\circ \times 2.717$$
$$= 0.007\,tf$$

where G : own weight of bar 0.0094 tf/m
θ : Gradient 73.3°

(3) Bending moment of bar : M

$$M = \frac{(Pw + P_G) \cdot L_1}{8}$$
$$= \frac{(0.419 + 0.007) \times 2.717}{8}$$
$$= 0.145\,tf - m$$

(4) Bending stress of bar : σ

$$\sigma = \frac{M}{Z}$$
$$= \frac{0.145 \times 10^5}{16.0}$$
$$= 906\,kgf\,/\,cm^2 < \sigma a$$

where σa : Critical stress considering horizontal buckling
Z : Modulus of section FB 100 × 12 Z=16.0 cm^3

$$\sigma a = 0.6 \times \sigma y \times \left(1.23 - 0.0153 \times \frac{L}{t}\right)$$
$$= 0.6 \times 2500 \times \left(1.23 - 0.0153 \times \frac{40.0}{1.0}\right)$$
$$= 927\,kgf\,/\,cm^2$$

σy : Yield strength of material
$\sigma y = 2500\,kgf\,/\,cm^2$
L : Distance of tie bolt 40.0 cm
t : Thickness of bar 1.0 cm

(5) Shearing force of bar : S

$$S = \frac{(Pw + P_G)}{2}$$
$$= \frac{(0.419 + 0.007)}{2}$$
$$= 0.213\,tf$$

where	Pw	:	The force due to water head	0.419 tf
	P_G	:	The force due to own weight	0.007 tf

(6) Shearing stress of bar : τ

$$\tau = \frac{S}{A}$$
$$= \frac{0.213 \times 10^3}{9.8}$$
$$= 22\,kgf\,/\,cm^2 < \tau a = 700\,kgf\,/\,cm^2$$

where	S	:	Shearing force	0.213 tf
	A	:	Sectional area of bar	9.8 cm^2
	τa	:	Allowable shearing stress	700 kgf/cm^2