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राष्ट्रीय जल अकादमी, पुणे

केन्द्रीय जल अभियांत्रिकी सेवा के नव नियुक्त
अधिकारियों का इकत्तीसवां प्रवेशन प्रशिक्षण कार्यक्रम

19 August 2019 – 07 February 2020

डिजाइन और अनुसंधान

Module V: Design of Hydro-mechanical Equipment Gates

पुणे
दिसंबर 2019

Government of India
Central Water Commission
National Water Academy

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Module- V

DESIGN OF HYDRO-MECHANICAL EQUIPMENT GATES

16-22 December, 2019

Module Co-ordinator

Shri S N Pande, Director (Designs)

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Design of Hydro-mechanical Equipment Gates

INDEX

Sr. No.	*Topics*	*Page No.*
1.	Overview of Hydromechanical Equipments	01
2.	Design of Vertical Lift Gates	18
3.	Design of Radial Gates	42
4.	Design of Rope Drum Hoist	50
5.	Manufacturing and Erection	72
6.	Operation and Maintenance	87
	Exercise Sheets	102-107

- Calculations for design of vertical lift gate and Hoist capacity for gates
- Exercise 1 : Design of Radial Gates
- Exercise 2 : Design of Radial Gates
- Exercise 3: Design of Radial Gates
- Exercise 4: Design of Raial Gates

<u>Overview of Hydro-mechanical Equipments</u>

The hydraulic gates are moving facilities provided in dams, barrages, hydropower projects, and reservoir and river control. They are essentially closure devices in which a leaf or closure member is moved across the fluid-way from an external position to control the flow of water. The gates are generally made of steel and are meant to control the flow of water as desired.

Gates are neither like concrete dam nor like other reinforced concrete hydraulic structure, which always remain stagnant. Therefore, the gates are more complicated and critical components than the dam or other hydraulic structures. Evidently, gates are of vital importance for water resources projects and should always be in smooth functioning. Their failure to fulfill the intended purpose can have devastating results, sometime may even endanger the safety of the entire project. Hoists are operating mechanisms for the gates. These are the systems through which the effort is transmitted to move the gate.

HISTORY AND DEVELOPMENT:

The construction of hydraulic gates was closely related with the development of irrigation, water supply and river navigation systems. In the early days of hydraulic engineering, Water was backed up by small dams and conveyed to side irrigation canals. The excess water was discharged over the dam. As a natural evolution, 'movable dams' were built. These movable dams could be removed from their normal position to provide passage for excess water, thus permitting greater safety and flexibility in the operation of hydraulic works.

The first canals for transportation of goods and drainage of floodwaters were built in China. Originally, the Chinese solved the problem of fluvial transportation in the region of river rapids by buildings dikes with slopes on the banks of the canal. The boats were then manually hoisted up and down the slope. These operations, however, were both time and power consuming. Around the year 983, the Chinese discovered that by constructing two dams a certain distance apart, the boats could enter the 'pool' created between them and the water level could be slowly increased or decreased. The earliest dams had wood or stone piers on each side of the canal. Vertical grooves were cut into opposite sides of the banks and tree trunks were fitted horizontally into the grooves, which held the water at the highest level. Ropes were used to lift the trunks.

In 1795, the Little Falls canal was completed, making it the first canal with locks in America. Design of wooden gates for the Little Falls locks was unusual. Two wood swinging gates were placed at each end of a lock. Instead of closing to a flat plane, the gates closed to form an angle pointing upstream, facing the current. Water pressure thus locked them together. Double-leaf gates originated in Europe, and are found in Japan. Double –leaf metal gates 5 m wide by 5 high, were used to close the 111 arches of the Assiout dam, Egypt, in 1902.

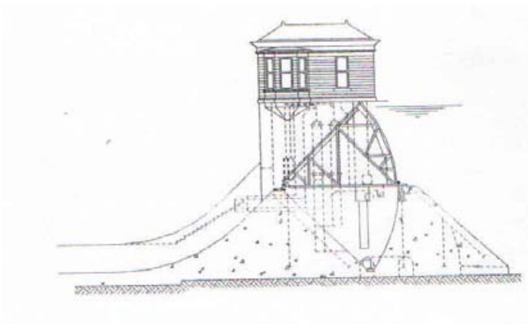
In 1908, ten double leaves fixed –wheel gates were installed on the August-Wyhlen dam, on the Rhine River, Switzerland, each gate being 17.5 m wide and 9 m high. The modern double fixed-wheel gate was developed by M.A.N. and installed for the first time on the Reckingen dam, Switzerland, in 1930.

Similar to the double-leaf fixed-wheel hook type gate, double segment gates were developed. However, few installations were built in Switzerland. The sector gate was invented in the USA by C.L. Cooley, and used for the first time in 1907 in the Lockport dam on the Chicago drainage canal. Two gated were installed to regulate the flow in the canal and to carry off ice and floating debris. One had a 3.66 m span, and the other a 14.6 m span. In both gates the curvature radius of the skin plate was 7.92 m and the height 5.79m.

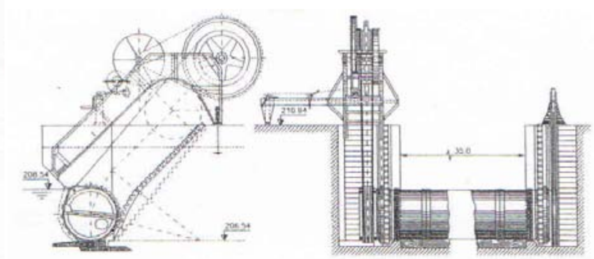
In Europe, the first application of the sector gate was in 1911, when two gates were installed on the Weser dam, near Hemelingen, Germany, with a 54 m span and 4.6 m height. According to H. Ackermann, during the early studies of that dam, the use of rolling, fixed-wheel, segment and flap gates was also studied. The choice of the type, however, favored the sector gate because of the need for a submersible gate. At the time, submersible gates of the roller, fixed-wheel and segment types were already known, but had not yet been tested in practice. The original roller gates were plain cylinders. Experience with the operation of such gates installed at Poppenweiler, on the Necker River, Germany, indicated the occurrence of excessive vibrations as a result of the suction effect under the lifted cylinder. Later, a section of curved skin plate in the shape of an apron was added to the lower portion of the cylinder, assuring the separation of the under flowing nappe. The high torsion resistance inherent in the cylinder shape allowed for the design of gates consisting of a slightly curved shield placed upstream of a small cylinder. Roller gates were often used in USA, designed by the U.S. Corps of Engineers, mainly on the Ohio and Mississippi rivers, and by the Bureau of Reclamation. One of the earliest applications was in 1915 on the Colorado River, near Grand Junction, Colorado, where gates 21.3 m wide by 3 m high were installed. For the canalization of Mississippi, the U.S. Corps of Engineers installed roller gates with 18.3 m, 24.4 m and 30.5 m spans.

The segment gates were initially used in the USA for flow control in conduits and used for the first time in lock aqueducts in the construction of the New York barge canal, in 1905.

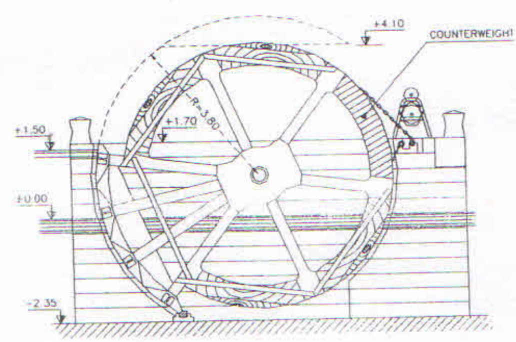
The stoney gate named after its inventor, Mr.F.G.M.Stoney. These gates were first constructed in 1883 at Belleek, Ireland. Four sluice gates were placed between masonry piers to control the outfall from a chain of lakes. Each gate was 8.9 m wide and 4.4 m high. They were made of plate iron and beams. Stoney gates were extensively used in Europe, USA, Egypt and India at the beginning of the 20th century.



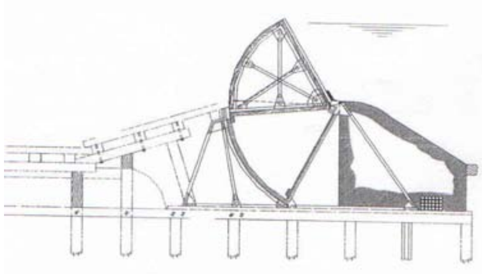
.6 Sector gate, Lockport dam (1907)



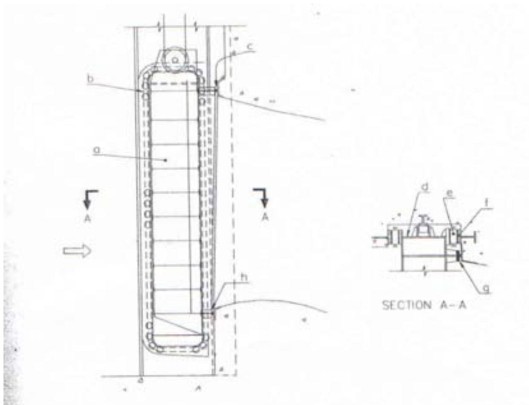
.7 Roller gate, Schweinfurt dam (1902)



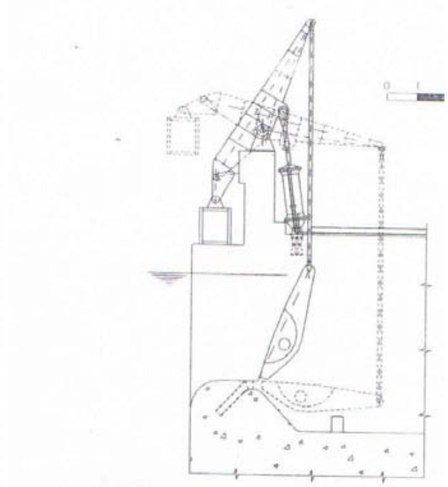
1.4 Segment gate with counterweights, Lez River, France (1888)



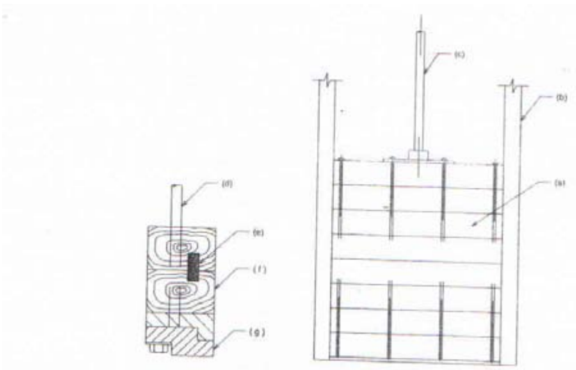
1.8 Chittenden drum gate (1911)



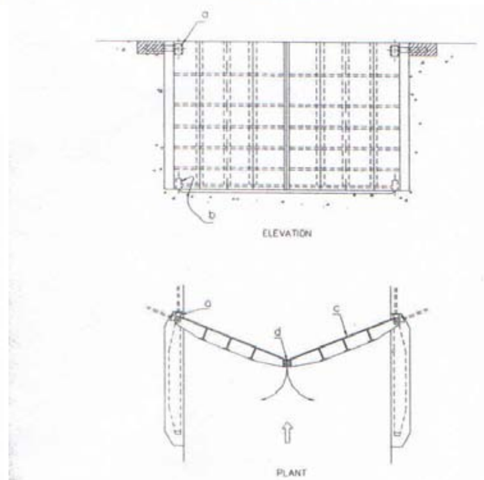
Caterpillar gate
(a) gate leaf; (b) roller train; (c) top seal; (d) end girder; (e) roller; (f) roller track; (g) lateral seal; (h) bottom seal



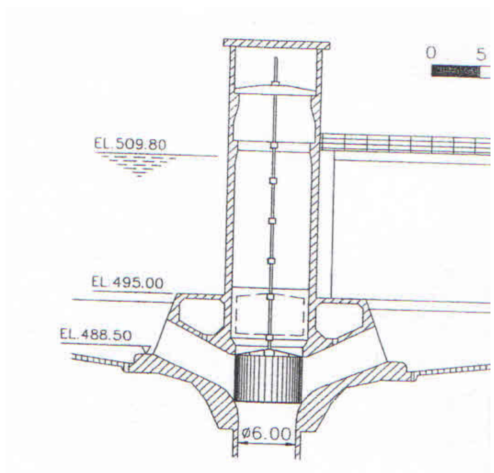
Flap gate with counterweight, Juquiaguassu Dam (DSD-NO



Timber slide gate (RODNEY HUNT)
(a) gate; (b) side guide; (c) operating stem; (d) tie rod; (e) timber spline; (f) timbe
bottom seal



Miter gate
a) gudgeon; (b) pintle; (c) skin plate; (d) center seal



Cylinder gate, Vianden Powerplant

Invention and Earlier uses of gates:

Year	Gate Type	Project	Span x height (m)
1490	Segment		
1818	Bear-trap	Mauch Chunk Creek	7.6(span)
1828	Milter(metallic structure)	Nivemais, France	8.75 x 1.00
1853	Segment	Senne River	6.00 x 5.10
1860	Reverse segment	Nile River Delta	3.52 x 1.97
1873	Bottom-hinged flap	Ile Brulee, France(*)	8.90 x 4.40
1883	Stoney	Belleek,Ireland	
1886	Segment	(USA patent)	
1896	Drum	(USA)	
1898	Roller	(Germany)	
1902	Double-leaf fixed-wheel	Assiout, Egypt(*)	5.0 x 5.0
1902	Roller	Schweinfurt	18.00 x 4.14
1907	Sector	Lockport Dam, USA	14.60 x 5.79
1910	Reverse segment	(USA patent)	
1911	Drum	Dam no.1, Osage River	
1911	Sector	Weser Dam (*)	54 x 4.6
1915	Broome (caterpillar)	Turner Falls, USA (*)	3.00 x 4.88
1920	Cylinder(*)	Kern	2.43 dia. X 6.70
1926	Fixed-wheel with flap	Juliana canal(*)	23.00 x 4.40
1930	Double-leaf hook type	Reckingen	
1933	Segment with flap	Munster(*)	23.30 x 7.40
1936	Ring	Owyhee Dam	18.0 dia x 3.60
1943	Double segment	Rupperswill-Auenstein	22.00 x 8.00
1955	Inflatable	(France)	
1958	Reverse segment with flap	Oberelchingen(*)	16.00 x 8.20
1960	Visor	Hagenstein,Holland	48.00 x 6.00
1966	Inflatable	Shiga, Japan(*)	0.45 x 3.7
1991	Fusegate	Lussas Dam, France	3.5 x 2.15

(*) Refers to earlier use, but not necessarily to the first application.

Types of Gates:

In general, Gates are classified according to following criteria:

- Function in a dam or barrage
- Location
- Shape
- Head

Classification according to function:

The gates could be either regulating, non-regulating or maintenance gate. For example service gates are regulating in nature whereas emergency gates are non-regulating. However, the emergency gate in special circumstances only can be used in partial opening (by crack opening) for filling penstock.

Service gate: - Spillway, barrage, weir, bottom outlet and flow control gate.

Emergency:- Intake, gate u/s of penstock service valve/bottom outlet, draft-tube gate\

Maintenance:- Stoplogs (operated under balanced head of water)

Classification according to location:

Here the gates could be termed as per the location in the layout of any water resources development project like Power House etc. Following terminologies are generally adopted:

- Spillway crest gates
- Outlet gates
- Service gates
- Intake gates
- Depletion sluice gate
- Draft tube gates
- Stoplog gates
- Bulkhead gates

Classification according to shape

The gates are also identified with geometrical shapes they resemble, for example:

- Vertical gates
- Radial/Tainter gates
- Fish belly gates etc.

Classification according to Head of water

Classification on the basis of water head on gates:

- High head gates where head is 30 m. or more.
- Medium head gates where head is between 15 and 30 m.
- Low head gates where head is < 15 m.

Depending of water head; design and acceptance criteria is distinctly different for different types of gates. For high head gates installations, the design criteria are quite stringent as compared to medium and low head gates installations.

Commonly used Gated Installations

In India, control structures mainly use gated arrangements. Valves are not traditionally provided due to their low discharging capacities and manufacturing constraints in the initial years of water resources planning in this country. As a result, valves are provided mainly in turbines as inlet valves in India. However valves are extensively used in the Water Resources Projects of developed countries.

Coming to the popular types of gates which are in vogue in India, following arrangements are generally adopted at different installations.

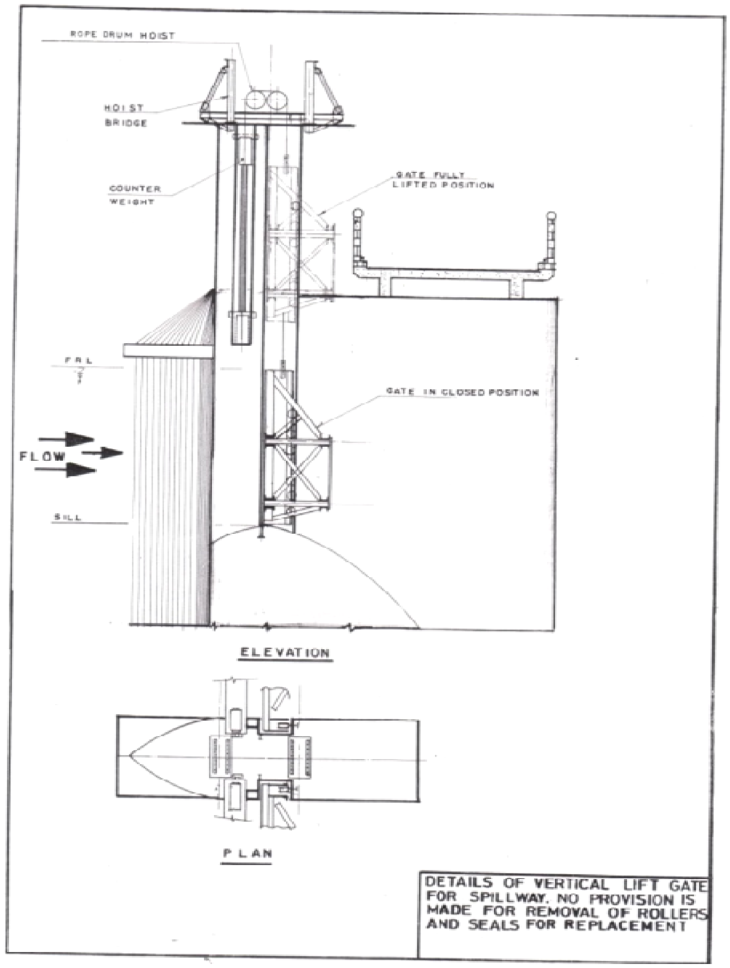
Gates for Spillways

For spillways, normally following types of gates are adopted:

- Vertical lift gates
- Radial (tainter) gates

Vertical lift gates:

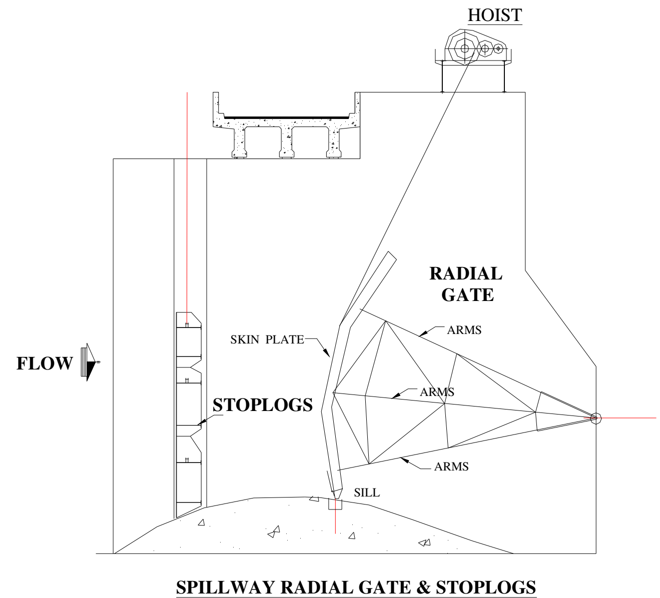
As the name implies, these gates are flat and are operated in vertical direction. They consist of a flat plate called skin plate which is supported by a system of horizontal girders and vertical stiffeners which in turn are connected to end girders and wheels or sliding pads. These wheels (or sliding pads) transfer the load to concrete through tracks embedded in it. Figure given below illustrates a typical arrangement for vertical lift gate for spillway.



Radial Gates:

Radial or tainter gate is in the form of a curved plate, storing water usually on convex side, having an arc of a circle as its main member which is supported on a system of steel framework which in turn transfers the thrust of water to concrete through another system of steel grillage or anchorages. Radial gates do not require grooves in the piers. They move on side guide plates which are in flush with the concrete surface.

For spillways, simplicity of operation and smooth flow pattern past the gate and avoidance of flow disturbance due to absence of grooves are positive features for radial gates. If the head over the spillway is 8m or more, overall arrangement of radial type gate generally proves economical in comparison to other types of gates.



-General Arrangement

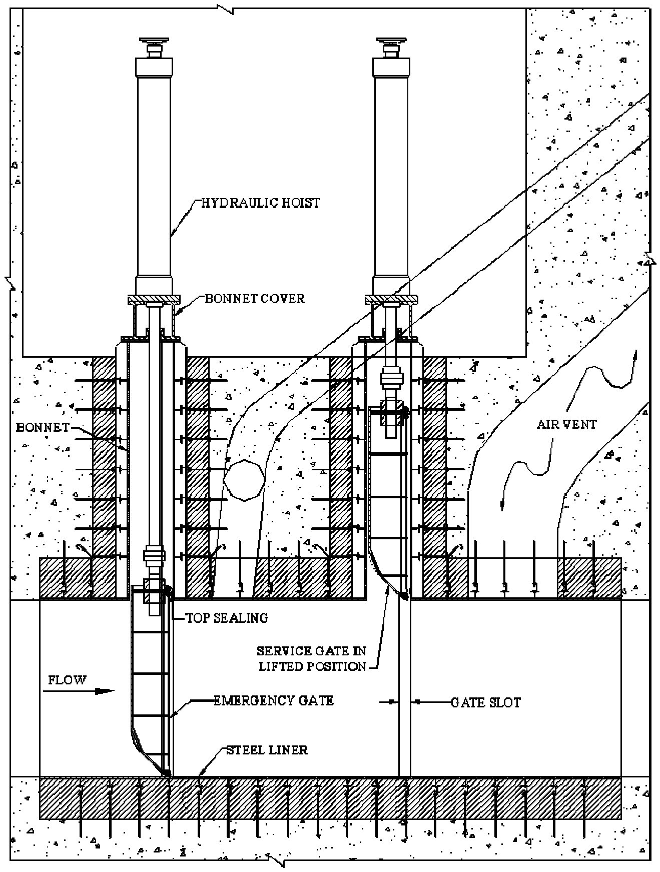
Gates for Outlets

The basic function of any outlet is to provide an efficient, economical means of releasing water from a reservoir to obtain the desired downstream use or uses. The conduits, pipes or penstocks for high head outlets are usually metal, and have gates or valves located at the upstream entrance, at an intermediate point or at the downstream end. Such outlets may also utilize a combination of these arrangements, and have a guard gate at the entrance or at an intermediate point with a regulating gate or valve at the downstream end.

Each outlet should be provided with two gates or valves capable of closing under flow. An upstream guard gate or valve is required primarily to ensure the safety of the conduit and equipment downstream and also to permit inspection and maintenance of the downstream pipe and the equipment.

Guard gates must be capable of closing under the full head and maximum possible flow, but are normally operated under balanced pressure/ no flow conditions.

In addition to gates or valves which can be closed with water flowing, most outlets are provided with a bulkhead gate or stoplogs at the upstream end to permit inspection or repair at the entrance of the conduit. Bulkhead gates and stoplogs are normally designed to be placed and removed under balanced head no flow conditions.



Arrangement of TICAL LIFT SLIDE GATES IN TANDEM

Slide Gates:

These gates are usually adopted where high pressure application is called for. They are used for both guard as well as regulating services. Basically, a slide gate consists of a leaf which is either closed by being positioned across the fluid-way in the body or opened by being withdrawn into the bonnet by a hoist mounted on the bonnet cover. The mating seats on the gate leaf, body and bonnet serve as sliding surfaces for carrying the hydrostatic load on the leaf and as the sealing surfaces when the gate is closed. The body and bonnet are sufficiently stiffened to eliminate any distortion when the gates frame/embedment are embedded in concrete. The bonnet cover is designed to resist internal water pressure. Figure given above indicates typical details of a slide gate.

Main applications, advantages and disadvantages of various type of gate:

Type	Main Applications	Advantages	Disadvantages
Gate in open channels			
Radial gate-Motorized operation	Sluice installations. River control. Spillways. Barrages.	No unbalanced forces. Absence of gate slots. Low hoisting force. Mechanically simple. Bearing out of water. Can be fitted with overflow section. Some inspection with gate in service possible.	Extended flume walls. High concentrated load. Increased fabrication complexity.
Radial gate-Automatic	Sluice installations, River control.	No outside source of power required. Absence of machinery. Low maintenance.	Wide piers to accommodate displacers. Counterbalance visually intrusive. Can malfunction due to incorrect design. Can malfunction due to blockage of inlet of control system.
Vertical –lift gates	Sluice installations. River control. Old installations. Spillways. Barrages.	Can be fitted with overflow sections. Short piers. Wide span gates can be engineered to provide good navigation openings. Up and over gates can reduce height of supporting structure.	Gate slots required. Load roller under water. Can jam due to debris. High hoisting load unless counterbalanced. Overhead support structure visually intrusive.
Flap gate-Bottom hinged	Tidal barrages. Sluice installation. River control.	Complete separation of saline and fresh water. Overflow to clear debris. No visually intrusive overhead structure. Can in some cases be designed to open under gravity in emergency.	Requires extensive side staunching for side sealing or very accurately constructed pier walls. Hinge bearings not easily accessible and permanently immersed.
Flap gate-Top hinged	Tidal outlets.	No outside source of power required, automatic in operation. Absence of machinery. Little maintenance. Simple construction.	Cannot control water levels. Will not entirely exclude tidal water if D/S water level rises above sill. Gate slam can occurs.
Drum and sector gates	Spillways.	No outside source of power required, automatic in operation.	Complex gates. Require civil works. Require zero d/s water level. Control system critical. Can silt up. Not preferred.
Gate in submerged outlets.			
Vertical lift intake gate-Hydraulic hoist operated.	Control and emergency closure.	Reliable control gate. Good load distribution in the slide version. Damped.	Gate slots required. Load rollers/ slide operate under water. Requires stem connection between hydraulic hoist cylinder & gate. Possible cavitations problems. Slow operation to raise to the maintenance position. Require air admission.
Vertical lift intake gate-Rope drum	Bulkhead gate.	Can be roller or slide type. Does not require air admission.	Cannot be used as a Control or emergency closure gate. Requires balanced head for

hoist operated.			operation. Guide slots required. Possible cavitations problems. Requires bypass system.
Caterpillar or coaster gate.	Control and emergency closure.	Control gate for very high heads.	Wide gate slots required. Caterpillar train operates under water. Requires stem connection between hydraulic hoist cylinder & gate. Cavitations problems. Slow operation to raise to the maintenance position. Very costly. Require air admission.
Radial – intake gate.	Control and emergency closure gate. Intake gate.	Absence of gate slots. Requires no load rollers or slides.	Require chamber to retract. High concentrated load. Lintel seal critical. Require dewatering of tunnel to carry out maintenance. Require air admission.
Slide gates.	Control gates in conduit. Back-up gate for a control gate.	Reliable control gate or emergency closure gate. Inherently damped due to sliding friction.	Gate slots required. Require bonnet for withdrawal. Require air admission.
Radial gates.	Control gates in conduit.	Absence of gate slots Requires no load rollers or slides. Lower hoisting force required.	Require chamber to retract. High concentrated load. Lintel seal critical. Require dewatering of tunnel to carry out maintenance. Require air admission.

The gate consists of following components:

Skin Plate: This is a thin plate and is designed for the span between supporting stiffeners/girders. As per the codal criteria, it is assumed to act effectively with stiffeners/girder.

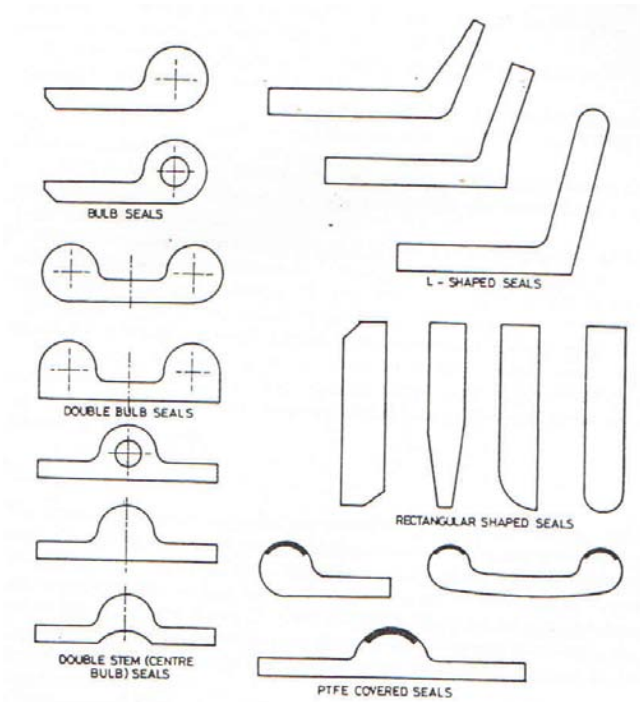
Stiffeners: The load from skin plate is transferred to vertical stiffeners which are designed as continuous beams spanning over the horizontal girders.

Horizontal Girders: They are main support members of gate and are designed for reactions transferred from the vertical stiffeners. They span between end girders and are designed as simply supported horizontal girders.

End Girders: They transfer the load to gate wheels /slide blocks. They are designed as beams spanning between supports at wheels or as continuous beams over slide blocks.

Gate Embedments: Gate embedments are in the form of a steel track (Vertical lift gate)/ load carry anchorages (radial gate) which are embedded in structural concrete. The tracks are designed as beams on elastic foundation.

Gate Seals: Appropriate types of seals should be chosen to achieve water tightness. A variety of seals is available in India and different types these are shown in Figure below given. The seals are made from natural or synthetic rubber and should confirm to BIS standard IS:11855.



Type of hoisting arrangement:

- Electro-mechanical rope drum hoists
- Gantry/Mobile cranes
- Monorail crane
- Hydraulic Hoists
- Screw hoists
- Manually arrangement (Chain pulley block, etc).

Criteria for selection of type of hoisting arrangement:

Rope Drum Hoist is the most versatile and the arrangement can be made adaptable to meet almost any gate layout. If the gate is capable of closing under its own weight with or without the addition of ballast a rope drum hoist shall be suitable. However, if a positive thrust is required to be provided; only a hydraulic hoist or a screw hoist shall be recommended. In general the hoist capacity is designed to take care of Gate weight, Hydraulic uplift or down pull, Friction of gate seal, Guide friction, Wheel/sliding friction and any other force opposing gate movement. The high head gates especial those required for regulation of flow should be provided with hydraulic hoist for their operation in order to have dampening effect on vibration resulting from hydro dynamic forces. Moreover, in order to avoid/ reduce the vibration problems, it is required that the high head gates be rigidly supported during their operation. Rigidity of supports is also required in case the gate is not capable of self-closing i.e. gravity closure by its own weight. Requirement of rigidity of suspension for high head gates can be fulfilled either by using a screw hoist (limited to small size gate) or by hydraulic hoists more often.

The gantry/mobile crane/ monorail crane are provided for operation of stoplogs/bulkhead /emergency gate in more than one bay. The gantry/mobile crane are provided with fixed or mobile (Trolley mounted) Electro-mechanical rope drum hoist for operation of gate or stoplogs apart from arrangement of long travel for moving the crane from one bay to another.

The gated installation requiring very small capacity, it may be advantageous to operate the gate manually by means of chain pulley block etc.

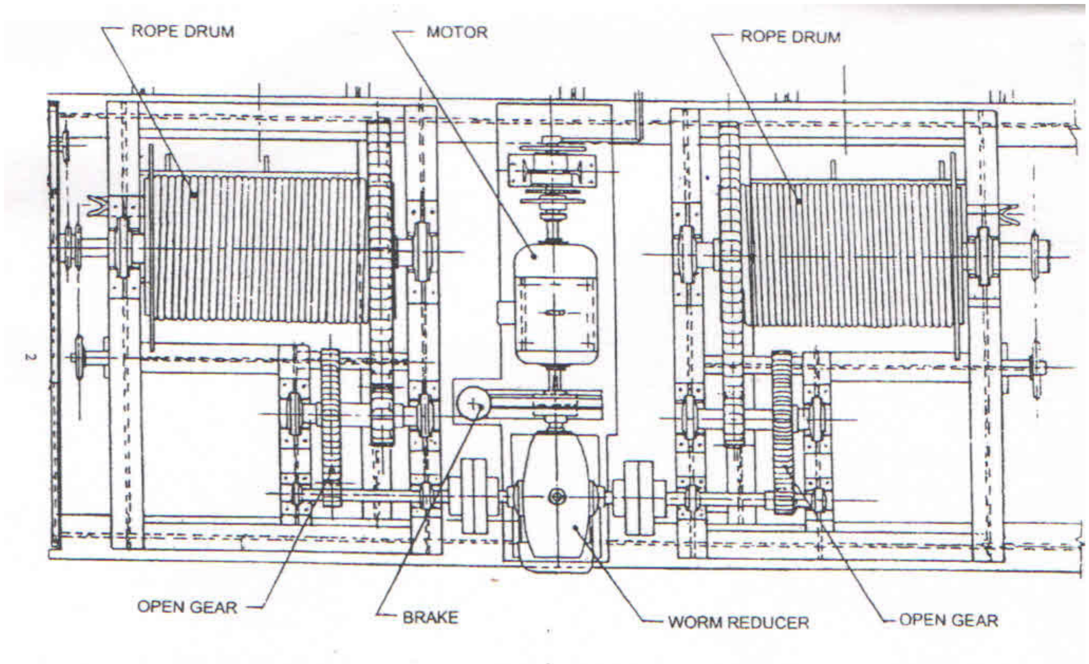
<u>The hoist arrangement should be such designed that it:</u>

- Shall be capable of raising or lowering the gate at the specified speed and stopping as desired.
- Shall have adequate reserve capacity to cater to any eventuality.
- Shall provide adequate seating pressure on the sill for effective sealing.
- Shall have a provision for alternative means of operation in case of failure of power supply.
- Shall withstand changes in atmospheric conditions encountered at the installations.

<u>A brief description of hoist is given as under:</u>

Rope Drum Hoist:

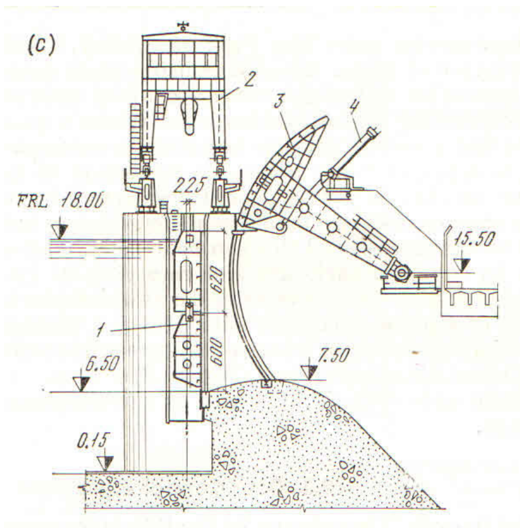
In case of rope drum hoists, gates are required to be necessarily capable of self closing/gravity closure. In such hoisting arrangements, gates are connected to hoists through steel ropes. These ropes are systematically wound over steel drums which when rotated cause gates to move up or down in the opening. The rotation of drum is caused by electrical motors/manual effort through a system of gears and pinions for transmission of torque. Lay out of an Electro-mechanical Rope Drum Hoist is given below.

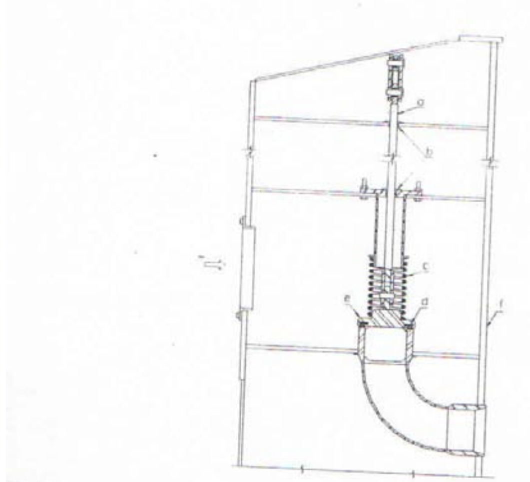


Rope Drum Hoist (Plan)

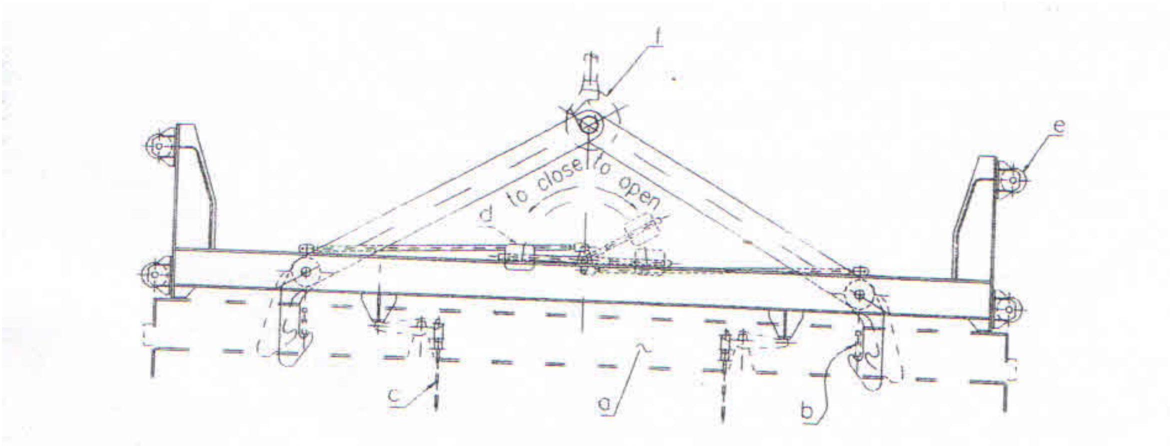
Gantry/Mobile cranes

The gantry/mobile cranes are provided for operation of stoplogs/bulkhead /emergency gate in more than one bay. These are provided with **fixed or mobile (Trolley mounted)** Electro-mechanical rope drum hoist for operation of gate or stoplogs apart from arrangement of long travel for moving the crane from one bay to another. The general arrangement of a gantry crane for operation stoplogs is shown in the below given figure.





By-pass valve
(a) stem; (b) bushings; (c) spring; (d) seal; (e) disc; (f) skin plate



Lifting beam
(a) stoplog panel; (b) lifting lug; (c) by-pass valve stem actuator; (d) counterweight; (e) roller; (f) hook

Hydraulic Hoists:

Hydraulic hoists operate on the system of hydraulic pressure applied through oil. The gates are connected through hoist stems to pistons located inside a cylinder filled with oil. The oil being an incompressible medium, higher pressure can be applied which when transmitted to gates over-come the hoisting resistance and the gate is able to move.

Figure given below indicates an arrangement for hydraulic hoist alongwith various components. The hoists have an advantage that positive i.e. downward thrust could be imparted to gates if required.

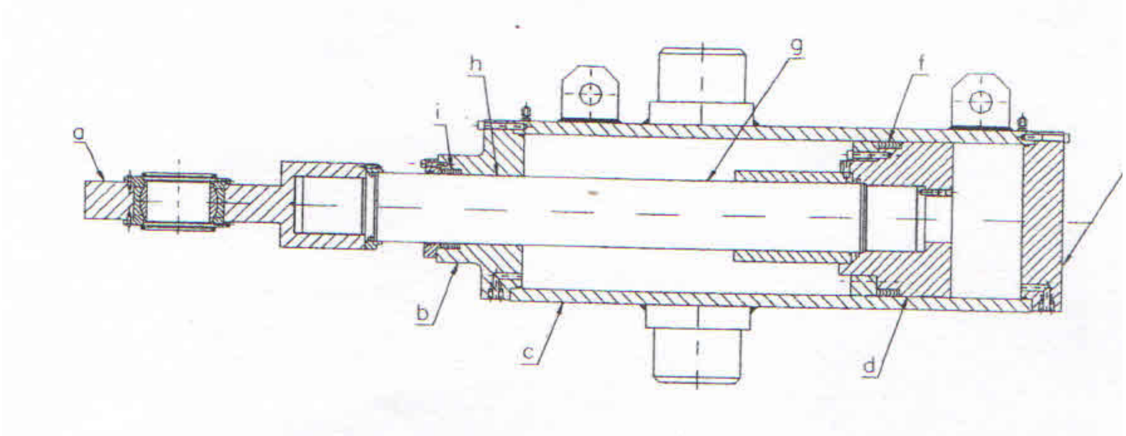
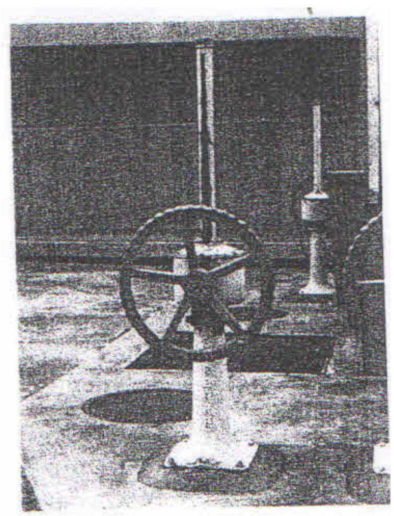


Fig. Hydraulic cylinder (Rexroth Hydraudyne B.V.)
(a) clevis; (b) upper head; (c) cylinder shell; (d) piston; (e) bottom head; (f) piston seal; (g) stem; (h) guiding strip; (i) rod seal

Screw Hoists:

Screw hoist use a threaded stem attached to gates which pass through appropriately designed nut. This nut is connected to an manually operated handle or an electrical motor through a gear box which causes stem and gate to move in gate grooves. For small gates, screw hoists are economical. They also offer advantages of a positive thrust but for longer lifts, unsupported lengths of hoist stem is a limitation here.

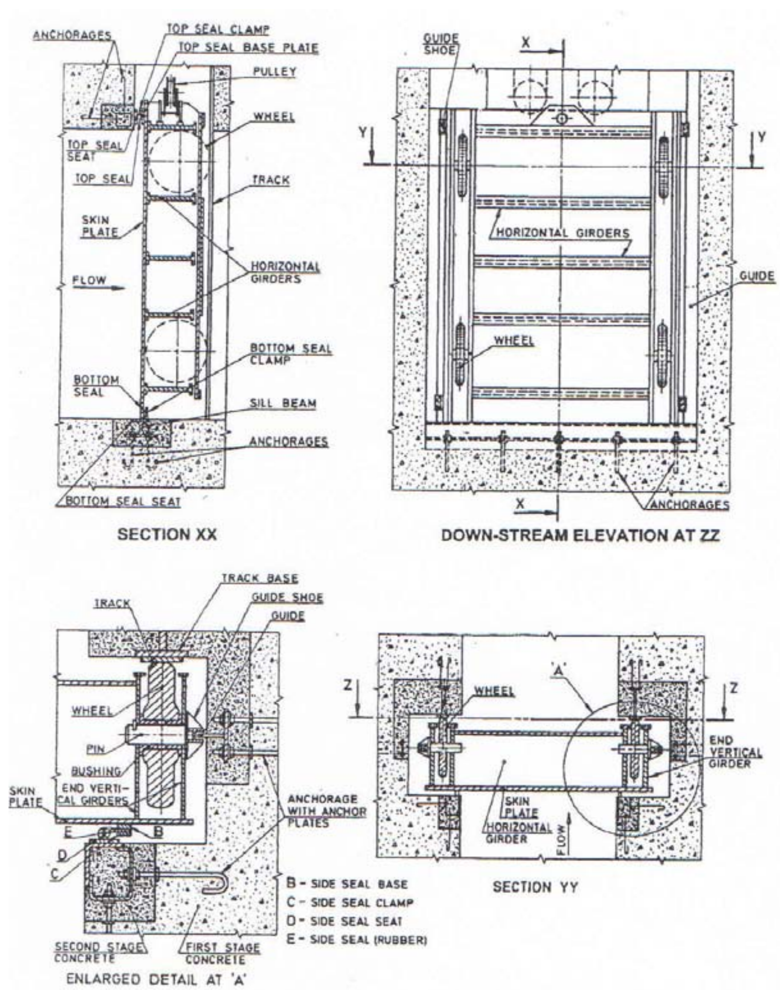


Sketch of a screw hoist manually operated.

DESIGN OF VERTICAL LIFT GATES:

As the name implies, these gates are flat and are operated in vertical direction. They consist of a flat plate called skin plate which is supported by a system of horizontal girders and vertical stiffeners which in turn are connected to end girders and wheels or sliding pads. These wheels (or sliding pads) transfer the load to concrete through tracks embedded in it.

While designing a gate; the higher the head, the more serious the hydraulics problems, the larger the gate area, the more serious the structural problems and manufacturing difficulties, the larger the total dynamic pressure, the more serious the hoist problems. These three parameters, i.e. the water head, the gate opening area and the total dynamic pressure are the major indices, indicating the technical level of gates. Depending of water head; design and acceptance criteria is distinctly different for different types of gates. For high head gates installations, the design criteria are quite stringent as compared to medium and low head gates installations.



LOADING ON THE GATE:

HYDROSTATIC LOAD:

When dimensioning a gate, the first step is to calculate the water thrust acting on the skin plate for the various gate-opening positions. Its maximum value occurs with the gate closed and subject to the maximum head water level.

For gates with water on both sides of the skin plate, the maximum water thrust corresponds to the most unfavorable unbalanced level between the upstream and the downstream reservoirs.

(A) WEIR/CREST GATES

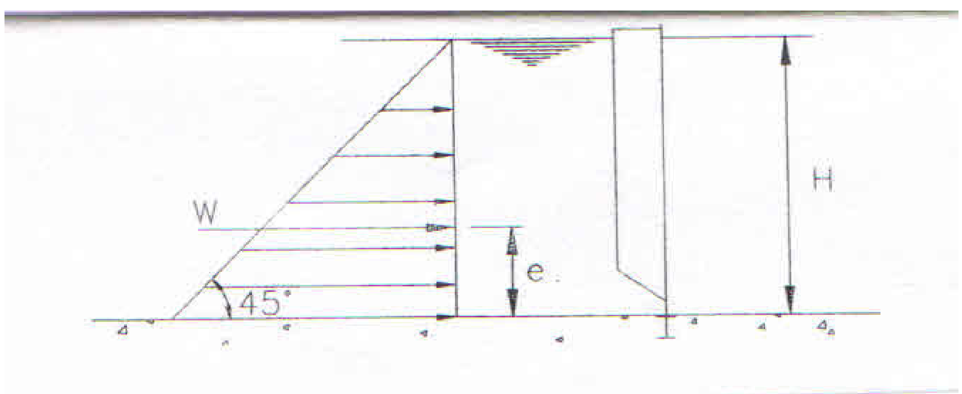
(a) For gates with only one side of the skin plate in contact with water, the maximum water thrust is given by the following formula:

$W=\frac{1}{2}\gamma\ B\ H^2$

Where:

γ= specific weight of water= 9.81kN/m^3
B=span of side seals
H= maximum water head on the sill.

Its line of action is normal to the skin plate and passes through the centre of pressure of the surface, that is, at a distance of **e=1/3H**above the sill.



(b) For the gate with both sides of the skin plate in contact with water, the water thrust due to the upstream reservoir is:

$W_M=\frac{1}{2}\gamma\ B\ H^2$

And its centroid is

$e_M=1/3H$

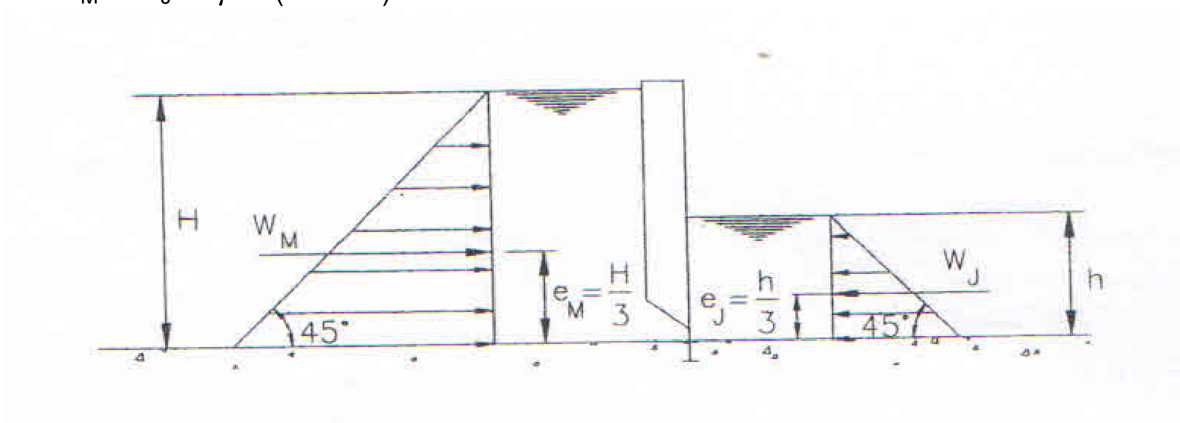
On the downstream side,
$W_J=\frac{1}{2}\gamma\ B\ h^2$

And
$e_J=1/3h$

where h is the minimum downstream headwater on the sill.

The resultant water trust will then be,

$W = W_M - W_J = ½\gamma B (H^2 - h^2)$



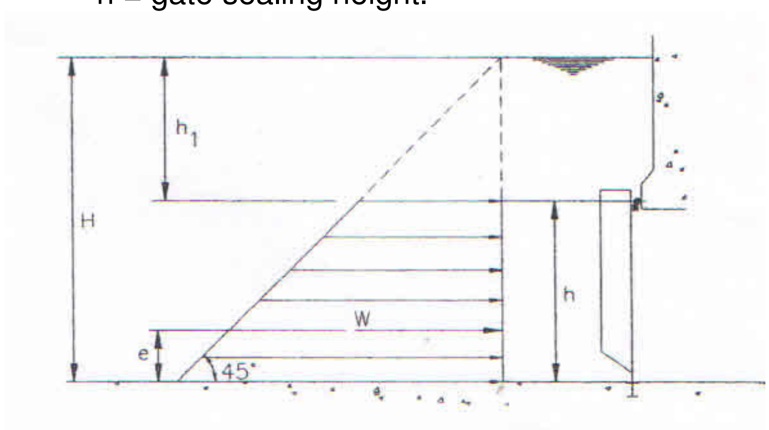
(B) SUBMERGED GATES:

(a) For submerged gates with only one side of the skin plate in contact with water, the water thrust is calculated by

$W = \gamma B h (H - h/2)$

Where:

γ= specific weight of water= 9.81kN/m^3
B=span of side seals
H= maximum headwater on sill
h = gate sealing height.



The pressure diagram has a trapezoidal shape. In this case, the position of the resultant water trust is given by

$e = \frac{h}{3}(1 + \frac{H-h}{2H-h})$

Substituting in the above equations

$h = H - h_1$

results, after simplification,

$W = ½\gamma B (H^2 - h_1^2)$

And

$$e = \left(\frac{H-h1}{3}\right)\left(\frac{H+2h1}{H+h1}\right)$$

where h, is the vertical between the free surface of water and the top seal.

(b) For submerged gates, with both sides of the skin plate in contact with water, the resultant water trust is the difference between the hydrostatic forces due to each reservoir.

Upstream water trust

$$W = \frac{1}{2}\gamma\, B\, (H^2 - h_1^2)$$

And

$$e = \left(\frac{H-h1}{3}\right)\left(\frac{H+2h1}{H+h1}\right)$$

Downstream water thrust

$$W_J = \frac{1}{2}\gamma\, B\, h_J^2$$

Where h_J is the minimum depth of the tailwater.

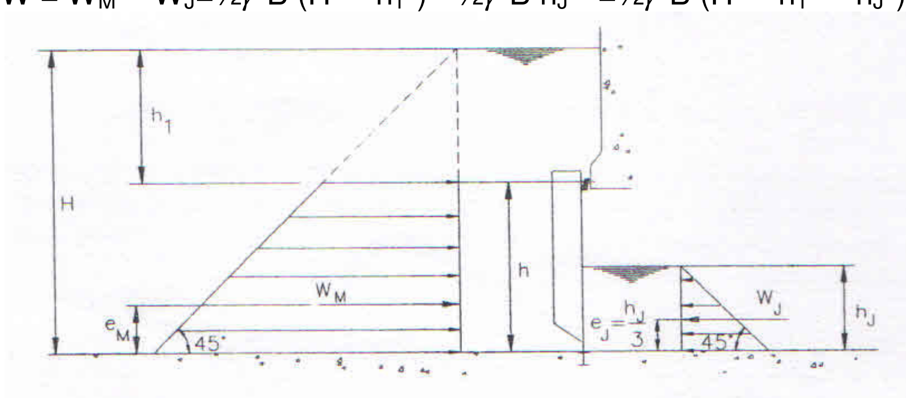
The centroid of W_J is calculated by

$$e_J = 1/3 h_J$$

Since the pressure diagram has a triangular shape.

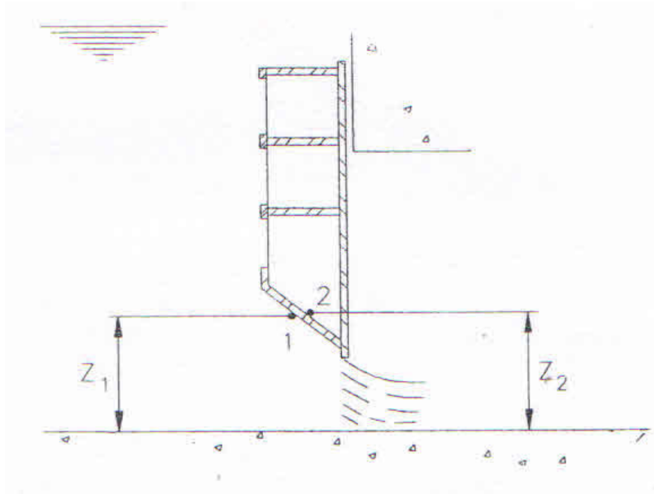
The result water trust is:

$$W = W_M - W_J = \frac{1}{2}\gamma\, B\, (H^2 - h_1^2) - \frac{1}{2}\gamma\, B\, h_J^2 = \frac{1}{2}\gamma\, B\, (H^2 - h_1^2 - h_J^2)$$



HYDRODYNMIC LOAD:

When a gate is totally closed and the water is at rest, the pressures obey the hydrostatic laws and the hydraulic forces are easily determined by analytical methods. In the absence of any flow, the calculation of the vertical component of the hydraulic forces on the gate comprises solely the determination of its buoyancy. This static condition is characterized by a uniform value of the piezometric head in the conduit, near the gate, is observed. However, whenever there is water flow past the gate, the high flow velocities at the bottom surface of the gate, which reduces the local pressure, cause the phenomenon of hydrodynamic forces on the gate structure. Hydrodynamic forces are generally determined by means of model tests. These tests are made in hydraulic laboratories and may substantially increase the cost of small gates. In such cases, it is usual to determine the hydrodynamic forces by analytical methods. However for critical and very high head gated installation help of model studies need to taken for more accurate and precise calculations.



LOAD CASES:

The three load cases for design of gates, according to the frequency of occurrence and the nature of the loads and the probability of their coincidence are considered:

- **Normal load case** – considers the most unfavorable values and combinations of the hydrostatic loads at normal water levels (including the influence of waves), hydrodynamic effects, friction forces, silt load, dead weight, buoyancy, transit loads and driving forces. For gate located in the conduits/sluices, provision for sub-atmospheric pressure d/s of the gate (generally 2 m for medium and 5m of water head for high head gate) shall be considered.
  The simultaneous occurrence of these loads and water levels, as well their combinations, should only be considered when possible and probable.
- **Occasional load case** – considers the loads which occur less frequently, such as:
  1. Hydrostatic and hydrodynamic forces at unusual water levels;
  2. Wind loads;
  3. Temperature effects;
  4. Friction by ships;
  5. Ice impact and pressure.

The simultaneous occurrence of these loads and water levels, as well as their combinations, should only be considered when possible and probable.

- **Exceptional load case** – considers loads occurring during transportation, erection, maintenance services or other exceptional cases, as well as the following:
  1. Hydrodynamic effects and overloads due to the driving forces in the event of failure of lining or penstock;
  2. Asymmetrical loads and overloads due to the driving forces caused by jamming / or the impact of ships;
  3. Seismic effects;
  4. Changes in conditions of support.

The simultaneous occurrence of these loads should only be considered when their combination is possible and probable.

The influence of the operating forces on the structural elements should be considered according to the hoist rated capacity for the normal load case, or with the maximum capacity, for the exceptional case. The maximum capacity to be considered, in the case of fluid power systems (i.e. hydraulic hoist), is the one corresponding to the relief value pressure; in the case of mechanical hoists, that of the limiting device or, in its absence, that of the maximum torque of the driving motor. In gravity- closure gates, the preponderance of the closing forces should be proved with a safety margin of 20 per cent, for the normal load case, and 15 percent, for the exceptional case.

The seismic influence is taken into account in the gate design with their effect simulated as a horizontal force of magnitude equal to the gate mass multiplied by the probable horizontal seismic acceleration in the region. The possible occurrence of the resonance phenomena and its effects should be investigated.

The influence of ice pressure and impact is considered according to the local conditions.

Design of gates is grouped as under:

- Structural design of gate
- Hydraulic design
- Design of gate slots and embedments

Structural Design:

Structural design of vertical lift gates in India is covered in following Indian Standards brought out by Bureau of Indian Standards (BIS):

(i) IS 4622

(ii) IS 5620

(iii) IS 9349

Apart from above, there are many publications and manuals brought out by USBR, U.S. Army Corps of Engineers, CWC etc-etc.

These standards cover in detail the criteria for the design of various components. besides above there are few more standards available which are related to the assembly, erection and testing of gates. Basic standards like IS-456 and IS-800 for RCC and structural steel designs are also adopted.

MATERIALS:

In the manufacture of gates and appurtenances a great variety of materials, such as rolled, stainless, cast and forged steels, cast iron, bronze and its alloys, natural and synthetic rubber for seals and, in some cases, timber, is used. The wide range of types and the amount of materials available can satisfy all the needs and requirements of the gate designers, thus leading to an adequate and economic selection of the material. This selection must comply with sound criteria, in order to warrant reliable operation and long life for the equipment. Therefore, the designer should take into account not only the cost and availability of the material in the market but also its main characteristics such as the chemical composition, physical and mechanical properties (yield and tensile strength, elongation, toughness, hardness, weldability, machinability, heat treatment capability and the corrosion resistance. The material for various parts of gate leaf/embedded is given below.

Sl No.	Component Part	Recommended Materials	Ref to, IS No.
i)	Wheel	Cast steel	1030 : 1998
		Cast iron	210 : 1993
		Wrought steel	
		Forged steel	2004 : 1991
ii)	Bearing/Bushing	Anti-friction bearing/bronze, phosphor bronze, aluminium bronze, self lubricating bushing of high strength brass castings	318 : 1981 305 : 1981
iii)	Wheel pins or axles	Chrome nickel steel or corrosion resistance steel, mild steel with nickel or hard chromium plating	2004 : 1991 2062 : 1999 1068 : 1993 1337 : 1993
iv)	Structural parts of gate leaf, track base, etc	Carbon steel, structural steel	1875 : 1992 2062 : 1999 8500 : 1991
v)	Seal	Rubber	11855 : 1986
vi)	Wheel track	a) Stainless steel b) Corrosion resistance steel	1570 (Part 5) : 1985
vii)	Seal seat	Stainless steel plate	1570 (Part 5) : 1985
viii)	Seal base, seal seat base, sill beam	Structural steel of convenient shape	2062 : 1999 8500 : 1991
ix)	Seal clamp	Structural steel	2062 : 1999 8500 : 1991 6603 : 2001
		Stainless steel	
x)	Guide	Structural steel or corrosion resistance steel or stainless steel	2062 : 1999 8500 : 1991 6603 : 2001
xi)	Springs	Spring steel Stainless steel	6527 : 1995 2062 : 1999
xii)	Anchor bolts	Structural steel	6527 : 1995
xiii)	Guide rollers and guide shoes	Structural steel or corrosion resistance steel, cast iron, cast steel or forged steel	2062 : 1999 8500 : 1991 210 : 1993 1030 : 1998 2004 : 1991

NOTES

1 Grade of the material conforming to the specifications mentioned above shall be specified by the designer to suit to the particular requirement.

2 Cast iron shall not be used for wheels and tracks for high head gates.

3 The choice of material is governed by the type of installation, accessibility for maintenance, reservoir water properties, silt, etc.

ALLOWABLE STRESSES:

The allowable stresses are determined according to the yield strength of the material and should take into account the load case. The permissible allowable stresses for various conditions are given below.

PERMISSIBLE MONOAXIAL STRESSES FOR STRUCTURAL COMPONENTS OF HYDRAULIC GATES

Sl No.	Material and Type	Wet Condition		Dry Condition	
		Accessible	Inaccessible	Accessible	Inaccessible
(1)	(2)	(3)	(4)	(5)	(6)
a) *Structural steel:*					
i)	Direct compression	$0.45\ \gamma_P$	$0.40\ \gamma_P$	$0.55\ \gamma_P$	$0.45\ \gamma_P$
ii)	Compression/Tension in bending	$0.45\ \gamma_P$	$0.40\ \gamma_P$	$0.55\ \gamma_P$	$0.45\ \gamma_P$
iii)	Direct tension	$0.45\ \gamma_P$	$0.40\ \gamma_P$	$0.55\ \gamma_P$	$0.45\ \gamma_P$
iv)	Shear stress	$0.35\ \gamma_P$	$0.30\ \gamma_P$	$0.40\ \gamma_P$	$0.35\ \gamma_P$
v)	Combined stress	$0.60\ \gamma_P$	$0.50\ \gamma_P$	$0.75\ \gamma_P$	$0.60\ \gamma_P$
vi)	Bearing stress	$0.65\ \gamma_P$	$0.45\ \gamma_P$	$0.75\ \gamma_P$	$0.65\ \gamma_P$
b) *Bronze or Brass:*					
	Bearing stress	0.035 UTS	0.030 UTS	0.040 UTS	0.035 UTS

The design of gates involves the design of the following components:

Skin Plate:

This is a thin plate and is designed for the span between supporting ribs (stiffeners) girders. As per the codal criteria, it is assumed to act effectively with stiffeners/ribs. The skin plate is generally designed for either of the two conditions:

i) In bending across the stiffeners or horizontal girders as applicable.

ii) As panels in accordance with the procedure and support conditions as per codal provisions.

While designing the stiffeners and horizontal girders the skin plate can be considered coacting with them as applicable.

(a) The coacting width of skin plate in non-panel fabrication shall be taken least of:

i) 40t + B (t= thickness of skin plate and B= width of stiffener flange in contact with skin plate)

ii) 0.11 span

iii) C/C of stiffeners and girders

(b) When the skin plate coacts with stiffeners as well as horizontal girders to form a panel construction, the width of skin plate coacting with stiffeners and horizontal girders shall be taken as under.

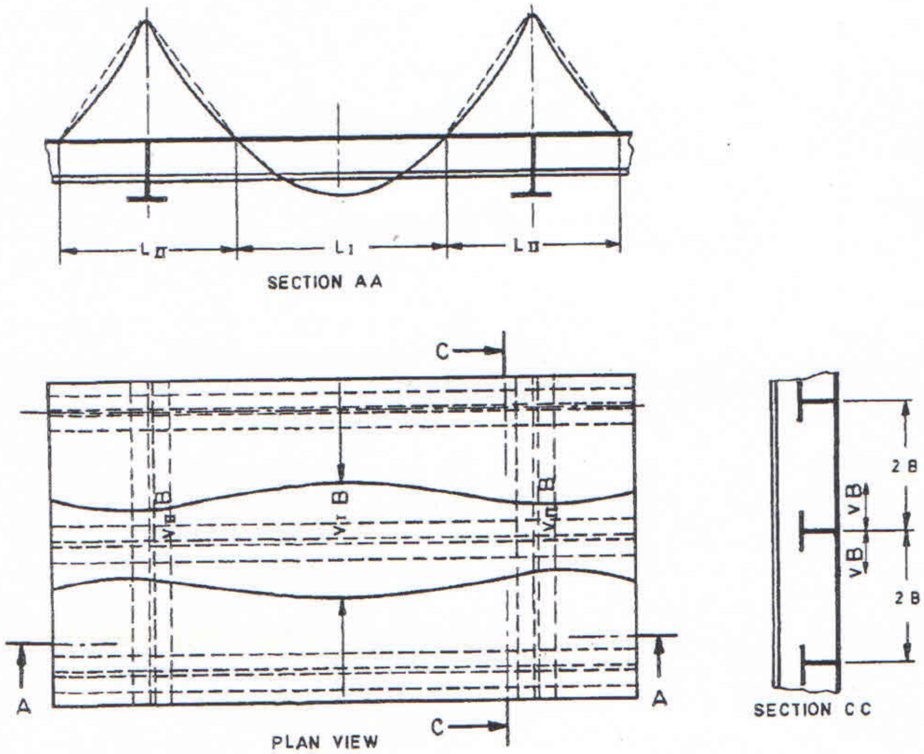
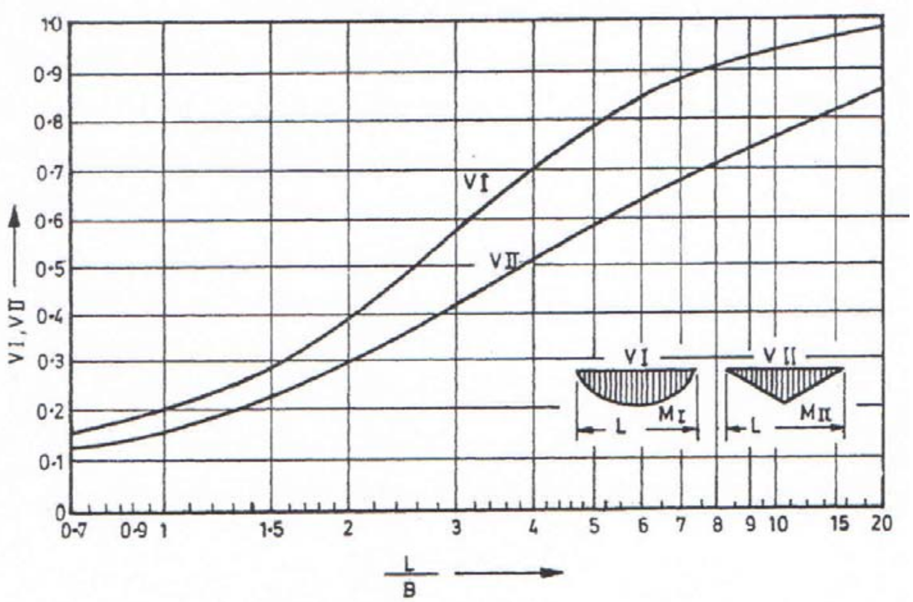
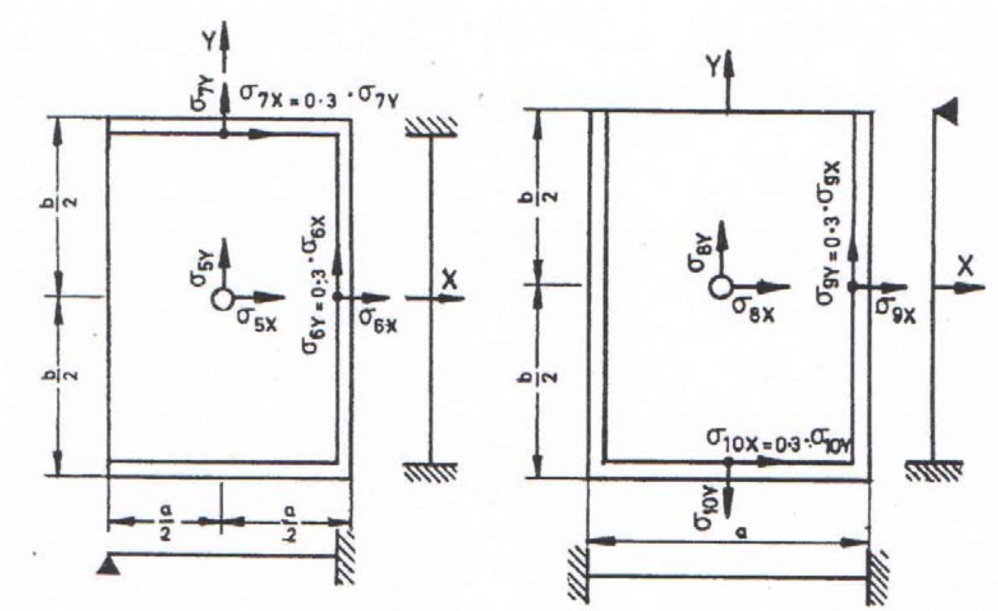
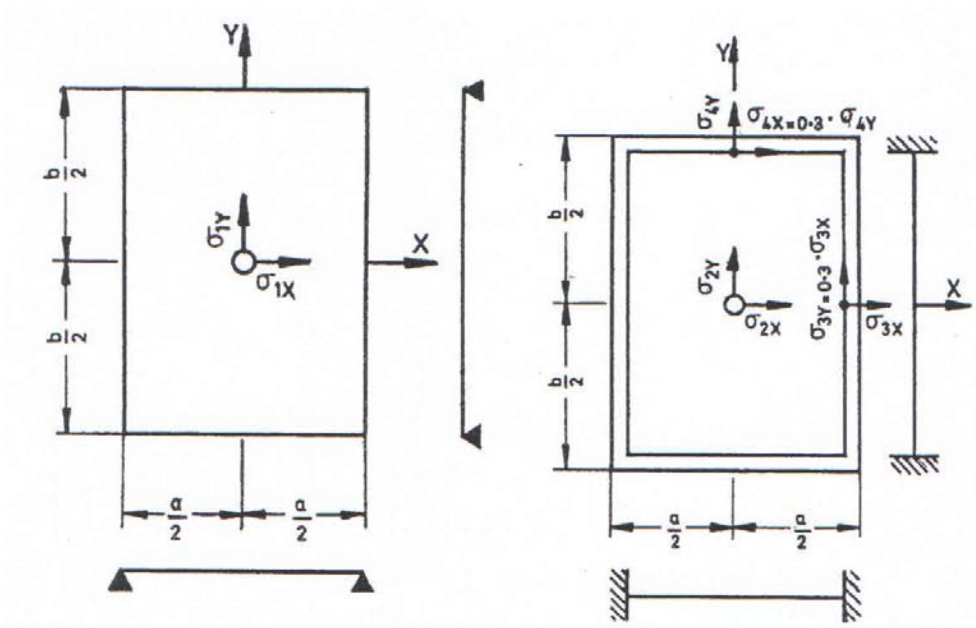


FIGURE SHOWING VARIATION OF COACTING WIDTH FROM SUPPORT TO SUPPORT



CURVES SHOWING RELATIONSHIP BETWEEN $\frac{L}{B}$ AND REDUCTION FACTORS V_I AND V_{II}





THICKNESS

The skin plate comprises the greatest part of the gate weight. Therefore, the designer should pay particular attention to its dimensioning in order to achieve the smallest possible thickness consistent with the required structural strength. Generally, the smallest thickness used in skin plates is 8 mm, which permits welding of the reinforcing elements without significant plate warping.

PLATE STRESSES

The plate bending stresses from water pressure are calculated with the theory of plates based on the theory of the elasticity as under:

$$\sigma = \pm\ \frac{k}{100} p \frac{a^2}{t^2}$$

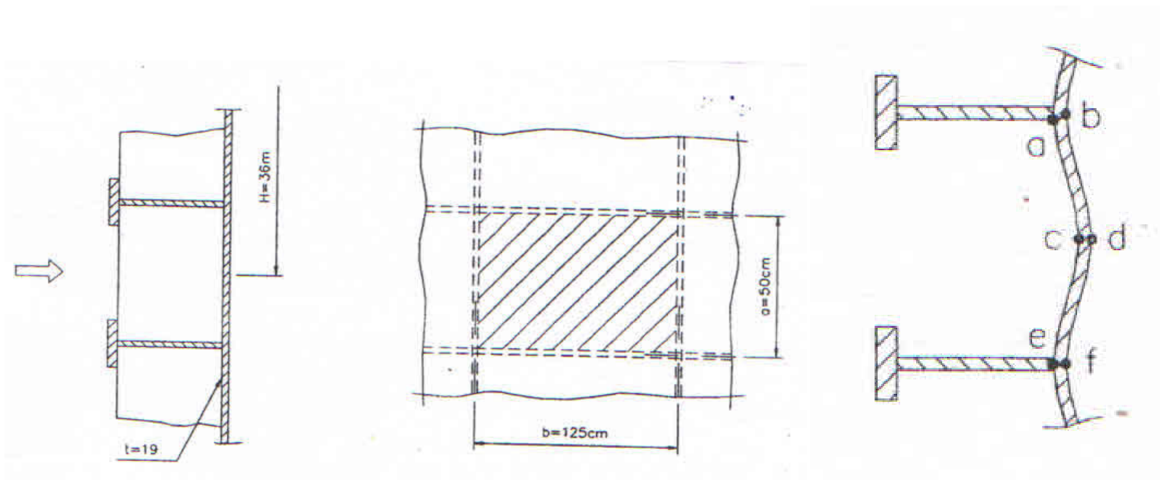
Where:

k = non-dimensional factor is function of the ration b/a (support length of the modules formed by the beams and/or stiffeners) and the support conditions of the panel given as per BIS code.

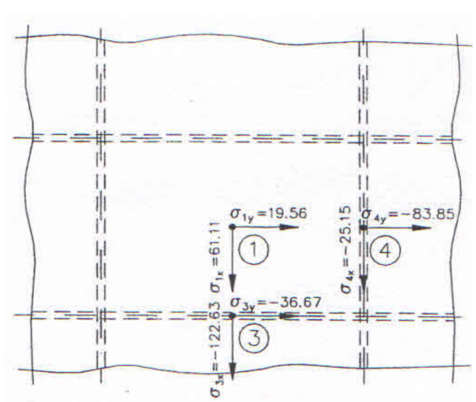
p = water pressure relative to the panel centre

a = minor support length

t = plate thickness.



The shape of the deflected skin plate determines the stress type (tension/ compression). In the present case, the skin plate deflects due to the water pressure as shown in figure given above.At points a, d and e, the fibers are stretched and, by convention, the stresses are considered positive. At points b,c and f, the fibers are compressed (therefore the stresses are, by convention, negatives). As result, the plate stresses in the downstream face of the skin plate are also shown in figure given below.



The values of mono-axial as well combined stresses thus computed shall not be greater than the permissible.

For bi-axial stress conditions, the combined stress is given by the formula:

$$\sigma^* = \sqrt{\sigma_x^2 + \sigma_y^2 - \sigma_x \sigma_y + 3\tau_{xy}^2}$$

Where:

σ_x = sum of stresses along x-axis

σ_y = sum of Stresses along y-axis

τ_{xy} = shear stress in plane normal to x-axis or y-axis

Permissible values of stress in welds shall same as for parent material. However, for site welds efficiency of 80% of shop welds shall be considered.

Corrosion allowance of atleast 1.5mm shall be added to the theoretical computed thickness of skin plate. Minimum thickness of skin plate shall be 8mm including corrosion allowance.

<u>HORIZONTAL GIRDERS:</u>

They are main support members of gate and are designed for reactions transferred from the vertical stiffeners. They span between end girders and are designed as simply supported horizontal girders. Spacing of horizontal girders is influenced by the skin plate thickness; the thicker the plate, the more spaced the beams may be. If, for constructive or economic reasons, the design specifies equal sized horizontal beams, their spacing should be gradual, increasing with height, so that all be subjected to the same part of the water thrust. If the beams are equally spaced, the lower ones must be stronger since they are subjected to greater loads.

NUMBER OF HOROZONTAL GIRDERS:

When starting the gate leaf dimensioning, the designer faces the following problem; how many horizontal girders should the gate have? The determination of the number of beams follows a trial and error procedure. Initially, the number and dimensions of the beams are set out; then, stresses and deflections are calculated. If the results prove unsatisfactory, new values are determined and the stresses and deflections recalculated. This procedure is repeated until the desired result is attained.To overcome this initial difficulty, the following empirical formula may be used for vertical lift gates:

$$N = \frac{100h}{t}\sqrt{\frac{H_m}{2\sigma_{adm}}}$$

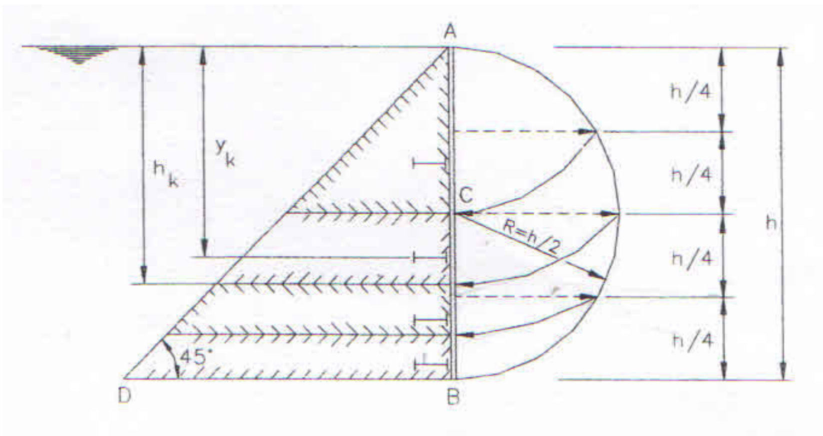
Where:
N = number of horizontal girders
h = gate seal height, in meters
t = skin plate thickness, in millimeters
H_m= water head referred to the gate centre, in meters
σ_{adm}= allowable bending stress, in MP_a.
The number of beams thus determined serves as a reference for the preliminary calculations of the gate leaf and only for that purpose. The final number of beams, as

well as their spacing, is indicated only through the complete dimensioning of the structure.

Spacing Of Horizontal Girders:

From the viewpoint of costs, it is worthwhile to have all horizontal beams equally loaded, in order to design a unique cross section for all beams. This is achieved by dividing the pressure diagram into equivalent areas and locating the centerline of each beam in the centroid of each area.

a) Weir/Crest Gates



The graphic method for division of the pressure into equivalent areas is shown in Figure above. The sequence is:

- To divide the height h (segment AB) in n equal parts;
- To draw a semi-circumference centered on C;
- To horizontally link the divisions of the segment AB to the semi-circumference;
- Centered on A, transport to the segment AB the intersection points marked in the semi - circumference.

The new points marked on the segment AB outline, in the load triangle ABD, n surface of equivalent areas. The horizontal beams should be located in the centroid of each area; it should be noted that all areas have a trapezoidal shape, except the top one, which is triangular. The outlining of the equivalent areas and the positioning of the horizontal beams can be made, alternatively, by means of an analytical procedure, with the use of the following equations:

- depth h_k

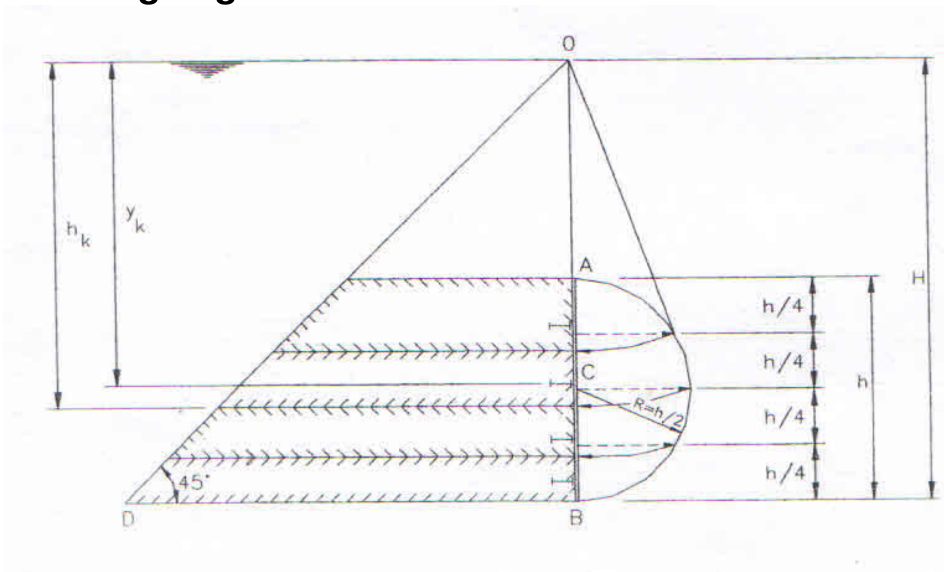
$h_k = h\sqrt{\frac{k}{n}}$ (where k = 1, 2, 3, …,n)

- depth of the horizontal beams

$$y_k = \frac{2h}{3\sqrt{n}}[k^{3/2} - (k-1)^{3/2}]$$

Where n is the quantity of beams or areas.

b) Submerged gates



The graphic method for division of the load diagram into n equivalent areas is similar to that suggested for the weir gates, except that the compass should be centered on point O located on the free surface of water, in the extension of the segment AB.

- Depth h_k

$$h_k = H\sqrt{\frac{k+\beta}{n+\beta}} \qquad (\text{ where } k = 1, 2, 3, \ldots, n)$$

Where

$$\beta = \frac{n(H-h)^2}{H^2-(H-h)^2}$$

H= maximum headwater on sill
h = gate sealing height.
n = quantity of areas (orbeams)

Position of horizontal beams

$$yk = \frac{2H}{3x\ \sqrt{n+\beta}}\,[\,(k+\beta)^{3/2} - (\,k-1+\beta))^{3/2}]$$

With this method, all beams will be equally loaded. It can be also used to determine the position of equally loaded wheels of fixedwheel gates.

GIRDER DIMENSIONS:

WEB THICKNESS

Once the number of horizontal girders is determined, the next step is the choice of their cross-section. For beams supported at the ends, the minimum thickness in the region of the support is given by the formula

$$t = \frac{F}{2h\tau_{adm}}$$

where:

F = water load on the girder

h = web depth

τ_{adm}= allowable shear stress.

In the case of very wide gates, it is usually advantageous to build the web with plates thinner in the center region than at the ends of the beam, for shear is null in the centre and maximum at the ends. The minimum recommended thickness for the web is 8 mm.

WEB DEPTH

For structural reasons, the larger the head and the support span, the higher the depth of horizontal girders. As a reference for the preliminary calculations of the characteristics of the cross-section of flat gate girders, see the empirical relations given below.

Depth of Horizontal Girders:

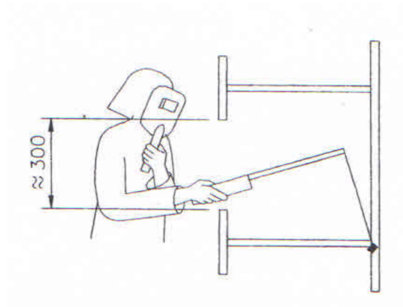
Head on Sill	Web depth
Up to 15 m	From 1/12 up to 1/9 L
From 15 m to 3 0m	From 1/9 up to 1/7 L
Over 30 m	From 1/7 up to 1/5 L

Where, L is the girder support length.

Girders may be designed with constant or variable depth along the span. Variable depth girders reduce the gate weight. Sloping of the horizontal girder depth at the ends permits reduction of the lateral slot dimensions.

FLANGES:

Flanges are made from plates with thickness equal to or greater than that of the web. Their width can be taken equal to 1/5th of the girder depth, in the preliminary calculations. When dimensioning the gate, the designer should consider as a whole the flange width, the spacing and depth of the horizontal girders, so as to facilitate access to the interior of the gate frame for welding. A minimum gap of 300 mm gap is recommended (see Figure below) for gates with very large numbers of girders.



COMPRESSION FLANGES:

For built-up beams with loads applied in the plane of the web, enough safety should be built in against lateral buckling. Checking of lateral buckling may have to be done according to the standard practices. The compression flange is considered stable when the following condition is fulfilled.

$i_y > \frac{c}{40}$

Where:

i_y= major radius of gyration of the section formed by the flange and 1/5 of the web area;

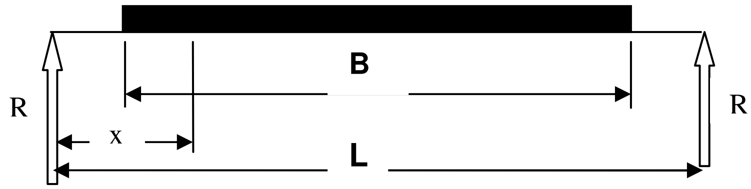
c =distance between the girder rigid points.

WEB STABILITY

When dimensioning girders subjected to bending, it is convenient to space the flanges as much as possible and work with low thickness webs. However, greater the ratio between the web depth and the thickness, the greater the possibility of buckling. The web buckling should be checked for the built girder where ratio of web depth/thickness is more than or equal 45.

SIMPLE BENDING OF BEAMS:

The load diagram of horizontal girders of flat gates (fixed-wheel, slide, stoplogs and caterpillar) is shown as under:



The bending moment at any point, such that

L/2 $\geq x > \frac{L-B}{2}$

Is given by

$M_x = R_x - \frac{F}{2B}[x - \frac{1}{2}(L-B)]^2$

And its maximum value occurs at the midspan (x = L/2), being determined by the equation

M = (2L –B) F/8

Where:

R = support reaction = F/2

x = distance between the support and the considered point

F = water load acting on the girder

B = seal span

L = support length

q = load per unit length = F/B.

The horizontal girder deflection under load should be limited so as not to affect the safety, the movement and, in the case of upstream seals, the gate water tightness. Maximum deflection occurs at midspan and is determined by

Deflection = $\frac{5\ FL^2}{384\ EI}$

Where:
F = water load on the girder
L = support length
E = modulus of elasticity of steel
I = moment of inertia of girder cross-section.

Deflection of the gate:

Maximum deflection of the Horizontal girders/gate under normal conditions of loading shall be limited to:

1/800 of the span (c/c of the wheels) –Fixed wheel gate

1/800 of the span (c/c of the sliding track) –Low head slide gate

1/2000 of the span (c/c of the sliding track) –Medium and high head slide gate

1/1200 of the span (c/c of the sliding track) –Medium and high head slide Bulkhead gate

However, maximum deflection shall not be more than 80% of initial interference of the seal in case of gate with upstream top seal.

Stiffeners:

The load from skin plate is transferred to vertical stiffeners which are designed as continuous beams spanning over the horizontal girders.

It is possible to increase the critical buckling stress of a plate without increasing its thickness, through the use of stiffeners adequately provided. Generally, the installation of stiffeners obeys the following recommendations:

Pure compressions: longitudinal stiffeners placed symmetrically in relation to the longitudinal axis;

Simple bending: longitudinal stiffeners placed at a fourth or a fifth of the web depth, near the compression flange, on one side of the web plate;

Shear: transverse stiffeners, dividing the web into square plates with each side equal to the web depth.

End Girders:

They transfer the load to gate wheels /slide blocks. They are designed as beams spanning between supports at wheels or as continuous beams over slide blocks.

Design of Wheel (line contact:)

The contact stresses between the wheel and the track shall be as under:

$$f_c=0.418\sqrt{\frac{PE}{rl}}$$

f_c= contact stress in N/mm^2

P= wheel load in N

E= modulus of elasticity, N/mm^2

r = radius of wheel in mm

l= tread width in mm

The contact stress shall not exceed the permissible value.

Wheel pin

Wheel pin shall be designed for bearing, bending and shear. The pin shall be given suitable eccentricity (normally 3 to 5 mm) for permitting alignment of wheels.

Wheel bearing

Wheel bearing may be of bronze bussing, self lubricating bushing or antifriction roller bearing. For bronze bussing bearing stress shall not exceeds the value given in table-

For antifriction roller bearing the outer dia of the roller bearing shall not exceeds 0.6 times the wheel dia in case of point contact and 0.8 times the wheel dia in case of line contact. The bearing shall have a factor of safety of 1.5 on the static capacity.

Dimension of Bushing:

Bearing pressure= P/ld

P= wheel load

l= effective length of bushing

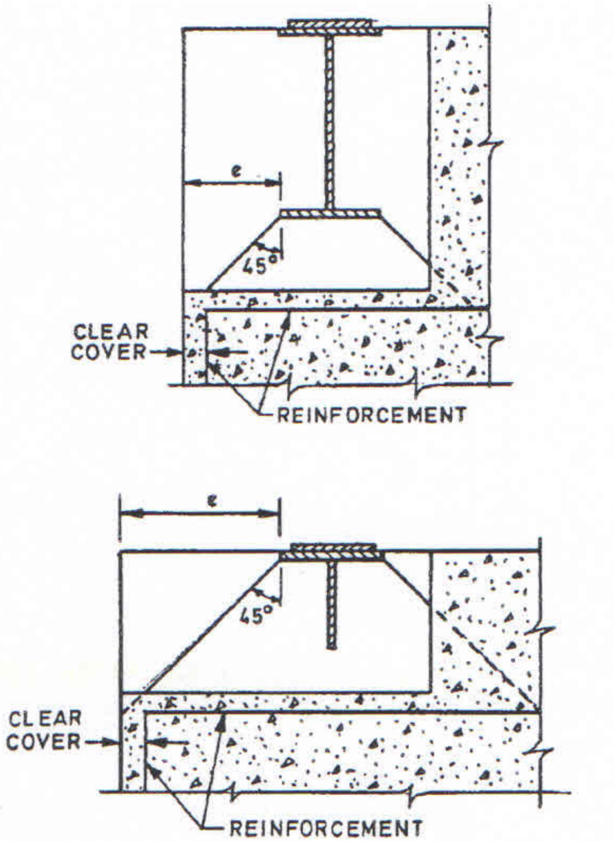
d=inner dia of bushing

The combined stress, for mechanical elements (wheels, pins, bearings, bush, hook, shafts, etc) subjected to a normal stress and a shear stress, is given by

$$\sigma^* = \sqrt{\sigma^2 + 3_\tau{}^2}$$

Where:
σ = tensile or compressive stress
τ= shear stress.
The combined stress should not exceed 1.25 times the allowable stress for the cases of normal and occasional loads and upto the yield strength, in the case of exceptional loads.

Gate Embedments:Gate embedments are in the form of a steel track, guides, seal seat, seal base and sill beam and anchorages which are embedded in the concrete in the grooves. The minimum edge distance **'e'** of the bearing flange plate shall in no case be less than 150mm



EDGE DISTANCE CRITERIA FOR TRACK BASE

Gate Slot/Groove:

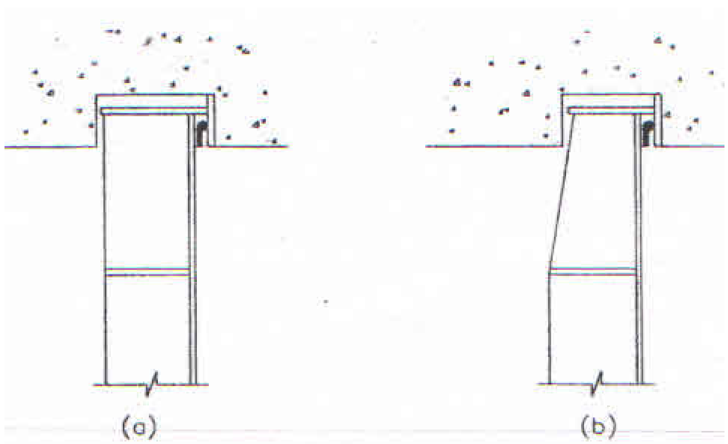
Vertical lift gate (Fixed wheel/Slide type) transfer water load on the embedded parts installed in the gate slot. Gate slot usually houses the gate support, guide elements, wheel and sliding tracks, seal seats, side guides, etc. Gate slots disrupt the boundary lines, create vortices and cause the separation of the flow at their boundaries resulting in low pressure in the vicinity of the slot. High flow velocity coupled with severe low pressures my cause erosion and cavitations in the downstream. It is desirable to keep gate slot dimensions as small as possible to minimize flow disturbances and to avoid trapping of any debris.

Offsetting (0.1 to 0.2 of slot length) the d/s slot edge considerably improves upon the local condition of the flow, eliminates or reduces the low pressure near the wall. In case of high head installation, the d/s edge of gate slot should be rounded and side wall given slope of 1 in 10 or flatter. Offsetting of gate slot is not required for the low head gated installations.

Rectangular gate slots should not be provided except for very low head gates.

Width (W) of gate slot should be kept as small as practicable. Depth (D) of slot has little effect on cavitations hazard. The optimum W/D ratio falls in the range of 1.4 to 1.8. In practice, higher values can be adopted as per physical requirements.

For gates operating under a head of say 10 m or more, the downstream edge of the gate slot should be off-set to reduce the cavitations hazard. A downstream offset of 0.075 to 0.10 of the slot width (W) with gradient of 1/10 to 1/12 for heads upto 30 m & 1/24 or flatter beyond 30m head, downstream of the gate slot and a rounded point of inter-section with Radius 'R' as 0.10 times the D (say R=3 cm to 5 cm) is recommended. Upstream slot face should have a sharp and not rounded corner.

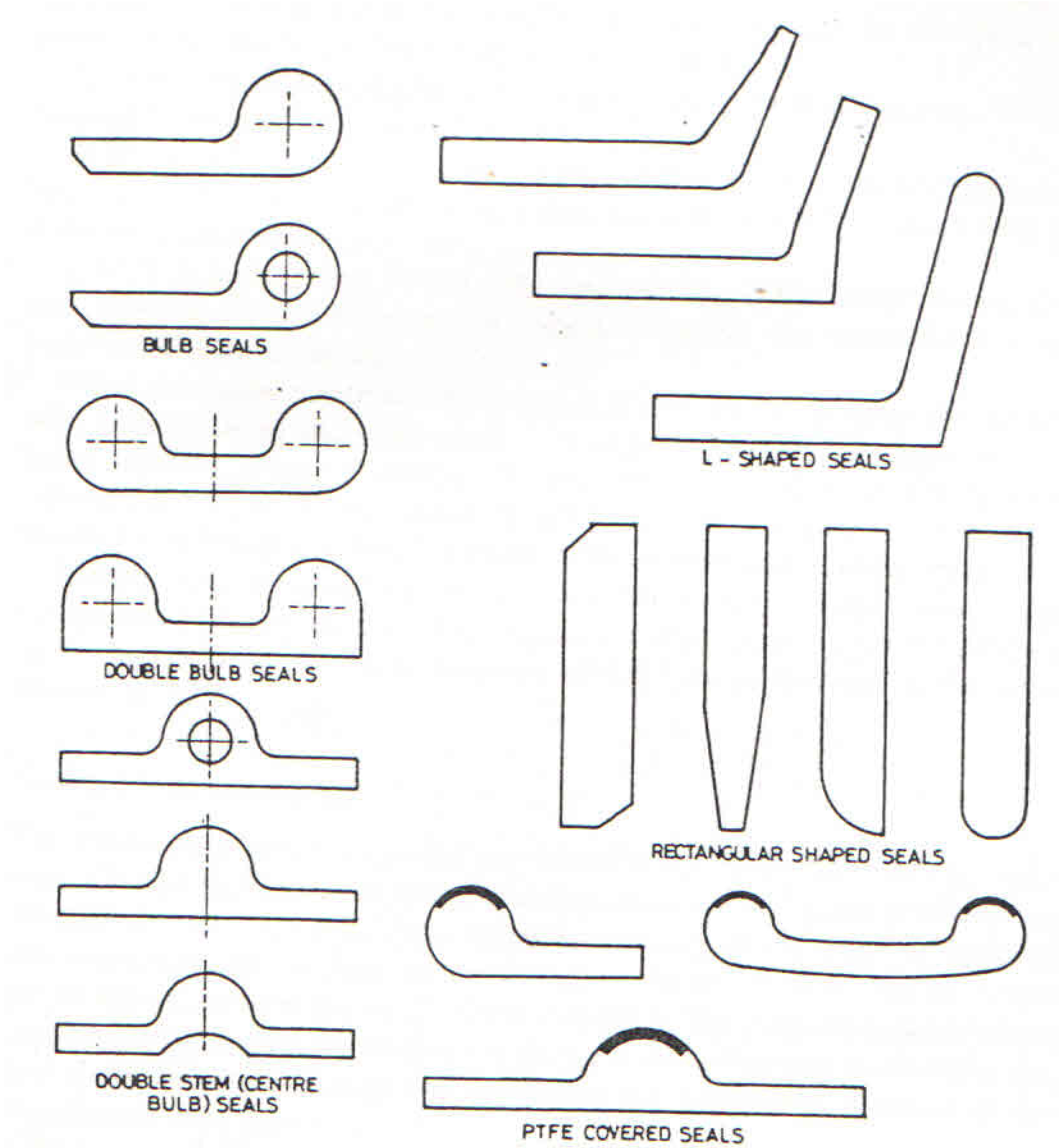


Guide rollers/guide shoes

The guides shall be fixed inside the groove/slots. The guide shall be flat plate or a rail section as required. The minimum thickness of plate shall be 20mm (Low head gate), 32mm (Medium head gate) and 40mm (High head gate). The guide shall continue for the full range of gate travel.

Seals/seal seats:

Appropriate types of seals should be chosen to achieve water tightness. A variety of seals is available in India and different types of these are shown in figure given below. The seals are made from natural or synthetic rubber and should confirm to BIS standard IS: 11855.



Double stem type (preferably with cladding) for top and top corner seals, music note seal for sides of the high head gate.

Solid bulb music note type seal for the medium head gate.

Hollow/Solid bulb music note type or L-type seal for the low head gate.

Wedge type seal may be used at the bottom of the gate when the gate happens to rest on the sill. However, if the gate slides on the face of the opening, music note or double stem seal may be used.The minimum width of stainless steel seal seat shall be 80mm and minimum thickness shall be 6mm(low head) and 8mm(Medium and high head).

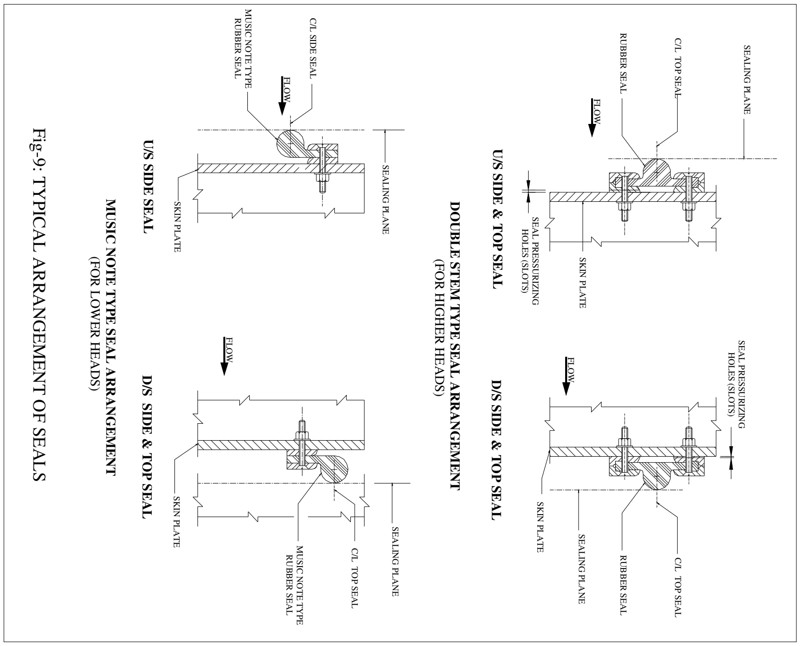


Fig-9: TYPICAL ARRANGEMENT OF SEALS

Upstream sealing gates have more chances of leakage as compared to downstream sealing.A seal guard is usually provided for those installations, where presence of debris is likely to damage the gate seals, particularly in case of bottom seals. Solid bulb music note seals are recommended at sides & top of gates operated under medium head (i.e. at a head of water ≥ 15m but less than 30m). These seals are also recommended for high head installations (i.e. water head ≥ 30m) as side seals. However, double stem seals are recommended for application as top seals because music note type seals at this location particularly for upstream sealing gates suffer from rolling action, when the gate is moved.Double stem seals should be clamped only on the extreme edges of seals. Projection of gate bottom seal should be restricted to the minimum possible as per design requirements as it can become one of the sources of gate vibration.

Wheel/slides track:

These tracks are designed as an infinitely long beams resting on elastic foundation subjected concentrated or uniformly distributed load transmitted by the wheel or sliding track respectively.

The hardness of the wheel track shall be 50 point BHN higher than that of wheel tread to reduce its wear.

Thickness of Track plate (line contact):

$$b=1.55\sqrt{\frac{P\,r}{l\,E}}$$

P= wheel load in N

E= modulus of elasticity, N/mm^2

r = radius of wheel in mm

l= tread width in mm

Minimum thickness of track, t = 6 x 0.786 x b

Thickness of Track plate (point contact):

$$t = \frac{1.27\,P}{2cf}$$

t= thickness of track in mm

P= wheel load in N

2c= track width in mm

f= allowable track bending stress in N/mm^2

The minimum thickness of track plate any case shall not be less than 10mm.

Bearing stress in concrete:

The stress in bearing for concrete shall not exceed the value specified in IS: 456. Concretein contact with track shall of atleast M20 grade.

p= 0.2833 x P (Ec /Es x I x w2)1/3

p= bearing stress in concrete, N/mm2

P= wheel load in N

Ec=modulus of elasticity of concrete, N/mm2

Es= modulus of elasticity of steel, N/mm2

I= moment of inertia of track base, mm4

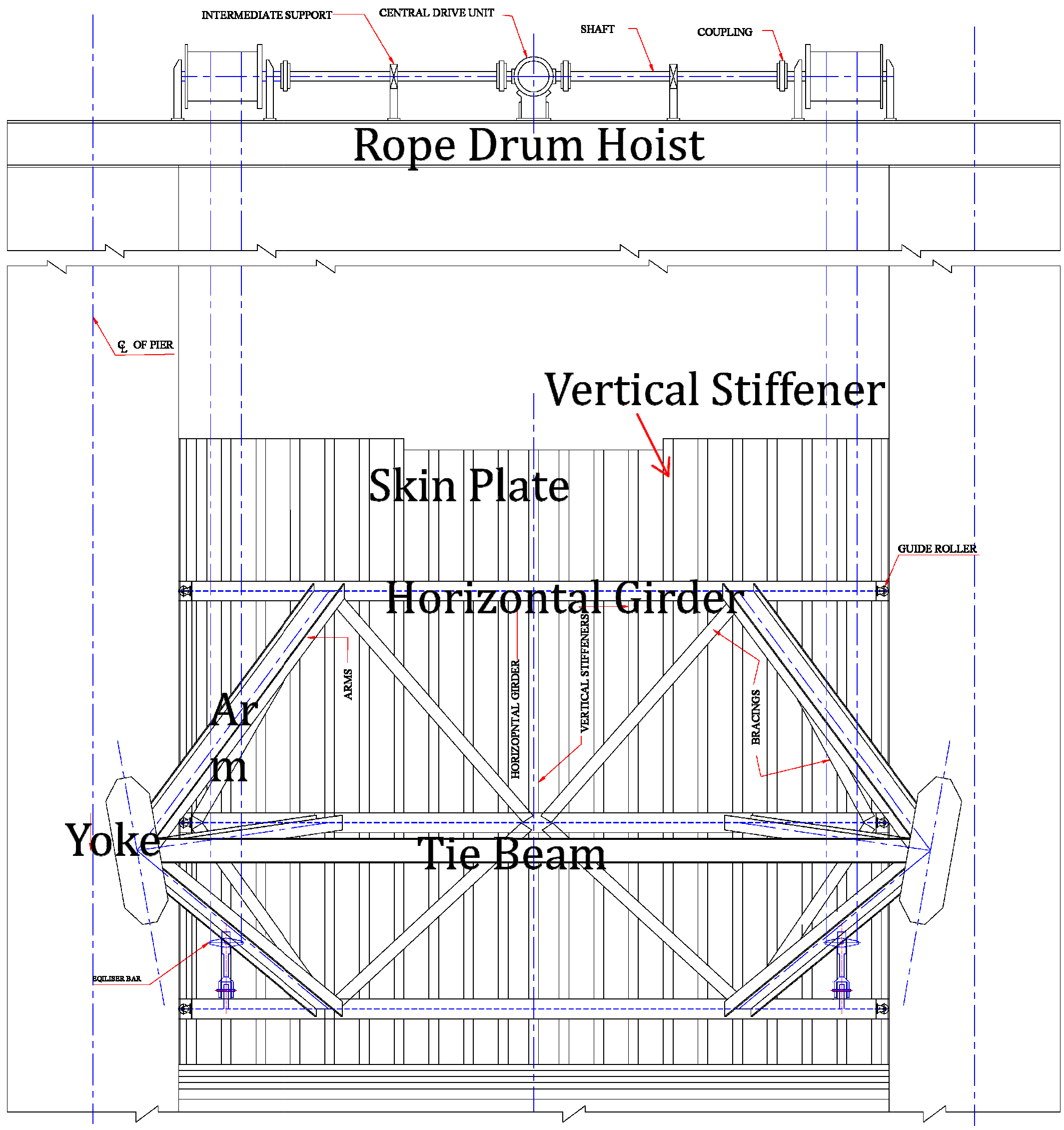
w = width of track base in contact with concrete, mm

If the pressure distribution under adjacent wheels overlaps, superposition of pressure shall be adopted and checked for the worst condition.

DESIGN OF RADIAL GATES

1. Radial Gate

Radial or tainter gate is in the form of a curved plate, storing water usually on convex side, having an arc of a circle as its main member which is supported on a system of steel framework which in turn transfers the thrust of water to concrete through another system of steel grillage or rods called anchorages. Fig. No. ‘1’ shows view of radial gate from downstream side.



Definitions of main component parts of a radial gate are given as under:

Skin Plate :

A membrane which transfers the water load on a radial gate to the other components.

Horizontal Girders :

The main structural members of a radial gate, spanning horizontally to transfer the water pressure from skin plate and vertical stiffeners to end arms of the gate.

End Arms :

Main structural members which carry the reactions from the horizontal girders to the gate trunnions.

Trunnion Hub :

A hub to which the converging end arms of a radial gate are rigidly connected. It houses the trunnion bushings/bearings and rotate about the trunnion pin.

Trunnion Assembly :

An assembly consisting of trunnion hub, trunnion bush or bearing, trunnion pin and trunnion bracket.

Yoke/Trunnion Girder :

A structural member supporting the trunnion bracket and held in place by load carrying anchors or tension members embedded in piers/abutments.

Anchor Flats/Anchors:

Structural tension members provided for transferring water load from the trunnion girder of a radial gate to the piers/abutments.

Anchor Girder:

An embedded structural member, transferring load from a radial gate to its surrounding structure.

Thrust Block or Thrust Pad :

A structural member designed to transfer to the pier or abutment that component of water thrust on a radial gate caused by lateral force induced due to inclination of end arms.

Trunnion Tie :

A structural tension member connecting two trunnion assemblies of a radial gate to cater to the effect of lateral force induced due to inclination of end arms.

Wall Plate :

A plate embedded flush in a pier/abutment to provide a track for the seal and guide rollers of a radial gate.

Sill Beam: A steel beam embedded in concrete supports the gate at bottom in closed position of gate. It also act as smooth surface for bottom seal.

Advantages of Radial Gate

Elimination of gate grooves, Less hoisting effort required, Self Closing, High Co-efficient of discharge, Large Size Possible and Less Vibrations are some of the advantages of radial gates over other type of gates.

However complicated design and requirement of extra civil structure restricts its application for many locations.

Uses

Spillways for storing and maintaining FRL

Top seal radial gate for increasing the spillway capacity

Under Sluices to discharge silt

Waterways to allow Ships to pass

Intake

Canal Regulator

Automatic Level Regulator

Design loads In general, the gate is designed for hydrostatic pressure acting on the gate and checked for occasional forces such as earthquake effect, wave effect and occasional overtopping. The maximum stresses in various parts of the gate under the action of occasional forces are restricted to 133% of the normal permissible stresses subject to a maximum of 85% of the yield stress of the material as per provisions of IS:4623 (Recommendations for structural design of radial gates). Ice load shall also be taken into account, if so specified. Load due to reaction from sill and due to rope tension shall be combined with hydrostatic pressure while carrying out the design analysis.

COMPONENT PARTS TO BE DESIGNED:

Following parts are required to be designed for a radial gate.

i) Skin plate

ii) Stiffeners (vertical or/and horizontal)

iii) Horizontal girders

iv) Diaphragms (if provided)

v) End arms and their bracings

vi) Trunnion assembly

vii) Thrust pad or Tie beam

viii) Seal assembly

ix) Guiding system

x) Anchorages

xi) Gate hoist connection

Gate Geometry :

Gate Sill Location :

Gate sill is located on downstream of crest and as close as possible to the crest of the dam to economise on height of gate and size of pier. From hydraulic standpoint, the location of gate sill should be such that the flow underneath the partly open gate continues to hug the spillway profile. As a general guideline sill may be placed at about 0.30 to 0.80 m below the crest.

Radius of Gate :

Radius of gate is normally reckoned from the inside surface of skin plate to centre of the trunnion. The radius of gate should be ideally between 1.00 H to 1.25 H, where 'H' is the vertical distance between the top of gate and gate sill.

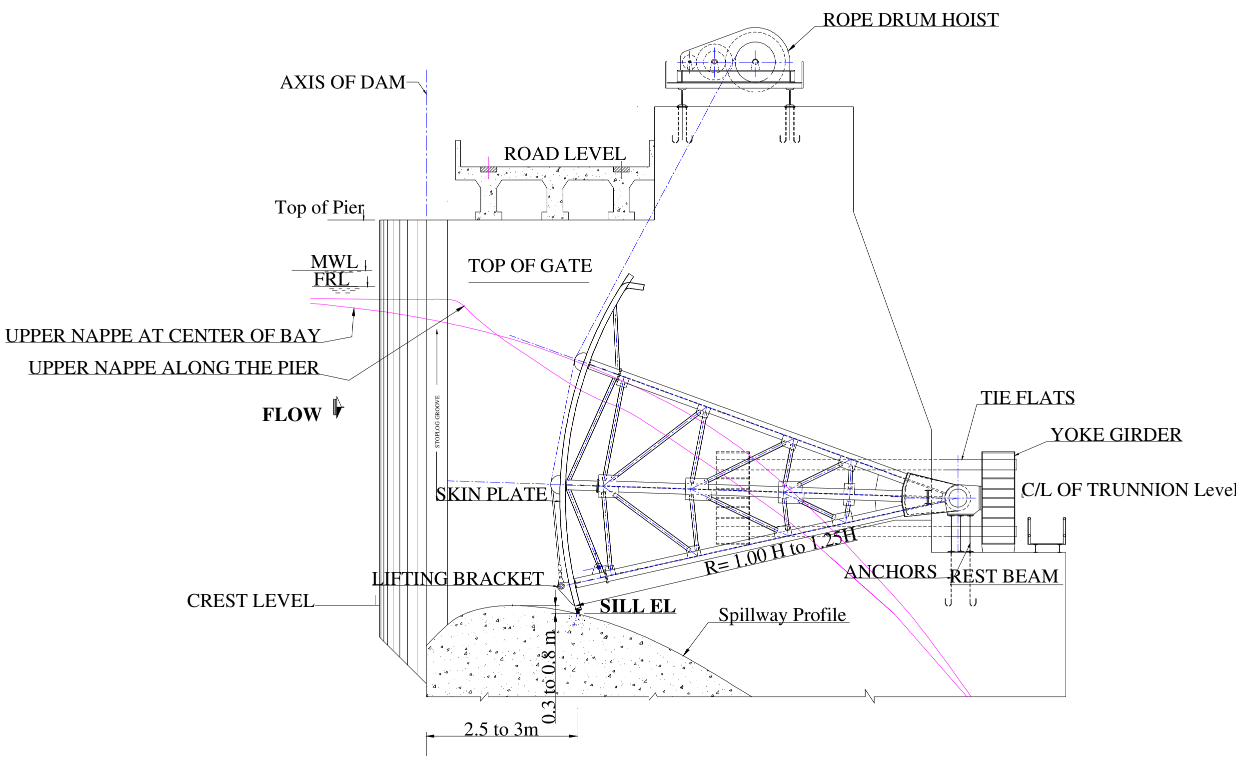
Gate Trunnion :

Generally gate trunnions are located sufficiently above the upper nappe (along the pier) to prevent any submergence. It would be advantageous to place the trunnion centre at about one third the height of gate above the sill so that the resultant reaction is as close to horizontal as possible thereby avoiding any major vertical force on trunnion.

However, in case where tail water is very high, above criterion is not possible to be met and trunnions are required to be located far above the one third gate height.

Location of Gate with respect to Stoplogs :

The gate, if provided with stoplogs for isolation, should be placed sufficiently away from stoplog grooves. In general, a distance of 2.50 to 3.00 m is found satisfactory in most cases.



Location of Hoists :

Radial gates are usually operated either by rope drum hoists or hydraulic hoists. If hydraulic hoists are provided, they are required to be located on downstream only. In cases where rope drum type (or wire rope type hoists) are used, choice of suspension has to be a judicious one. Whereas upstream hoists offer lower hoisting capacities due to increased leverage lengths, they have a disadvantage of inaccessible suspension and gate connection. Downstream suspensions have advantage of accessibility but they result in higher hoisting efforts due to smaller leverage length.

WORKING STRESSES :

Working stresses for radial gate components are as per IS:4623. The skin plate is designed for wet and inaccessible conditions while other components of gate like stiffeners, horizontal girders and arms are designed for dry and inaccessible conditions. Gate trunnion parts can be designed for dry and accessible conditions. Gate anchorages are required to be designed for wet and inaccessible conditions as these are permanently placed inside the concrete.

For end arms, stresses corresponding to respective slenderness ratios as given in IS:800 are generally.

Hoist attachments for gates should be designed by considering permissible stresses for hoist components as contained in IS:6938. These connections should also be checked for rope tensions in wire ropes corresponding to the breakdown torque conditions of hoist motor.

SELECTION OF MATERIALS:

The types of materials recommended for gate components should have high yield strength and be ductile in nature. The steel used for fabrication should be weldable and should satisfy all the criteria regarding weldability as laid down in the relevant Indian Standards. Following table shows the materials generally used for various gate components:

Component Part	**Recommended Material**	**Relevant IS Code**
Skin Plate, Stiffeners, Horizontal Girders, Arms, Bracings, Anchor Girder, Yoke Girder, Load carrying Anchors etc.	Structural Steel	2062
Guide Rollers	Cast Steel Structural Steel	1030 2062
Trunnion Hub and Bracket	Cast Steel Structural Steel	1030 2062
Trunnion Pins, Lifting Pin	Corrosion Resisting Steel	1570
Bushings	Self lubricating	305
Seal seats	Stainless steel	1570
Seal base, seal clamp and sill beam	Structural Steel	2062

DESIGN OF MAIN COMPONENTS:

Anchorages:

The anchorage system for a radial gate is provided for the transfer of water load through the gate trunnion to the piers and abutments. Anchorages are normally selected as bonded or of unbonded type depending on the size of gate. Smaller gate size say up to 12m x 12m may be provided a bonded type of anchorage while for bigger gates unbonded type of anchors may prove economical.

Bonded Anchorage :

In bonded type, the load transfer takes place in bond between the anchors and the concrete. Bonded anchors should be provided adequate anchorage length in concrete as per provisions contained in IS:456 subject to a minimum of two-thirds of the radius of the gate.

Unbonded Anchorage :

In unbonded type, the load transfer takes place in bearing as a bearing stress between the concrete and the embedded anchor girder at the upstream end of the anchors, which in this case are insulated from concrete, and the anchors are designed as pure tension members. The length of the anchors shall be such as to limit the shear stress in the 45^0 planes at the anchor girder to a safe permissible value subject to a minimum of 0.60 of the radius of gate.

Prestressed Anchorage :

The anchorage for gates could also be provided in the system of prestressed anchorages. Large gates of size, say 15m x 15m and higher, should find prestressed anchorages an optimum alternative considering overall economics of gate as well as pier design.

SEAL ASSEMBLIES:

Radial gates provided on spillway generally have seals on sides and bottom. Top seals are necessary where breast walls are provided for spillways and also for outlets.

Bottom seals of radial gate are generally flat type and they seal against bottom seal seats by compression under the self-weight of gates to provide requisite sealing effect and stability. Angle-shaped seals (also called L-type) are commonly used as side seals for spillway radial gates because of their superior flexibility and resilience characteristics such that minor dimensional changes in the leaf structure due to thermal expansion and contraction can be accommodated without impairing sealing capability. The sealing effect is obtained partly due to initial interference (varying from 2 mm to 6 mm) and partly due to water load

Outlet gates require sealing at top also, which is accomplished by providing two sets of seals, one attached to the embedded lintel beam to prevent leakage at the top when the gate is partially open, while the other is attached to the gate skin plate to ensure tight sealing when the gate is fully closed.

GUIDING SYSTEM:

The gate is provided with a guiding system consisting of guide rollers mounted on the gate, and wall plates embedded in concrete. Guide rollers are arranged on the sides to limit the lateral motion or side sway of the gate to not more than 6 mm in either direction by rolling contact.

Gate Leaf Design

Normally all members are analysed as having simple supports with due considerations for end restraints. Skin plates in middle panels (between the vertical stiffeners) are generally treated as continuously supported. The vertical stiffeners are also analysed as continuous beams spanning between horizontal girders. They will have skin plates as co-acting members. The horizontal girders are treated as simply supported beams spanning between end arms' centres as supports. In addition to normal bending and shear, they may be required to carry axial thrusts in case inclined end arms are provided. End arms are designed as compression members carrying thrust from horizontal girders in addition to moments shared by them from horizontal girders, taking into consideration the type of fixity to the girder

Trunnion Hubs:

The trunnion hubs are treated as thick or thin cylinders subjected to internal pressure generated by the resultant load on trunnion, which is distributed over the entire bearing surface housed inside the hub. The trunnion hub shall have thickness of not less than 0.3 d, where 'd' is diameter of pin (outer diameter if hollow).

Trunnion Bushings :

Trunnion bushings shall be either aluminium bronze or self-lubricating types.

Thrust Block:

Thrust blocks transfer the lateral thrust induced due to the inclination of end arms to the piers supporting the gate. The thrust blocks are designed to withstand the bending and shear force caused by the side thrust which is ultimately transferred to the concrete as a bearing stress.

References:

- BIS codes
- Design manual of Radial Gate (CWC publication)
- Manual on design of Spillway Tainter Gate by US Army corps of Engineers
- Design & Drawings of projects
- Davis C.V, Handbook of Applied Hydraulics

DESIGN OF ROPE DRUM HOISTS

Most commonly adopted hoisting equipment

- Rope drum hoist – For self closure
- Screw hoist – For positive thrust
- Hydraulic hoist – For Higher capacity
- Gantry Crane – For stoplogs
- **Monorail Cranes**

CONCEPT OF A ROPE DRUM HOIST

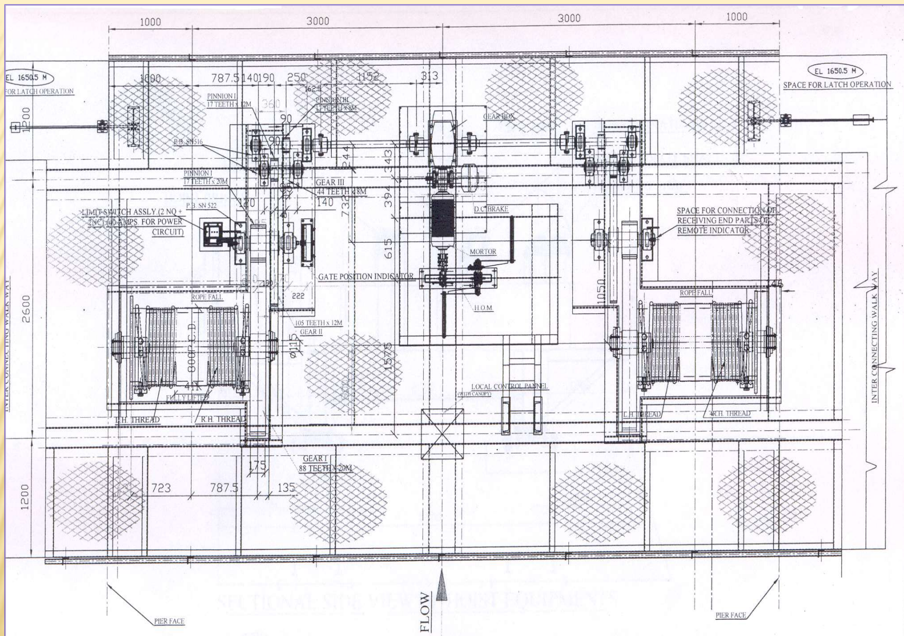
- FLEXIBLE ROPE OF SPECIAL STEEL WOUND ON A GROOVED DRUM OF STEEL
- ONE END CONNECTED WITH GATE AND OTHER WITH DRUM
- WINDING EFFECTED WITH ROTATION OF DRUM
- ROTATION OF DRUM THROUH A SOURCE SUCH AS ELECTRICAL MOTOR

ROPE DRUM HOIST

Rope drum hoists are exclusively used for gates which are *self closing* i.e. gates will close by their own weight. These are very popular due to their indigenous manufacture and easy maintenance.

VIEW OF INSTALLED ROPE DRUM HOISTS FOR MANASI WAKAL PROJECT (RAJASTHAN)

VIEW OF INSTALLED ROPE DRUM HOISTS FOR MANASI WAKAL PROJECT (RAJASTHAN)



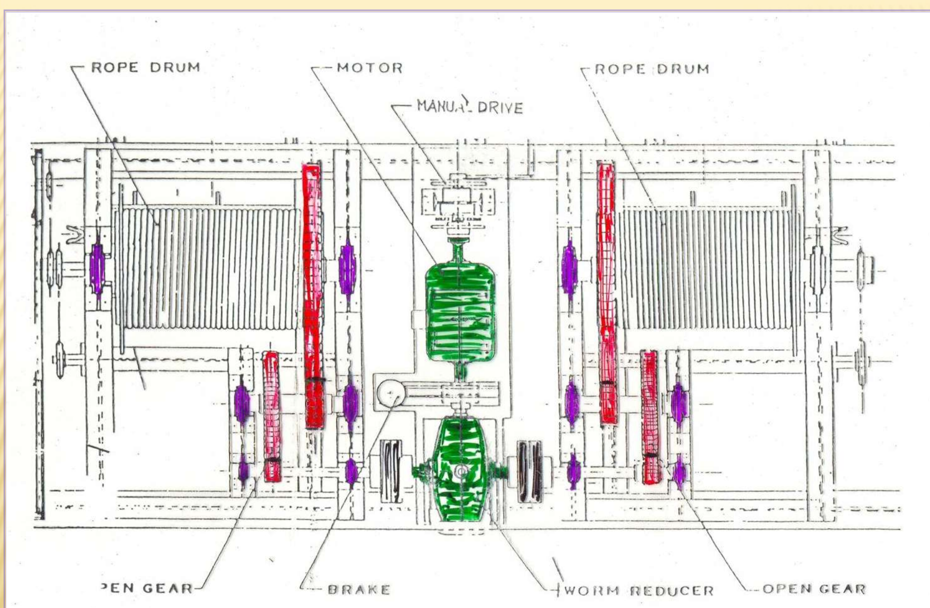


FIG. I – ROPE DRUM HOIST

ADVANTAGES OF ROPE DRUM HOISTS

- SIMPLE FOR DESIGN,FABRICATION & ERECTION
- LOW COST FOR MODERATE CAPACITIES
- EASY MAINTENANCE AND COMPONENT REPLACEMENT
- CONVENIENT FOR HIGH LIFTS FOR GATES LOCATED UNDER WELLS OR DUCTS
- CAN RESULT IN OPTIMUM CAPACITIES DUE TO GATE CONNECTION IN RADIAL GATES
- IS THE ONLY CHOICE IF GATE MUST TRAVEL ABOVE THE OPENING FOR STORAGE

LIMITATIONS

- ABSENCE OF POSITIVE THRUST
- COMPLEXITY IN ROPE LAYOUT FOR HIGHER CAPACITIES
- DANGER OF ROPE SNAPPING
- LARGER SPACE REQUIREMENT
- LIMITED OPERATING SPEEDS
- EXPENSIVE FOR HIGHER CAPACITIES
- PRONE TO MALFUNCTIONING DUE TO MULTIPLE COMPONENTS
- NEED RIGOURIOUS UPKEEP
- NOT FRIENDLY FOR AUTOMATION

CRITERIA FOR ADOPTNG ROPE DRUM HOISTS

- USED ONLY IN CASE OF SELF CLOSING GATES
- FOR MODERATE CAPACITIES
- IN INDIA USED CONVENIENTLY UPTO 200 t.
- BEYOND 200 t. ONLY FEW EXAMPLES AVAILABLE
- ECONOMICS SHOULD BE CONSIDERED BEFORE ADOPTING THEM
- CAPABILITY OF MANUFACTURER

COMPONENTS

- HOISTNG COMPONENTS
- CENTRAL DIVE
- STRUCTURE
- OTHER ASSOCIATED PARTS

COMPONENTS

- HOISTNG COMPONENTS
- STEEL WIRE ROPES
- GROOVED OR PLAIN DRUM
- SETS OF OPEN GEAR REDUCTION
- SHAFTS
- COUPLINGS,BEARINGS,PLUMMER BLOCKS ETC.

COMPONENTS

CENTRAL DRIVE

- REDUCER
- MOTOR
- SHAFTS
- COUPLINGS,BEARINGS,PLUMMER BLOCKS ETC.
- BRAKES

COMPONENTS

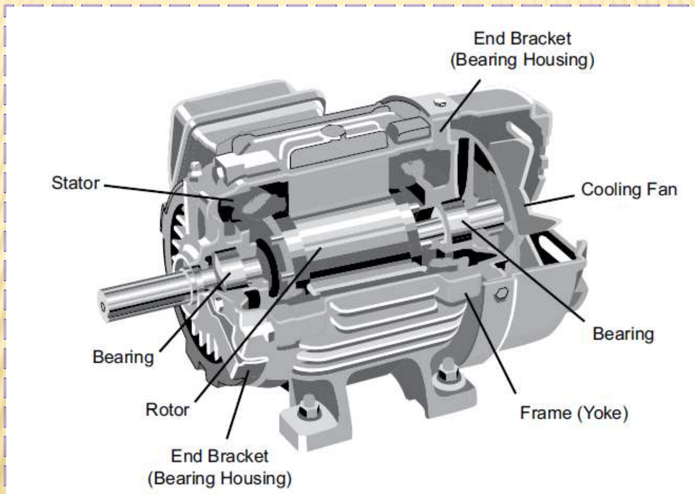
STRUCTURAL PARTS

- GEAR BOX CHAIR
- DRIVE UNIT STOOLS/BASE FRAMES
- HOIST BRIDGE
- GATE HOIST CONNECTION

OTHER COMPONENTS

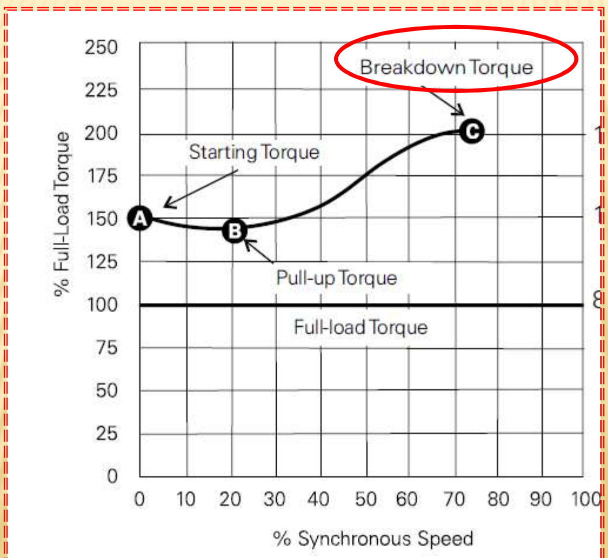
- GATE POSITION INDICATOR
- HAND OPERATION
- COVERS FOR DRIVE UNITS AND HOIST
- LADDERS,WALKWAYS AND GRATINGS

AC Motors



Cutaway View of Motor

AC Motors…



AC Motors…

- 3-phase induction motor is most widely used for modern industrial applications.
- Starting Torque: Starting torque, also referred to as locked rotor torque, is the torque that the motor develops each time it is started at rated voltage and frequency.
- Pull-up Torque: **As the motor picks up speed, torque decreases slightly until point B on the graph is reached. The torque available at this point is called pull-up torque.**
- Break-down Torque: As speed continues to increase from point B to point C, torque increases up to a maximum value at approximately 200% of full-load torque. This maximum value of torque is referred to as breakdown torque.

AC Motors…

- TEFC Motors are most commonly used for hydro mechanical equipments.

- TEFC (Totally Enclosed Fan Cooled) motors have external fan mounted opposite to drive end of the motor. The fan blows air over the motor’s exterior for additional cooling. The fan is covered by a shroud to prevent anyone from touching it. TEFC motors can be used in dirty, moist, or mildly corrosive environments.

AC Motors…

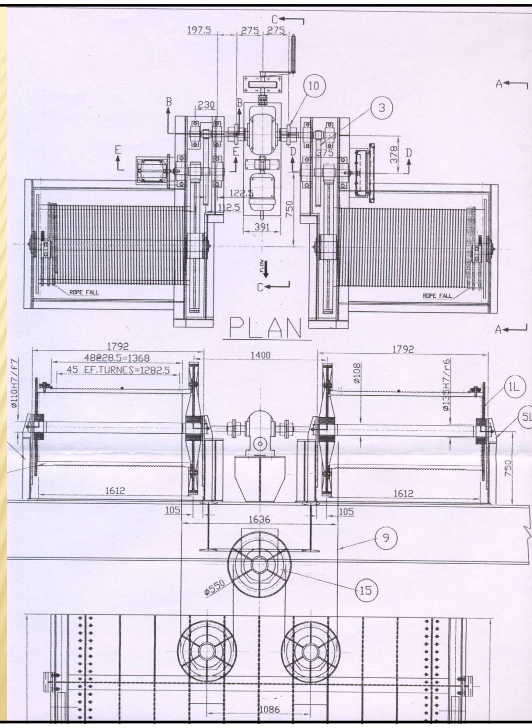
✓ **Squirrel cage induction motor**
- Not having rotor winding
- low Starting Torque
- can Not add external resistance
- Not having Slip ring brush
- self starting

✓**Slip ring motor**
- Having rotor winding
- High Starting Torque
- Add some external Resistance
- Having Slip ring brush
- easy starting

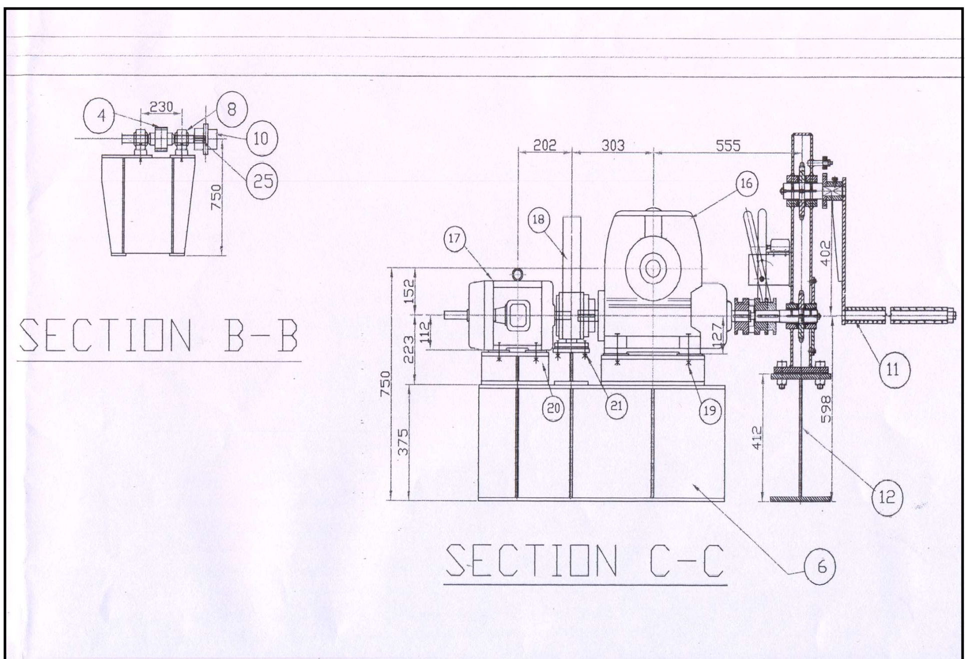
AC Motors…

Advantages of Squirrel Cage Induction Motor:

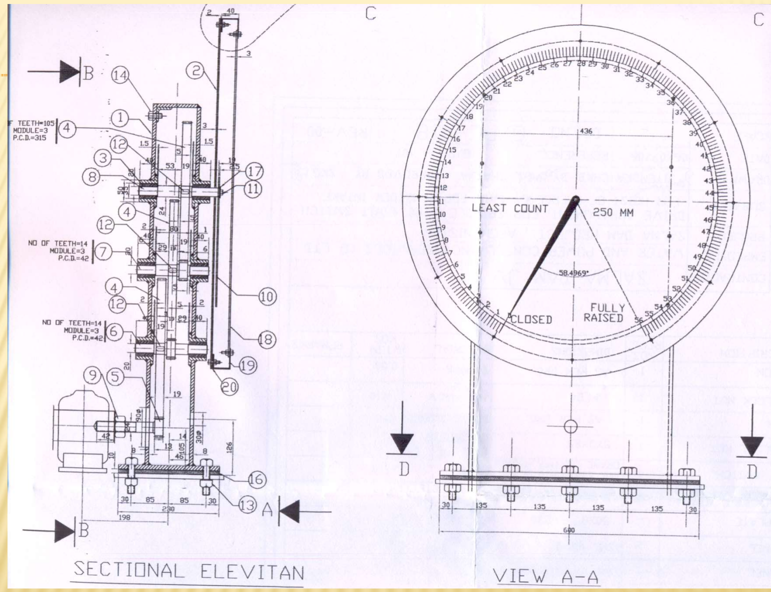
- Squirrel Cage Induction motors are *cheaper in cost* compared to Slip Ring Induction motors.
- Requires *less maintenance and rugged construction*. Because of the absence of slip rings, brushes maintenance duration and cost associated with the wear and tear of brushes are minimized
- Squirrel Cage Induction Motors requires less conductor material than slip ring motor, hence copper losses in squirrel cage motors are less results in *higher efficiency* compared to slip ring induction motor
- Squirrel cage motors are *explosion proof* due to the absence of brushes slip rings and brushes which eliminates the risks of sparking.
- Squirrel Cage motors are *better cooled* compared to slip ring induction motors
- Squirrel cage motors *operate at nearly constant speed*, high over load capacity, and operates at better power factor.



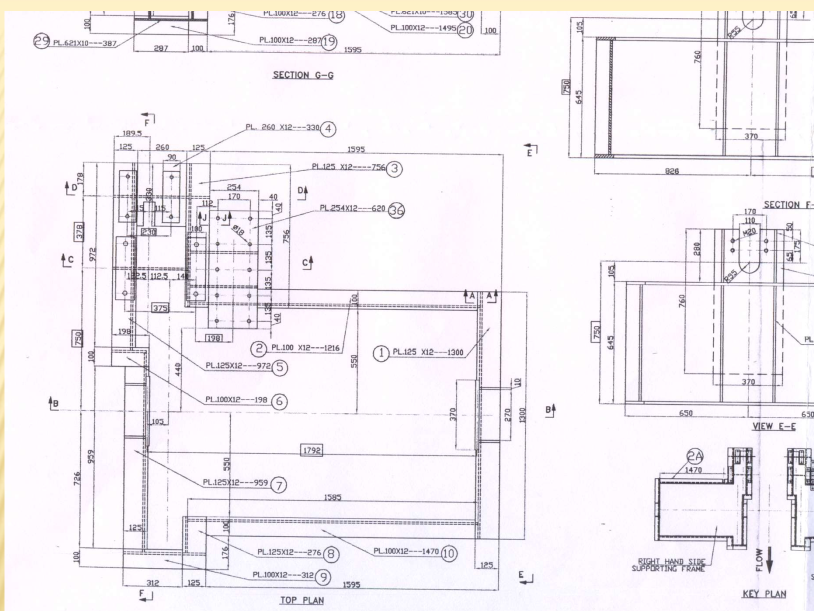
ARRANGEMENT OF ROPE DRUM HOIST FOR VERTICAL LIFT GATE



DRIVE UNIT ASSEMBLY OF A ROPE DRUM HOIST



POSITION INDICATOR OF ROPE DRUM HOIST



GEAR BOX BASE FRAME

MATERIALS FOR VARIOUS COMPONENTS

- MOTORS , REDUCERS& BRAKES:
  STANDARD AND RPLACEABLE MAKES
- SHAFTS:
  MILD STEEL, FORGED STEEL
- COUPLINGS:
  CAST STEEL OR CAST IRON

Contd....

MATERIALS FOR VARIOUS COMPONENTS

- ROPES:
  IMPROVED PLOUGH STEEL TO IS:2266
- DRUMS:
  CAST STEEL IS:1030
  MILD STEEL IS:2062
  CAST IRON IS:210
- OPEN GEARS:
  CAST STEEL IS:1030
  FORGED STEEL IS:1875,IS:2004,IS:1570 ETC.

Contd....

MATERIALS FOR VARIOUS COMPONENTS

- BEARINGS:

RUNNING SHAFTS : SPHERICAL ROLLER BEARINGS

DRUM SHAFT: SPHERICAL ROLLER BEARINGS OR BUSH

PLUMMER BLOCKS: CAST STEEL OR CAST IRON

BEARINGS: STANDARD AND REPUTED MAKES

BUSHING : IS:305

Contd….

MATERIALS FOR VARIOUS COMPONENTS

- OPEN GEAR REDUCTION:

GEARS:

CAST STEEL TO IS:1030

FORGED STEEL TO: IS:2004,1875,1570 ETC.

PINIONS:

SIMILAR TO GEARS BUT ONE GRADE HIGHER

DESIGN STANDARD

- DESIGNED IN ACCORDANCE WITH
  IS:6938.
  THIS STANDARD COVERS DETAILED GUIDELINES APPLICABE FOR THE DESIGN OF ROPE DRUM HOISTS FOR GATES IN WRD PROJECTS

STEPS FOR THE DESIGN OF ROPE DRUM HOISTS

- COMPUTE HOIST CAPACITY
  - GATE WEIGHT
  - BUOYANCY
  - FRICTION AT INTERFACES
  - HYDRODYNAMIC FORCES
  - SEATING LOADS
- FIND OUT ROPE TENSION
  - CONSIDER NO. OF "ROPE FALLS" PER DRUM
  - CONSIDER NO. OF PULLEYS OVER WHICH THE ROPE IS PASSING
  - CONSIDER PULLEY EFFICIENCIES OVER WHICH THE ROPE IS PASSING

STEPS INVOLVED.....

- ROPE TENSION IS GIVEN BY:

  $T=W\{(1-n)/(1-n^f)\}\ \{1/n\}$

  WHERE,

  W=HOIST LOAD PER DRUM

  n =EFFICIENCY OF PULLEY

  f =NO. OF ROPE FALLS PER DRUM
- SELECT ROPE DIA. WHICH GIVES FOS AS 6 FROM BREAKING LOAD CONSIDERATION AS PER IS:2266.

STEPS INVOLVED.....

- FIND OUT OVERALL RUNNING EFFICIENCY "E"

  (MULTIPLICATION OF INDIVIDUAL EFFICIENCIES)
- DETERMINE MOTOR H.P.

  CONSIDER HOIST CAPACITY

  LIFTING/LOWERING SPEED

  OVERALL EFFICIENCY BY FOLLOWING RELATIONSHIP:

  HP=(HXV)/(4.5XE)

  WHERE H= HOIST CAPACITY IN t.

  V=LIFTING SPEED IN m/min.

- SELECT MOTOR GIVING SUITABLE HORSE POWER AND ADOPT CHARACTERISTICS
  IN DESIGN OF REDUCTION ETC.
- DETERMINE BRAKING TORQUE FOR BRAKES:
  $B_{T=}$ (71620XHPX1.5)/RPM OF MOTOR
- DESIGN OF DRUM:
  FIND PCD > 20XROPE DIA.
  FIND CIRCUMFERENCE: C=ΠXPCD
  NO. OF GROOVES: =(LIFT OF GATE XNO. OF FALLS)/PCD+3
  PITCH OF GROOVES=ROPE DIA+n
  (n=1.5 mm UPTO 12 mm DIA.
  =2.5 mm FROM 12 TO 30mm DIA.&
  =3.0 mm ABOVE 30 mm DIA.

- DEPTH OF GROOVE=0.35XROPE DIA
- RADIUS OF GROOVE=0.53XROPE DIA
- FIND LENGTH OF DRUM BY ACCOUNTING TURNS
- FIND CRUSHING STRENGTH BY:
  C=(KT/Pt) WHERE K=A FACTOR AS PER IS:6938,T=ROPE TEN. IN Kg, P=PITCH IN cm ,
  t= THICKNESS OF SHELL IN cm AND C=STRESS IN Kg/Sq. cm
- DETERMINE BENDING STRESS σ BY CONSIDERING SELF WT. AND ROPE TENSION AT CRITICAL LOCATION
- COMBINE CRUSHING AND BENDING STRESSES
  $=\sqrt{(C^2 + \sigma^2)}$, WHICH SHOULD BE WITHIN PERMOSSIBLE LIMITS

DESIGN OF REDUCTION UNIT

- INPUTS REQUIRED AS UNDER:
  HOISTING SPEED :V
  DRUM CIRCUMFERENCE
  DRUM SPEED =NO. OF FALLS PER
  DRUMXV/CIRCUMFERENCE
  TOTAL REDUCTION REQUIRED=R
  =MOTOR RPM/DRUM RPM
- DISTRIBUTE 'R' IN REDUCER AND OPEN REDUCTIONS
- SELECT NO. OF OPEN REDUCTION SETS AND ADJUST TEETH TO SUIT DESIRED REDUCTION

OPEN GEAR REDUCTION

- DESIGNED AS PER IS:6938
- FIND TOOTH LOAD ON DRUM GEAR

= (RTx PCD OF DRUM)/(DRUM GEAR PCDx EFF.)

- ROOT STRESS= Pxq/fxm WHERE,
  P IS TOOTH LOAD,q IS STERNGTH FACTOR
  f IS FACE WIDTH AND m IS MODULE
- REPEAT ABOVE PROCEDURE FOR SUBSEQUENT REDUCTIONS

REDUCER SELECTION

- GENERALLY WORM OR HELICAL TYPE
- SHOULD HAVE INPUT HP SUFFICIENTLY HIGHER THAN MOTOR HP
- ASCERTAIN STARTING AND RUNNING EFFICIENCIES FROM CATALOGUE SUPPLIED BY MANUFACTURER

PULLEYS AND SHAFTS

- PULLEYS
- FITTED WITH BUSH OR ROLLER BEARINGS
- PREFERABLY OF CAST STEEL
- CONFORMING TO STANDARD FEATURES
- PCD MORE THAN 20xROPE DIA
- SHAFTS
- DESIGNED FOR MOMENTS AND TORQUES TRANSMITTED
- CHECKED FOR BENDING AND SHEAR DUE TO LOADS AND TORQUES
- CHECKED FOR EQUIVALENT BENDING AND TORQUE

DESIGN FOR SHAFTS

- BENDING STRESS=M/Z_{XX}
- SHEAR STRESS =SF/CROSS SECTIONAL AREA
- EQ. TORQUE Te = $\sqrt{(M^2+T^2)}$
- EQ. B.M. =1/2(Te+M)
- TORSIONAL SEAR=Te/ POLAR M.I.
- BEARINGS FOR SHAFTS
- SELECT STANDARD ROLLER BEARINGS OF REPUTED MAKE AS FAR AS POSSIBLE HAVING SUFFICIENT STATIC AND DYNAMIC LOAD CAPACITIES

CHECK FOR BREAK DOWN TORQUE

ALL HOIST COMPONENTS ARE CHECKED FOR THE LOADING RESULTING FROM BDT CONDITION OF THE HOIST MOTOR AS UNDER

- $(\text{MOTOR TORQUE})_{BDT=}$ HPX71620X(Tb/Tr)X(1/RPM)
  (Tb AND Tr ARE VALUES SPECIFIED BY THE MANUFACTURER OF MOTOR)
- TORQUE AT DRUM= $(\text{MOTOR TORQUE})_{BDT}$ X R X Nst., WHERE R IS REDUCTION AND Nst IS STARTING EFFICIENCY
- BDT ROPE TENSION= TORQUE AT DRUM/(2XDRUM RADIUS)
  (DIVIDED BY 2 FOR SYMMETRICAL DRIVE)

CHECK ALL HOIST COMPONENTS AS BEFORE FOR THIS VALUE OF ROPE TENSION

OTHER MISCELLANIOUS COMPONENTS

- FLOATING SHAFT FOR PERMISSIBLE TWIST
- STRENGTH OF PLUMMER BLOCKS
- CONNECTION OF DRUM AND DRUM GEAR
- COMPUTAION OF GRADUATIONS FOR POSITION INDICATOR AND ITS REDUCTION

END OF PRESENTATION

Thank You

Manufacturing and Erection

Structural steel fabrication for Hydro-mechanical equipments i.e Gates and Hoists can be carried out in shop or at the construction site. Fabrication of steelwork carried out in shops is precise and of assured quality, whereas field fabrication is comparatively of inferior in quality. In India construction site fabrication is very common in large projects due to inexpensive field labor, high cost of transportation, difficulty in the transportation of large members, higher excise duty on products from shop. Beneficial taxation for site work is a major financial incentive for site fabrication. However, fabrication of Hydro-mechanical equipments is generally carried out in Workshops due to the level of accuracy and precision required. If the same work is carried out at site the methods followed in site fabrication are similar but the level of sophistication of equipment at site and environmental control would be usually less. The skill of personnel at site also tends to be inferior and hence the quality of finished product tends to be relatively inferior. Further, shop fabrication is efficient in term of cost time and quality.

1.0 Sequence of activities in fabricating shops

Sequence of fabrication in shop is usually as under with a little variation:-

Sl No.	Sequence of Operations
1	Surface cleaning
2	Cutting and machining
3	Punching and drilling
4	Straightening, bending and rolling
5	Fitting and reaming
6	Fastening (bolting, riveting and welding)
7	Finishing
8	Quality control
9	Surface treatment
10	Transportation

1.1 Surface Cleaning

Structural sections from the rolling mills may require surface cleaning to remove mill scale prior to fabrication and painting. Hand preparation, such as wire brushing, does not normally conform to the requirements of modern paint or surface protection system. However in some applications manual cleaning is used and depending on the quality of the cleaned surface they are categorized into Grade St-2 and Grade St-3.

Blast cleaning is the accepted way of carrying out surface preparation in a well-run fabrication shop. Abrasive sand or steel particles are projected on to the surface of the steel at high speed by either compressed air or centrifugal impeller to remove rust and roughen the surface before applying the protective coating.

Flame cleaning is another method of surface cleaning. In this method the surface is cleaned using an oxy-acetylene torch which works on the principle of differential thermal expansion between steel and mill scale. In another method the steel piece is immersed in a suitable acid and the scale and rust are removed.

1.2 Cutting and Machining

Following surface preparation, dimensional marking & cutting to length is always the first process to be carried out. Cutting is done by any of the following methods:-

- Shearing and cropping by Hydraulic shears
- Flame Cutting or Burning
- Arc Plasma Cutting
- Cold Sawing
- Punching and Drilling

Most fabrication shops have a range of machines, which can form holes for connections in structural steel work. The traditional drilling machine is the radial drill, a manually operated machine, which drills individual holes in structural steelwork. But this method has become too slow for primary line production. Therefore, larger fabricators have installed NC (Numerically Controlled) tooling, which registers and drills in response to keyed in data. It is also possible to punch holes, and this is particularly useful where square holes are specified such as anchor plates for foundation bolts.

Rolled steel may get distorted after rolling due to cooling process. Further during transportation and handling operations, materials may bend or may even undergo distortion. This may also occur during punching operation. Therefore before attempting further fabrication the material should be straightened. In current practice, either rolls or gag presses are used to straighten structural shapes

Gag press is generally used for straightening beams, channels, angles, and heavy bars. This machine has a horizontal plunger or ram that applies pressure at points along the bend to bring it into alignment. Long plates, which are cambered out of alignment longitudinally, are frequently straightened by rollers. They are passed through a series of rollers that bend them back and forth with progressively diminishing deformation.

Misalignments in structural shapes are sometimes corrected by spot or pattern heating. When heat is applied to a small area of steel, the larger unheated portion of the surrounding material prevents expansion. Upon cooling, the subsequent shrinkage produces a shortening of the member, thus pulling it back into alignment. This method is commonly employed to remove buckles in girder webs between stiffeners and to straighten members. It is frequently used to produce camber in rolled beams. A press brake is used to form angular bends in wide sheets and plates to produce cold formed steel members.

1.3 Fitting and Reaming

Before final assembly, the component parts of a member are fitted-up temporarily with rivets, bolts or small amount of welds. The fitting-up operation includes attachment of previously omitted splice plates and other fittings and the correction of minor defects found by the inspector. In riveted or bolted work, especially when done manually, some holes in the connecting material may not always be in perfect alignment and small amount of reaming may be required to permit insertion of fasteners. In this operation, the holes are punched, 4 to 6 mm smaller than final size, then after the pieces are assembled, the holes are reamed by electric or pneumatic reamers to the correct diameter, to produce well matched holes.

1.4 Fastening Methods

The strength of the entire structure depends upon the proper use of fastening methods. There are three methods of fastening namely bolting, riveting and welding. A few decades back, it was a common practice to assemble components in the workshop using bolts or rivets. Nowadays welding is the most common method of shop fabrication of steel structures. In addition to being simple to fabricate, welded connection considerably reduce the size of the joint and the additional fixtures and plates. However, there is still a demand for structural members to be bolted arising from a requirement to avoid welding because of the service conditions of the member under consideration. These may be low temperature performance criteria, the need to avoid welding stresses and distortion or the requirement for the component to be taken apart during service e.g. bolts in crane rails or bolted crane rails.

1.5 Finishing

Gate structural members like roller tracks/ thrust pads and thrust bearings whose ends must transmit loads by bearing against one another are usually finished to a smooth even surface. Finishing is performed by sawing, milling or other suitable means. Several types of sawing machines are available, which produce very satisfactory finished cuts. One type of milling machine employs a movable head fitted with one or more high-speed carbide tipped rotary cutters. The head moves over a bed, which securely holds the work piece in proper alignment during finishing operation. The term finish or mill is used on detail drawings to describe any operation that requires steel to be finished to a smooth even surface by milling, planning, sawing or other machines.

1.6 QUALITY CONTROL IN FABRICATION

Quality assurance during fabrication of gate components assumes utmost importance in ensuring that the completed gate assemblies behaves in the manner envisaged during design stage. Any deviation from these design considerations as reflected in detail drawings may introduce additional stresses to the structure and affect its strength and durability. This may also affect the sealing performance of the gates.

In order to ensure that the fabrication can be carried out in accordance with the drawings, it is necessary that inspection and checking is carried out in accordance with an agreed Quality Assurance Plan (QAP). The plan should elaborate on checks and inspections of the raw materials and also of the components as they are fabricated, joined etc. For fabrication activities being carried the absence of controlled environment (as in an organized workshop), the quality of workmanship of such fabrication is likely to suffer. It has, therefore, become all the more important to motivate the fabricators to appreciate the usefulness of Quality Assurance Plans and introduce the system in all their works and at site as well.

1.7 Painting

The gates and hoist components are painted in accordance with provision of IS:11477 Following gates and hoist components are painted to protect them against corrosion:-

- Embedded parts,
- Gate leaf,
- Hoists and its supporting structures

Paints are applied during manufacture and during maintenance.

1.7.1 Surface Preparation:

Surface preparation shall include through cleaning, smoothing, drying and similar operation that may be required to ensure that the primer and or paint is applied on suitable surfaces. Weld spatters or any other surface irregularities shall be removed by any suitable means before cleaning. All oil grease and dirt shall be removed from the surface by the use of clean material spirits, Xylol or white gasoline and clean wiping materials. Following the solvent cleaning, the surfaces to be painted shall be cleaned of all rust, mill scale and other lightly adhering objectionable substances by sand blasting. Surface of stainless steel, nickel, bronze and machined surface adjacent to metal work being cleaned or painted shall be protected by making tape or by other suitable means during the cleaning and painting operations. Primers shall be applied as soon as the surface preparation is complete and prior to the development of surface rusting. In case there is considerable time gap, the surface shall be cleaned prior to priming.

1.7.2 Shop painting:

All embedded parts which come in contact with concrete shall be cleaned and given two coats of cement Latex to prevent rusting during the shipment while awaiting installation. Embedded parts which are not in contact with concrete and gate parts shall be given two coats of zinc rich primer with epoxy resin to obtain a dry film thickness of 75 microns, which shall be followed by two coats at an interval of 24 hours of coal tar blend epoxy resin part so as to get a dry film thickness of 80 microns in each coat. Total dry film thickness of paint shall be 300 microns.

The following surfaces are not to be painted unless or other wise specified

a) Machine finished or similar surface
b) Surfaces which will be in contact with concrete
c) Stainless steel overlay surfaces.
d) Surfaces in sliding or rolling contact
e) Galvanized surfaces, brass and bronze surfaces.
f) Aluminum alloy surfaces

All finished surfaces of ferrous metal including bolts, screw threads etc., that will expose during shipment or while awaiting installation shall be cleaned and given heavy uniform coating of gasoline soluble rust preventive compound or equivalent

1.7.3 Hoist and supporting structure:

A) Structural components

Primer coats of zinc phosphate primer shall be applied to give a dry film thickness of 40±5 microns. One coat of alkyd based micaceous iron oxide paint to give a dry film thickness of 65 ± 5 microns followed by two coats of synthetic enamel paint confirming to IS 2932 – 1974 to give a dry film thickness of 25 ± 5 microns per coat. The interval between each coat shall be 24hours.The total dry thickness of all coats of paint including the primary coat shall not be less than 175 microns.

B)**Machinery:** Except machined surfaces all surfaces of machinery including gearing, housing, shafting, bearing pedestals etc., shall be given one coat of zinc phosphate priming paint to give minimum film thickness of 50 microns. Motors and other bought out items shall be painted if necessary. The finished paint shall consists of three coats of aluminum paint confirming to IS2339 – 1963 or synthetic enamel paint confirming to IS 2932 – 1977 to give a dry film thickness of 25±5 microns to obtain a minimum dry film thickness of 125 microns.

1.7.4 Inspection and testing of painting

The following steps involved in inspection of painting are general inspection before and during painting

- Viscosity test of paints
- Thickness test – using Elcometer
- Inspection of general appearance of finished work.

The aim of inspection and testing is to ascertain whether the recommended practice is being employed during every stage of application and whether the final results fulfill the object of painting, inspection therefore means a close supervision while the work is in progress. Any test carried out should be non – destructive nature or, if of destructive nature, should be either restricted to areas which can be restored without marring the general appearances, or be such that it is possible to restore easily without necessitating a complete repetition of the work.

When inspecting general painting work while in progress, it should be ensured:

- That painting follows immediately after pre cleaning or pre treatments; that any contamination which may occur in the interim period is removed, that special precautions are taken when painting after galvanizing;
- That no painting is carried out when there is danger of dew;
- That tools used are clean and not excessively worn;
- That the paint in the drums is thoroughly mixed prior to application; that drums are inspected to make sure that no sediment is left in them;
- That if paint has thickened because of long storage or because of the evaporation of the solvents, its viscosity is adjusted as recommended by the paint manufacturer;
- That each coat is allowed to dry sufficiently but not excessively before applying the following coat; that manufacturer's instructions for drying time are adhered to properly; and
- That every individual coat is properly applied, reasonably level and smooth and free from runs and 'holidays' (minute uncovered areas).

2.0 ERECTION

General:

Erection of gates, embedment and hoist machinery and structure is the process by which the fabricated structural members are assembled together to form the skeletal structure. The erection is normally carried out by the erection contractor. The erection process requires considerable planning in terms of material delivery, material handling, member assembly and member connection. Proper planning of material delivery would minimize storage requirement and additional handling from the site storage, particularly heavy items. Erection of structural steel work could be made safe and accurate if temporary support, false work, staging etc. are erected. Before erection the fabricated materials should be verified at site with respect to mark numbers, key plan and shipping list. The structural components received for erection should be stacked in such a way that erection sequence is not affected due to improper storing. Care also should be taken so that steel structural components should not come in contact with earth or accumulated water. Stacking of the structures should be done in such a way that, erection marks and mark numbers on the components are visible easily and handling do not become difficult. It is emphasized that safe transportation of fabricated items to the site, their proper storage and subsequent handling are the pivotal processes for the success of fabrication of structural steel work

As seen from the past executed projects, the accuracy and high quality of civil construction and erection of embedded metal parts plays predominant role in safe, satisfactory and trouble free erection and subsequent smooth operation of the hydro-mechanical equipments.

2.1 Sequence of Activities during Erection

- Receiving material from the shop and temporarily stacking them, if necessary.
- Lifting and placing the member and temporarily holding in place.
- Temporarily bracing the system to ensure stability during erection.
- Aligning and permanently connecting the members by bolting or welding.
- Connecting cladding to the steel structural skeleton.
- Application of a final coat of painting

3.0 Welding

Metal arc welding is the most widely used welding process for the fabrication, installation and erection of embedment, gate leaves and hoists. The main features of this process are as follows:

- Immediate heating.
- Depth of fusion and heating is fixed by electrode type size and current and can be controlled somewhat but not closely, by the operator.
- Nearly all metals can be welded.
- Welding can be carried out in all positions.
- Wide range of thickness can be welded.

The welding process involve:

- Preheating: Reduces stress and distortion
- Preparation for welding: Comprises cleaning the weld surface
- Welding: Requirement of proper welding technique
- Post heating: To reduce residual stresses in metal

Precautions for quality welds

Each bead and layer shall be thoroughly cleaned of all slag and spatter before the next bead or layer is deposited. Welds shall be free from cracks, tears and gross porosity. Defective welds shall be removed by gauging, chipping or grinding and the joint re-welded. Where complete penetration welds are to be welded from both sides, the root of the first side welded shall be gauged to sound metal before the second side is welded .When welding in the vertical position, the progression shall be upwards for all passes.

3.1 Welding defects ,causes and types

Normal welds always contain minute slag inclusions or porosity as revealed in non – destructive testing. Such small imperfections which cause some variations in the normal average properties of the weld – metal are called discontinuities. When discontinuity is large enough to affect the function of the joint, it is termed as defect and are caused due to :-

- Substandard welding consumables.
- Inefficient workman ship.
- Lack of cleanliness.
- Un-favourable properties of the base metal.
- Low ambient temperature and humid atmosphere.

Following defects are normally found :-

Incomplete Penetrations:- This defect occurs at the root of the joint when the weld metal fails to reach it or weld metal fails to fuse completely with the root faces of the joint. As a result, a void remains at the root zone which may contain slag, inclusions. In a fillet weld, poor penetrations at the root zone can give rise to cracking of single butt weld. In a weld adequate root penetration is ensured by size of electrode .sufficiently high current and directing the arc towards the root during deposition of the root pass..Rectification of this defect is a very costly proposition because it requires removal of the entire thickness of the weld and re welding.

Lack of Fusion :- . Lack of Fusion : Lack of fusion is the poor adhesion of the weld bead to the base metal and caused due to scale ((rusting),dirt, Oxide, slag and other non metallic substances which prevent the underlying metal from reaching metallic temperature. It can be prevented by Keeping the joint surface clean adequate welding current.

Undercut :-

Undercutting is when the fillet weld reduces the cross-sectional thickness of the base metal, which reduces the strength of the weld and work pieces. This defect is usually caused by :

- Excessive welding current
    - Too high speed of arc travel
    - Wrong electrode angle or excessive side manipulation
    - Also causes due to damp or improperly formulated electrodes.

Note :In the case of statically loaded structures the presence of small and intermittent under cutting will reduce fatigue endurance of the welded joint and hence it should not be permitted.

The defect is rectified by filling up the under cut groove with weld pass. If under cut is deep and contains slag, it should be clipped away before re --welding. If the rectification being carried out on thick joints and on high tensile steels, the welding procedure including pre heating should correspond to the recommended procedure for particular steel.

Over lap :-The defect occurs at the toes of weld and consists of weld – metal which has over flowed on the base metal surface without actually fusing to later. It can be isolated intermittent or continuous. It occurs more often in fillet welds and results in an apparent increase in the weld size.

Causes :

- It is occurred by an incorrect manipulation of the electrode, where by the weld metal flows away from the fusion zone.
- Use of too large an electrode in relation to the welding position, and excessive current coupled with a too low welding speed also promote its occurrence.
- When a single – pass fillet larger than 7.5mm in leg length is made in the horizontal position, the molten metal tends to sag and causes overlapping in at the toe of the horizontal member.

Rectification :

Slight and intermittent over lapping may be ignored in statically loaded structures, but it should not be permitted in dynamically loaded structure as over laps act as stress–raiser. Overlap is rectified by grinding, chipping or gouging out the excess infused weld metal. Care should be taken to leave the smooth surface.

Slag Inclusions :- Slag inclusions are detected by the normal non destructive testing methods. While non – metallic inclusions are observed in the weld micro structure at high magnification.

Non metallic particles of comparatively large size entrapped in the weld metal are termed as slag inclusion.Slag inclusions usually occurs in multi pass weld due to imperfect cleaning of the slag between the disposition of successive passes. It may also be caused by heavy mill scale, loose rust, dirt, grit and other substances present on the surface of base metal. Slag trapped in under cuts or between uneven preceding runs may give rise to elongated lines of included slag when a subsequent weld pass is deposited.

The melting characteristic of the welding consumables and particularly the viscosity of the rusting slag has an important bearing on inclusion. The molten slag should float freely to the surface of the weld pool and easily removable on solidification.It results in loss of strength and hair line cracks

Prevention :

- Use proper welding consumables.
- Keep joint surfaces (especially gas cut surfaces) and bare filler wires perfectly clean and clean the base metal thoroughly before welding.
- Avoid under cuts and gaps between deposited perfectly clean and clean the base metal thoroughly before welding.
- Avoid under cuts and gaps between deposited passes.
- Clean the slag thoroughly between weld passes.

Porosity :-The presence of a group of gas pores in a weld caused by the entrapment of gas during solidification is termed as Porosity.The pores are in the form of small spherical cavities either clustered locally or scattered through out the weld deposit. Sometimes entrapped gas gives rise to single large cavity, which is termed as a blow hole. In some rarer cases, elongated or tubular gas cavities are presented. These are referred to as piping or worm holes.

The gases are evolved by the chemical reactions in the welding and these gases may have high solubility in the molten weld metal, but as the metal solidifies and cools, their solubility decreases rapidly and they are released from the metal. Sometimes if the weld metal solidification and cooling is too rapid, the gas gets entrapped in the form of Porosity.

Causes :

- Chemically imperfect welding consumables for example deficient in deoxidizers
- Faulty composition of the base metal or electrode wire for example, high sulphur content.
- Oil, grease moisture and mill scale on the joint surface.
- Excessive moisture in the electrode coating or submerged – are flux.
- Inadequate gas shielding or impure gas in a gas shielded process.
- Low welding current or too long an arc.
- Quick freezing of the weld deposit.

Puddling of the weld metal and use of preheat or higher current allow sufficient time for the dissolved gases to escape from the weld metal. Presence of small, finally dispersed porosity is normally not expected to affect the static and even dynamic properties of a welded joint. However excessive porosity blow holes or piping must be guarded against as they seriously impair these properties. Their presence is detected by the conventional NDT methods. The defective portions must be removed and re-welded.

Cracks : -Crack is defined as a discontinuity caused by the tearing of the metal while in a plastic condition (hot crack) or by fracturing of the metal when cold (cold crack). Hot cracks are those that occur at elevated temperatures and are usually solidification related. These cracks occur at temperatures above 540°C and when observed under the microscope are seen to have traveled across the boundaries between the grains (inter granular). If the cracks has extended to the surface, the fractured surface is found to be coated with the blue scale or possibly black scale. Cold cracks are those that occur after the weld metal has cooled to room temperature and may be hydrogen related. Most forms of cracking result from the shrinkage strains that occur as the weld metal cools. Cracking can occur in the weld metal, at the fusion line or in the base metal.

3.2 Post Weld Fabrication Difficulties

Welding Distortions

When laying a weld bead, filler metal is deposited at a high temperature above the melting point of material. This is approximately 1,370 deg C for steel. The weld wants to shrink as it cools to room temperature, but is restrained from doing so by the adjacent cold base metal. This restraint creates high-residual tensile stress that causes the weld to act like a stretched rubber band, with the work piece holding the ends.For this reason, when the clamps that hold the work piece are removed the base metal is allowed to move (or spring back) the part is distorted. Thinner material is more susceptible to this because it has less stiffness. Stainless steels are also more susceptible because they have greater thermal expansion and lower thermal conductivity than carbon steels.

How to manage fabrication distortions

A full awareness of distortion is vital to all concerned with welding including the designer, detailer, factory foreman and the welders, as each in their actions could cause difficulties through lack of understanding and care. Weld sizes should be kept to the minimum required for the design in order to reduce distortional effects; in many cases, partial penetration welds can be used in preference to full penetration welds, deep penetration welds in preference to ordinary fillet welds. Some distortional effects can be corrected, but it is much more satisfactory to plan to avoid distortion and thereby avoid the difficulties and costs of straightening and flattening to achieve final acceptability.

Control of distortion

These can be avoided by taking following steps:-

- Avoid overwelding. The bigger the weld, the greater the shrinkage: correctly sizing a weld not only minimizes distortion, but also saves weld metal and time.
- Intermittent welding. Use intermittent welds instead of continuous welds where possible to minimize the amount of weld metal.
- Fewer weld passes. Because shrinkage accumulates from each weld pass, a fewer number of big passes results in less distortion than a greater number of small passes with small electrodes.
- Place welds near the neutral axis, or the center of the part. Reduce warpage by providing less leverage for the shrinkage forces to pull the plates out of alignment.
- Balance welds around the neutral axis. Welding on both sides of the plate offsets one shrinkage force with another, to minimize warpage
- Use the backstep welding technique. The general progression of welding in this technique may be left to right, but each bead segment is deposited from right to left .

- All members that are welded will shrink in their length, so each member will either be fabricated over-length and cut to length after welding, or an estimate of shrinkage will be added to anticipate the effect during the fabrication of the member.

- For the control of angular distortion and bowing, there are two methods of control that can be considered if the distortion is likely to be of significance :

Pre-setting. The section is bent in the opposite direction to that in which it is expected to distort and welding is then carried out under restraint. When cool, the clamps are removed and the section should spring straight. Trials and experience can determine the extent of pre-bend for any particular member.

Clamping. The units are held straight by clamps whilst the welding is carried out, which reduces the distortion to tolerable amounts.

- Thermal stress relieving. Another method for removing shrinkage forces is thermal stress relieving, i.e., the controlled heating of the weldment to an elevated temperature, followed by controlled cooling.
- Peening. Peening the weld bead stretches it and relieves the residual stresses. But peening must be used with care. For example, a root bead should never be peened because of the increased risk of concealing or causing crack.
- Peening on the final pass is not permitted because it can cover a crack and interfere with visual inspection.

4.0 Other Issues in Fabrication

- Non availability of standard steel material

  The non-standard steel plates may be undersize (thickness-wise) , may lack sufficient carbon content, rendering the material dangerously brittle; and may fail in tension tests.

- Delay in importing items such as bearings etc.

  It occurs due to delay in order placement, items being non standard, strikes or traffic congestion at ports. It causes fitment delays in assemblies

- Inadequate or lack of facilities for stress relieving in the shop / site etc.
- Lack of machines of desired ratings and capabilities etc.

- Lack of Inspection and quality monitoring mechanism at shop floor.
- Strikes of labourers
- Lack of inspection or quality monitoring instrumentations at shop or site.
- Non availability of skilled man power.
- Outsourcing of job to other contractors resulting in comprise of quality.
- Change in design during the progress of work etc.

5.0 Problems faced during erection of hydraulic gate & its components

- Accessibility of site where erection is proposed. Presence of railway bridge & road bridge causes hindrance of projects
- Carrying of various gate and its components assemblies to the erection site due to water way between road and the site of erection.
- Limited capacity of gantry crane for material handling etc.
- Lack of catwalk bays, stairs, rungs, ladders etc
- Distance between work space and storage yard may cause delay
- Limited access in tunnels possess difficulties in movement of gate components
- Lack of infrastructure facilities at Project site like storage yard, roads, markets, hospitals etc.
- Lack of infrastructure facilities from contractors like consumables welding rods, grinding wheels, gas cylinder, gas cutters, lubricants etc.
- Administrative delays from Project Authority for contractor's material and machinery induction , labour permit renewals, various inspections .
- Problems due to delay in timely payments.
- Lack coordination with other contractors.
- Lack of working space.
- Unavailability of tower/mobile cranes.
- Removal of additional equipments, reinforcements etc

- Simultaneous working with various civil contractors
- Lack of material handling equipment with the contractor.
- Natural barriers resulting in inaccessibility.
- Weather like rainy season, monsoon season etc.
- Accidents and diseases leading to lack of motivation in the workers
- Interferences or disturbance of already work done i.e. taking support, welding, damaging scaffolding, insulations etc.
- In foreign country, customs clearance takes time
- Hampering of work due to blasting etc wastage of time during transportation of materials etc.
- Reference axis and bench marks availability.
- Time of flood occurrence and max. flood level to decide the location machinery and parts to be placed.

OPERATION AND MAINTENANCE
OF GATES AND HOISTS

1.0 General:

Proper maintenance of Hydraulic gates and hoists is very important for satisfactory operation of Gates and to achieve the envisaged benefits from the project. For systematic operation and maintenance of the gates and their operating equipment, the availability of comprehensive Operation and Maintenance manual for the equipment is essential.

2.0 O&M Manuals

The O&M Manuals for Hydraulic gates and hoists normally should include the following :-

- The design features of various components.
- Particulars of bought-out items and source of availability with addresses and phone Nos.
- Operating instructions.
- Type of lubrication oil and grease to be used and its availability.
- Schedule of maintenance and repairs.

The above are prepared for each hydraulic gate installation and the operation staff shall be made well conversant with them and trained for the job.

3.0 Need for Maintenance

Gated structures need regular maintenance with inspection and monitoring. If faithfully followed under competent management, structures can give totally reliable service long after their initial designed life cycle. For proper maintenance, the steel structures must be periodically inspected.Failure of gates in most of the cases happens due to:

- Non-judicious choice of factor of safety at design stage to account for unforeseen forces.
- Loss of cross-section and strength of members due to near absence of preventive maintenance program.

Corrosion is the biggest culprit causing loss of cross-section of gate components and thereby reducing load carrying capacity of members. Corrosion implies destruction of metal by electro-chemical or simple chemical action.

In order to prevent long term structural damage, corrosion must be controlled through a program of inspection, evaluation and preventive maintenance. Corrosion being the primary reason of gates failure shall be focus of preventive methods adopted to prolong the economic life of steel structural components. There are various detectors like ultrasonic equipment, magnetic crack detectors, nuclear flow detectors and X-Ray detectors which can show the depth of corrosion damage, but the extent to which the tensile strength has been reduced by corrosion could only be found by subjecting an existing piece to various laboratory tests. Rust is permeable to air and water, therefore the interior metallic iron beneath a rust layer will continues to corrode. Rust prevention thus requires coatings that preclude rust formation.

4.0 Operation and Maintenance of Gates and Hoists

The list of parts involved in maintenance and operation of gates and hoists generally are as follows:

4.1. Vertical Lift Gates:

i. Embedded parts:

- Sill beam assembly
- Roller track
- Seal seat / Upstream Guide
- Top seal seat and side guide
- Dogging arrangement

ii. Gate Parts:

- Skin plate Assembly
- End Verticals or End box
- Horizontal girders
- Vertical Stiffeners
- Roller assembly
- Seal Assembly
- Side guide assembly

Iii. Lifting Arrangement

4.2. Radial Gates :

i. Embedded Parts:

Common anchorages (Bonded Anchorages)	Independent anchorages (Un-bonded Anchorages)
▪ Sill beam Assembly ▪ Wall plate Assembly ▪ Horizontal Anchor Rods ▪ Trunnion Girder ▪ Trunnion girder chairs ▪ Thrust block (If tie between trunnion is not used)	▪ Sill beam assembly ▪ Wall plate assembly ▪ Anchor girders ▪ Load Anchors / Tie flats ▪ Yoke girders ▪ Rest plate • Thrust block (If tie between trunnion is not used)

ii. Gate Leaf

Common anchorages (Bonded Anchorages)	Independent anchorages (Un-bonded Anchorages)
▪ Skin plate ▪ Side guide and seal assembly ▪ Vertical stiffeners ▪ Horizontal Girders ▪ Horizontal Girder Bracings ▪ Arm Assembly ▪ Trunnion ▪ Trunnion pin ▪ Trunnion Bush ▪ Trunnion Bracket ▪ Tie between trunnion or ▪ Thrust block ▪ Lifting Bracket	▪ Skin plate ▪ Side guide and seal assembly ▪ Vertical stiffeners ▪ Horizontal Girders ▪ Horizontal Girder Bracings ▪ Arm Assembly ▪ Trunnion ▪ Trunnion pin ▪ Trunnion Bush ▪ Trunnion Bracket ▪ Tie between trunnion or ▪ Thrust block ▪ Lifting Bracket

4.3.Rope drum Hoists:

A. For Vertical Lift Gates :

- Drive Unit Assembly
- Gear Box Assembly
- Hoist Supporting structures etc.

B. For Radial Gates :

Upstream Suspension	Down Stream Suspension
▪ Drive Unit Assembly ▪ Gear box assembly ▪ Hoist bridge ▪ Lifting arrangement	▪ Drive unit assembly ▪ Gear box assembly ▪ Fixed end support ▪ Hoist chasis ▪ Line shaft support girder ▪ Dial and Dial Assembly etc.,

5.0 Operation and Maintenance Schedule& Checks

Operating personnel are required to be properly trained and sufficiently experienced so that they can use their initiative and judgment based on their past experience for situations which may arise during operation. Day to-day experience on operation and difficulties if any, encountered should be faithfully recorded in the log book of gates so as to be available for studying the behavior of various structures and equipment. Detailed instructions for inspection and normal maintenance and repairs of gate installation should be given in operation and maintenance manual. However, for carrying out special repairs to gates if any, it is advisable to refer to Experts to execute. Inspection and maintenance experience are compiled in the form of History register of any installation so as to be useful for future designs, investigation of any failure, improper and unusual operation of gates. All such observations shall be recorded in the gates History register maintained for this purpose.

Once the gates have been erected, following precautions/ checks are to be taken before Dry - testing of Gates. The dry testing of the gates is normally done before the wet testing and during dry testing the gate is not subjected to any hydro static loading:

- Checking of all critical dimensions and proper seating of gate over embedded parts is to be ensured. Record of readings may be maintained for future reference.

- Worm reducer, plumber blocks, trunnion pin, gate wheels and gear wheels should be lubricated.

- Removal of temporary supports if any.

- Checking of weld between horizontal girders, arms and trunnions, tees and horizontal girders, cross girders and hoist bridge girders, final welding of lifting bracket etc., and are to be welded if left over. A comprehensive check list is to be maintained.
- Checking tightness of bolts between trunnion with arms and trunnion with horizontal girders, lock plate bolts of trunnion pin, wire rope clamp bolts and other bolts if used are to be tightened properly if loose.
- In case of unbounded anchorage one has to ensure the expansion of tie flats and yoke girder under load.
- The gates are to be inspected thoroughly for projections, temporary supports coming in the way of gate movement and excess concrete are to be removed if any.
- All the rubber seals are to be made wet before lowering the gate preferably with water to reduce heat generated between seal and seal seat and ensure fixing of all bolts and mouldings of site joints.
- Light test may be conducted for checking gap between seal and seal seat.
- All weld tests are to be conducted.

5.1Maintenance schedules for gates and hoists

(A)Radial Gates

Monthly maintenance:

- Seals and seal seating shall be inspected for leakages. Locations of excessive leakages shall be recorded for taking remedial measures.
- Excessive or wide spread leakages if any shall be reported to Engineer – in – charge and remedial measures like tightening of bolts is to be carried out. Further adjustment is carried out during annual maintenance or necessary plan for replacement of parts shall be initiated and carried out before floods.
- If leakage is so much that immediate repair is to be considered and seals are to be repaired or to be replaced by using stop log gates.
- Remove all dirt, girt, etc., from trunnion assembly and lubricate trunnion bearings of the gate with suitable water resisting grease.
- More concentration is to be given for checking of welds :
    - Between yoke girder web and tie flats.

- Between trunnion and tie between turnnion.
- Lifting bracket and gate.

Quarterly Maintenance:

The maintenance shall preferably be carried out once in three months but not less than thrice in a year including pre- monsoon and post monsoon maintenance. During this maintenance the following checks shall be done .

- All the nuts and bolts of trunnion assembly and its anchorages shall be checked for tightness.
- Check all the welds for soundness and rectify defects; if any.
- Check welding between latching bracket and skin plate with help of magnifying glass for cracks / defects and rectify the defects.
- Clean all drain holes including those in end arms, horizontal girders trunnion and pulley blocks.
- Check all nuts and bolts for tightness and tighten them; if loose.
- Check upstream face of skin plate for pitting, scaling and corrosion. Scale formation shall be removed, pitting shall be filled with weld and ground, and Corroded surface shall be cleaned and painted. In case of gate not being raised every quarter, these can be carried out in annual maintenance.
- The wheel bearings and guide rollers shall be lubricated.
- The seal shall be checked for damages, if damaged, shall be replaced.
- The guide assemblies, wheel assemblies and sealing assemblies shall be cleared of girt, sand or any other foreign material.
- General cleaning is to be done for the following :

✓ Trunnion girders / Yoke girders.
✓ Trunnion brackets, trunnions, arms and horizontal girders.

- Lubrication is to be attended for :

✓ Bearings at Gate wheels, trunnion bushes, hoist pulleys and pins provide in Hoist Bridge at hoist level and gate.
✓ Rope drum shaft Plummer blocks.
✓ Line shaft Plummer blocks.

- Check tightness of all coupling bolts of motor to work reducer and line shaft. If required they may be tightened.
- Care shall be taken to check the condition of holding rope with rope socket and balancing of gate is to be observed and if necessary adjusted.

<u>Annual maintenance:</u>

The following additional checks or maintenance shall be carried out in addition to checks mentioned under quarterly maintenance.

- All the embedded parts shall be checked for defects / damages and shall be rectified where ever noticed and exposed parts shall be painted for longer life.
- The sill beam and guides shall be cleared for all girt, sand etc.,
- The wire ropes shall be checked for equal tension. If broken strands are noticed, the wire rope shall be replaced. Fixing of rope sockets also shall be checked.
- The wire rope shall be greased.
- The guide roller pins shall be lubricated and ensure for its rotation.
- Check the condition of rubber seal. If damaged, replace the seals.

All bolts and nuts holding rubber seals shall be tightened. Adjust seal if leakages are found at local points

(B) Vertical Lift fixed wheeled

These gates are provided for controlling water discharge for flood control, water supply, irrigation and power generation etc., The gates shall be thoroughly inspected for cracks, defects or damages periodically. A schedule of maintenance is proposed which may be adopted with modifications, if required, to suit site conditions and use of gate.

<u>Monthly maintenance:</u>

- Wheels are to be greased properly.
- Check wheel rotation by hand for free rotation.
- Balance points same as Radial Gates

Nature of Quarterly Maintenance and Annual Maintenance for vertical lift gates is same as for Radial gates and the re-painting of the gates shall be carried out at intervals to be decided on the basis of painting schedule of the gates. Similarly, the inspection, testing and maintenance of the hoist shall also be carried out periodically as per the maintenance manual.

For installation with large number of gates ie., more than 10Nos. it is very difficult to take up maintenance in one go in the lean period available. Hence the No. of gates divided into 3 groups and thorough maintenance of welding, painting shall be carried out at least one in three to five years depends on requirement

(C) Electrically Operated Fixed Hoists for Radial Gates and Vertical Gates

The periodical maintenance of bought out items like motor, brakes, radicons, etc., shall be carried out as per the manufacturer's advice / maintenance schedule.

<u>Daily Inspection :</u>

- Entrance to all hoist platforms shall be kept locked. All keys shall remain with the shift supervisor.
- A cursory daily inspection shall be made of hoist and gate to ensure that there is no unusual happenings and **ensure operation when called for.**

<u>Monthly Maintenance:</u>

- Clean the dust of all hoisting machinery and hoist platform.
- Check oil level in gear boxes and replenish wherever required with oil of proper grade.
- Apply grease of suitable grade by grease gun through all the greasing nipples and replace grease nipple if missing.
- Lubricate all bearings, bushings, pins, linkages, etc.,
- Check all the fuses on power lines and ensure closing of panel board covers not to entry of dust and moist.
- All bolts and nuts on gear boxed, hoist drum and shaft couplings should be checked for tightness.
- Check the supply voltage.
- Check the expansion provision in case of independent anchorages.
- Starters should be cleaned free of moisture and dust.

- Each individual contactor should be examined to make sure that it operated freely.
- All wearing parts should be examined and take remedial action to avoid reoccurrence.
- The magnet faces should be cleaned if the contacted Hum.
- Examine all connections to se that no wires are broken and no connections are loose.
- Clean the surface of the moving armature and magnet cone which comes together when the contractor closes, free of dust or grease of any kind.
- The contact tips should be kept free from burns or pits by smoothening with fine sand paper or emery paper.
- Replace the contact tips which have worn half – way.
- Do not lubricate the contacts.
- Quarterly Maintenance:
- Carry out all those listed for monthly maintenance.
- Drain sample gear oil from each of the gear boxes; If excessive
- Foreign particles or sludge is found, the oil shall be drained, flushed and filled with new oil.
- All the geared couplings shall be greased.
- Raise and lower the gate by hoist motor and check for smooth and trouble free operation of gate without excessive vibration.
- Observe current drawn by motor at the time of lifting and check if it is more than normal. If so, stop the hoist and investigate the cause and rectify.
- Check for condition of painting of various components and remove rust wherever noticed and repaint the portion after proper cleaning as per painting schedule.
- Check Electrical connection and wiring:

a. From supply point to main switch.

b. Main switch to starter.

c. Starter to motor.

d. Contact points of starter.

e. From starter to all lighting points, availability of bulbs and its glowing.

Annual Maintenance:

- The annual maintenance shall be combined with one of the quarterly maintenance; the following shall be carried out in addition to those mentioned under Quarterly Maintenance.
- All trash, sediments and any foreign material shall be cleared off the lifting rope and lifting attachment.
- All ropes shall be checked for wear and tear and if broken wires more than permissible or marked corrosion is noticed, the rope shall be replaced. Refer IS code for maintenance of wire ropes.
- All wire ropes shall be checked and all visible oxidation shall be removed.
- All wire ropes shall be greased with cordium compound or equivalent brand.
- Adjust the rope tension of wire if unequal.
- Check the overload relays and limit switches for proper functioning.
- Check tightens of all nuts & bolts, soundness of welds. All bolts shall be tightened and defective welding must be rectified.
- Check the pulleys, sheaves and turn buckles for soundness.
- Check the limit switches and adjust for design limits duly operating.
- The effectiveness of the brakes shall be checked by stopping the gate in intermediate operation duly raising and lowering operations. The brakes shall be adjusted; if needed.
- When the gate is operated, there should not be any noise or chatter in the gears.
- Check for all gears and pinions for proper mesh, uneven wear and adjust for proper contact and grease the gears.
- Repaint the hoist components, hoisting platform and its supporting structures after a time interval depending upon the painting schedule.

5.2 General maintenance on Radial Gates / Vertical Gates

It shall be done every third and sixth years in accordance with IS7718, IS: 10096 (part 3) latest. In addition to check mentioned under annual, following checks will be carried out:-

(A) For every three years:

- Check seals for damage and alignment;
- Check seal bolts for damage;
- Check for damage to wire rope;
- Check for any damage to pulleys and pins;
- Check bearings for damages;
- Check gears and pinions for damage;
- Check Plummer blocks for damage;
- Check for any painting damage.

(B) For every Six years:

In addition to check mentioned under annual, following checks will be carried out every six year.

(a) Check for damaged / cracked welds at the following:

a. Skin plate joints
b. Splice joints
c. Hoist bridges
d. Arms, Horizontal girders and bracings
e. Tie flats
f. Trunnion girders / Yoke girders
g. Trunnion brackets
h. Tie between trunnion

(b) Check Wheel assemblies for the following:

a. Any breakage
b. Freezing
c. Corrosion
d. Misalignment

(c) Check seal seats, seal tracks, side guides for the following:

a. Any damages
b. Corrosion
c. Pitting
d. Misalignment

(d)Check Hoist Bridge and Platforms

a. For any welding cracks
b. Bent or loose bolts and nuts
c. Cracks in the bending or motors
d. Rope drum etc.,

5.3 Lubrication Schedule for gates and Hoists

Sl. No.	Parts to be lubricated	Mode of Lubrication	Lubricant	Frequency
1	Trunnion pin bush bearing	Pressure grease gun	Servo gear – 20 or bearing grease	Once in three months as per site conditions
2	Gate Wheel bearings	Pressure grease gun	Servo Gear – 20 or Bearing Grease	Once in three months as per site conditions
3	Guide rollers	Pressure grease gun	Bearing Grease	Once in three months as per site conditions
4	Hoisting wire rope	Hand applied	Servo Gear – 120 or Cordium Compound	Once in a year before monsoon sets in
5	Worm reducer	Oil bath	Servo HP - 30	Indicator level to be maintained always
6	Spur Gear Bearings	Pressure grease gun	Bearing Grease	Once in three months as per site conditions
7	Line shaft bearings	Pressure grease gun	Bearing Grease	Once in six months as per site conditions
8	Gear Wheels	Hand applied	Chassis Grease	Once in six months as per site conditions
9	Drum shaft	Pressure grease gun	Chassis Grease	Once in three months as per site conditions
10	Lifting Arrangement and buckles	Hand applied	M. P. Grease	Once in six months as per

				site conditions
11	Hand operation mechanism and other relating parts	Hand applied	Servolin - 140	Once in three months as per site conditions

5.4 Do's and Do not's for Operation and Maintenance of Gates

DO's	*Don'ts*
1. Authorised Personnel should be allowed near control Pane for operation of gates.	1. Un authorized persons should not be allowed to operate gates
2. Technically qualified or trained operators should be allowed to operate gates.	2. Unqualified persons technically should not be allowed to operate gates.
3. Operate the gates only when there is required power supply as per the design is available.	3. Not to operate gates during low voltage period
4. Adjust the brakes when the gate is lowered fully and rest on sill.	4. Not to adjust the brakes when gate is not dogged
5. Attend maintenance during pre-monsoon season	5. Not to adjust the brakes when gate is not dogged
6. Use proper tools for attending repairs / adjustments	6. Maintenance works should not be attended during rains.
7. Conduct Dry test before putting into operation	7. Do not operate gates without Dry testing
8. Maintain cleanliness of hoist platform, trunnion platforms	8. Not to keep any slippery material on Hoist walkway
9. Insulate damaged electrical wiring, which are exposed to atmosphere	9. Do not allow any persons to operate gate if Bare wires are seen
10. Protect Hoist gear box and motors from rains	10. Not to keep gear box cover open after daily maintenance
11. Ensure wire rope tightness on either side equally before operating gate	11. Not to operate gate when the wire rope is slacked
12. Safety precautions should be taken during maintenance works	12. Not to wear loose dresses during operation of gates

13. Cut off power supply after operation of gates	13.Do not allow power supply to motors when it is not at all required.
14. Check connections and functioning of limit switches before operation	14. Advised not to operate gate if limit switches are not functioning
15. Ensure before operation that no foreign materials fall in the gear teeth	15. Not to switch on Hoist motors if foreign material found in between teeth of gear wheels
16. Check tightness of Plummer block, drive unit, line shaft, coupling bolts	16. Do not operate gate if any bolts of Plummer block and coupling bolts are found loose
17. Ensure no foreign particles stuck up in between roller and roller track/ wall plate and rubber seals etc.,	17.Not advised to operate gates if foreign material found in between rollers and roller track and wall plates and rubber seals etc.,

Calculations for design of vertical lift gate and Hoist capacity for gates

1. Design of Vertical lift gate:

A vertical lift gate 4m wide by 6m high has six equally loaded horizontal girders and is subjected to a water head of 10m on the sill.

i) Draw the pressure diagram.

ii) Calculate maximum water thrust on the gate and its position?

iii) Determine the location of the horizontal girders?

iv) Give comments & suggestions if any on the positioning of the top most and bottom most girder.

2. Hoist capacity calculation:

Calculate the hoist capacity for operation of Vertical lift type fixed wheel gates designed for water head corresponding to FRL are provided on the spillway of the project. The gates are having U/S skin plate & sealing. Side seals are hollow bulb J-type rubber seals and flat type rubber seal (rectangular section) at bottom. The gates are designed as per IS 4622. The gates are operated by means of individual electrical operated Rope Drum Hoist under unbalanced head. Check also the requirement of ballast if any for self closing of the gate?

Technical details:

- Vent width (Span) :12000mm
- Sill level :EL 241.30 m
- FRL /MWL : EL 246.50 m
- Spill way crest level : EL 241.50 m
- Top of pier level : EL 251.00m
- Thickness of bottom seal : 14 mm
- Dia of hollow bulb Side seals : 44mm
- Thickness of seal clamp plate :10 mm
- Wheel outer dia : 200 mm
- Wheel pin outer dia : 100 mm

Assume suitable data if any required.

Gate weight (G):

G= $0.735(B^2hH)^{\mathbf{0.697}}$ for Fixed wheel gate with $B^2hH>2000m^4$

G= $0.886(B^2hH)^{\mathbf{0.654}}$ for Fixed wheel gate with $B^2hH<2000m^4$

G=weight of gate in kN, B=span of gate in m,

H=head on the sill in m & h=height of gate in m

Hoist capacity calculations:-

A. VERTICAL LIFT GATES:

The downward forces acting on a gate when it is being raised are:

i) Self weight;
ii) Weight of ballast, if any;
iii) Friction at the seal(s)
iv) Friction at slide blocks/wheels
v) Downpull

Note:

(i) Seal friction is common for all types of gates and is caused by the sliding of seals on the seal seat.
(ii) Frictional load in slide gate is the product of the total water thrust load on the gate and the co-efficient of friction.
(iii) Wheel friction load consists of rolling friction of wheel on track and the friction at the bearing of the wheel pin.
The capacity required for lifting would thus be the sum of the forces at **i) to v)** above. This would, of course, be slightly reduced because of buoyancy. In practice, however, no reduction is made in the capacity on this account.

The upward forces acting on a gate when it is being lowered are:-

i) Friction at the seal(s)
ii) Friction at slide blocks/wheels
iii) Uplift
iv) Buoyancy

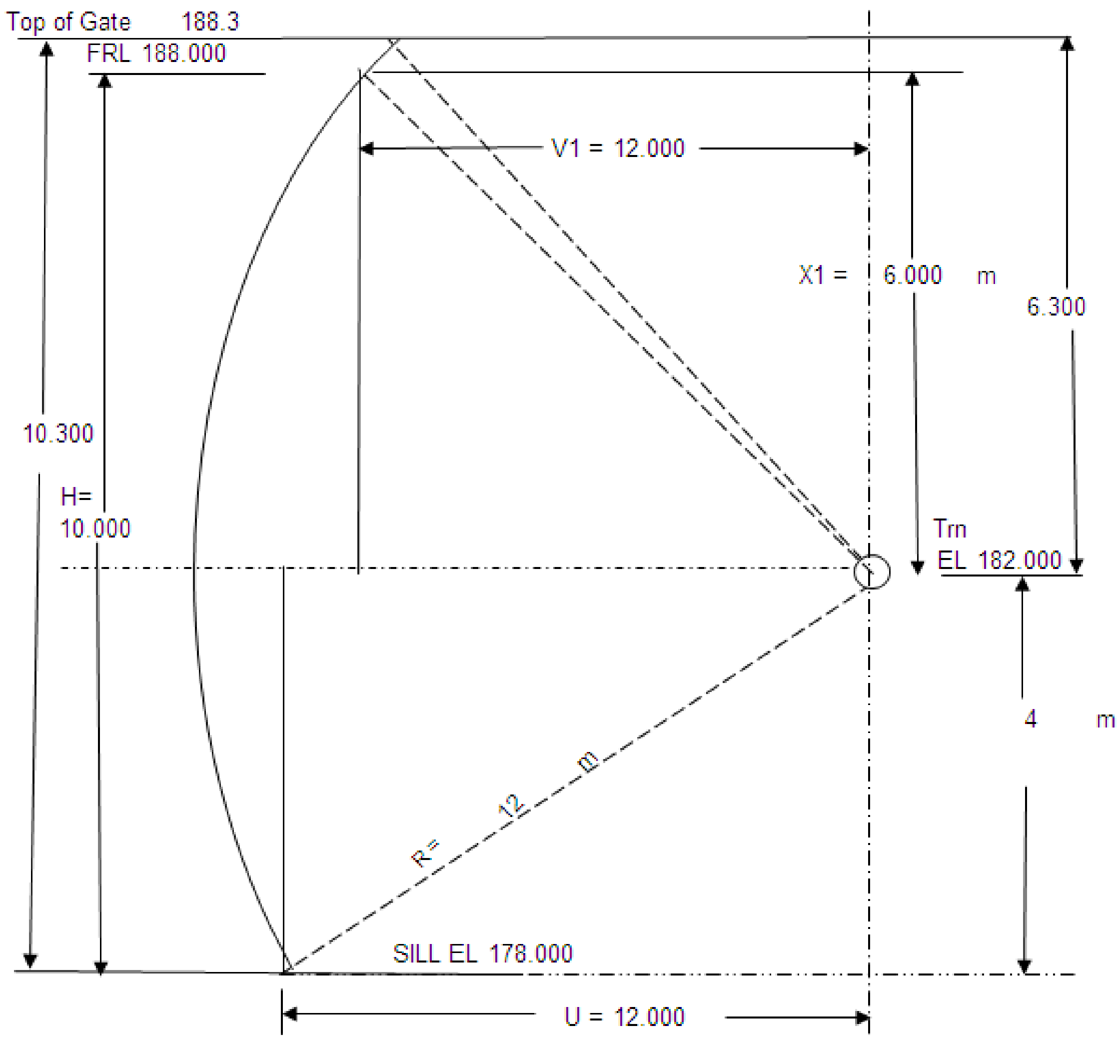
The capacity required while lowering would be the sum of the self weight and weight of ballast, if any, less the sum of the forces at i) to iv) as applicable.

Exercise 1

Details of radial gate are as follows:

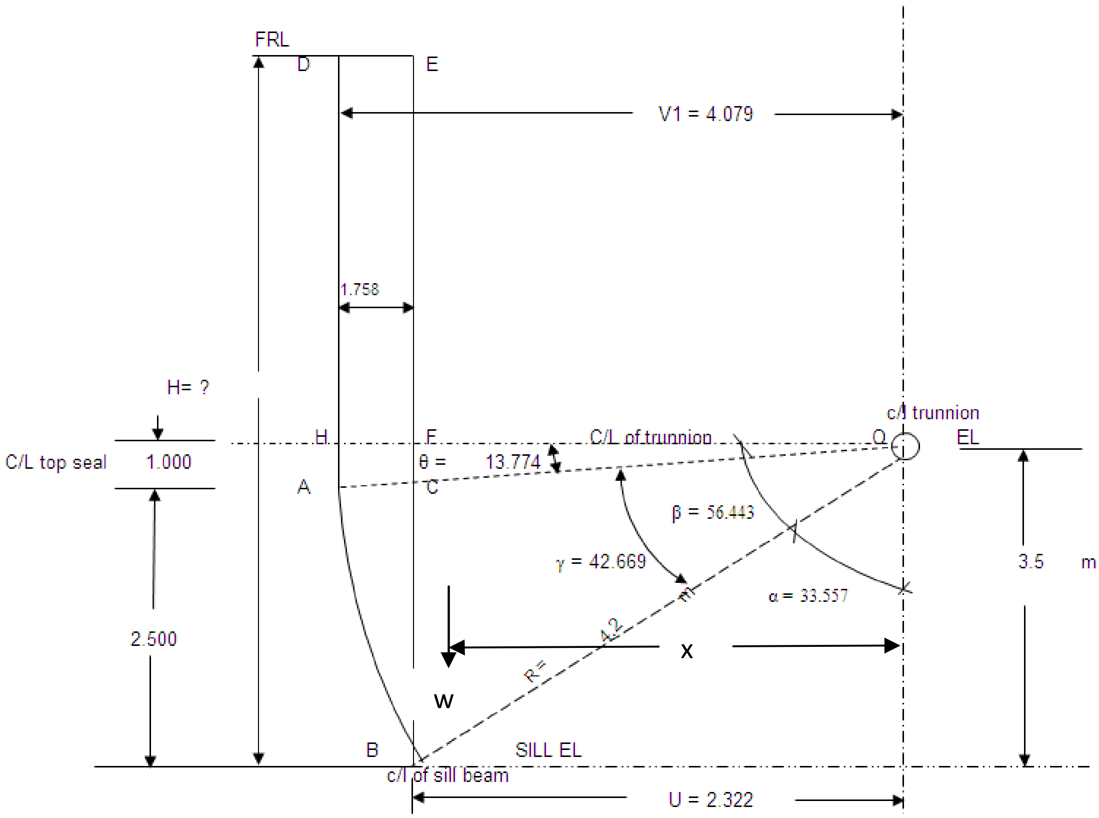
Width of opening	12.5	m
Height of opening	10	m
Radius to inside of skin plate	12	m
Sill level	178	m
Trunnion Level	182	m
Elevation of Hoist	190	m
Pond Level	188	m
Top of Gate Hood	188.3	m
Bottom of gate in fully raised position	184.5	m
Hoisting arrangement	Rope Drum Hoist	
Width of Pier	3600	mm
Water density	1 t/m2	

Calculate the water thrust and its angle from the horizontal.



Exercise 2

Radial gate of size 3m X 2.5m (Width X Height) has the self weight of 8.5 t. The self weight is acting at a distance x m from trunnion point (x = 0.8 times the radius of the gate). What is the maximum water head H in meter such that the gate remains self closing against the hydrostatic force? Neglect frictional forces. Density of water is 1t/m^2. Assume any missing value.



Exercise 3

Calculate the hoist capacity of downstream hoist of a radial gate (3m X 2.5 m) weighing 8.5t and having the radial Water thrust as 229 t. The radius of radial gate is 4.2m. The other data is given below:

Ballast on the gate = 3.5 t

Length of side seal = 3.128 m

Length of top seal = 3m

Seal bulb dia = 45 mm

Distance of C.G. point from trunnion centre = 3.49 m

Trunnion Pin Dia, = 0.24 m

Thickness of skin plate = 16 mm

Radius to C/L of side seals = 4.289 m

Guide track radius = 4.11 m

Co-efficient of friction for rubber on stainless steel, μr = 0.20

Co-efficient of friction for bronze on stainless steel pin, μp =0.5

Co-efficient of friction for silt on steel, μs = 0.50

Avg. water head on side seals, h = 25.219 m

water head on top seals, h1 =23.525 m

Silt pr. at bottom of gate = 0.8875 t/m^2

Total silt load on gate, Ps = 3.328 t

Guide roller force 5% of moving parts

Guide roller radius, w = 50 mm

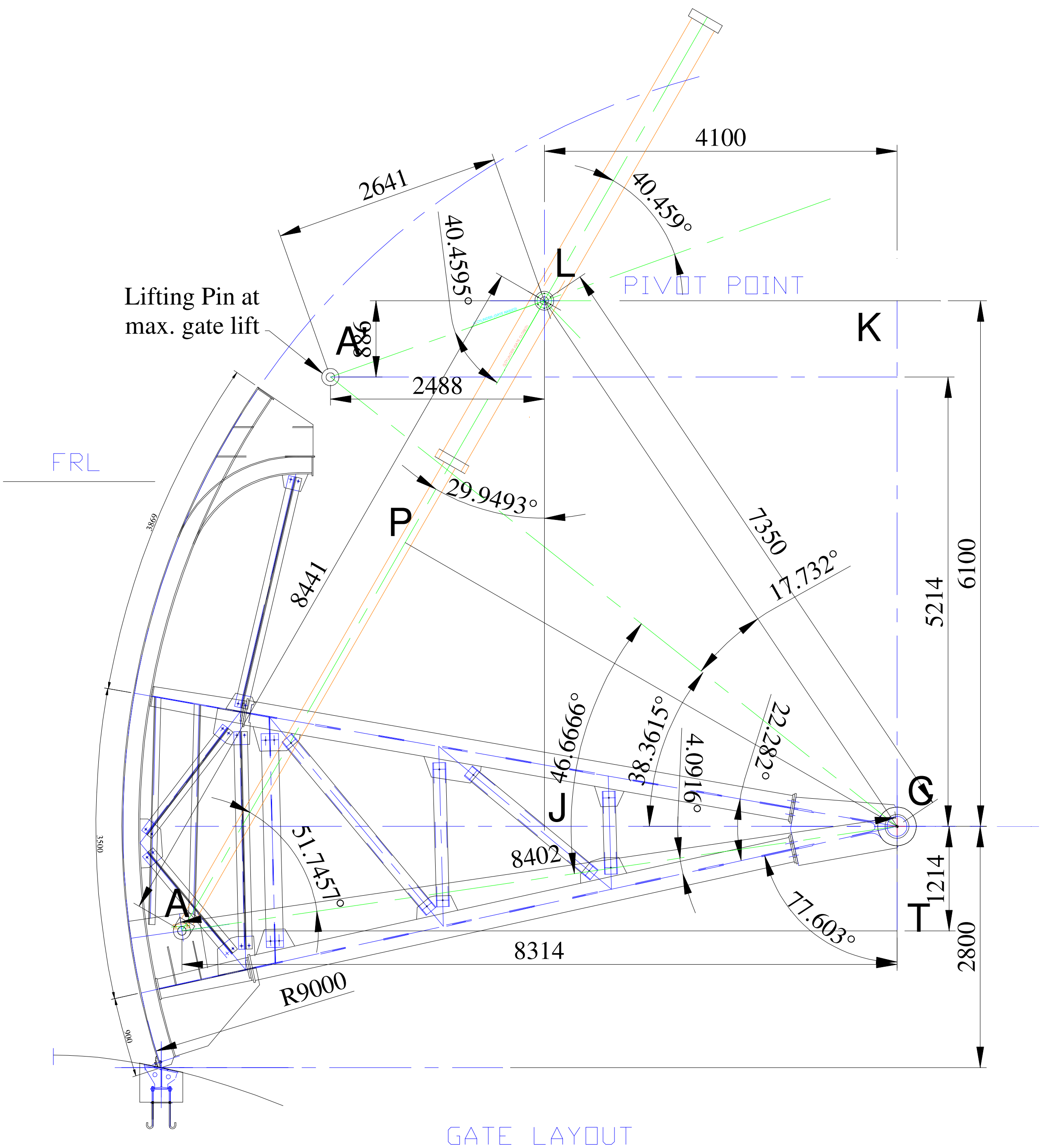
Guide roller bush radius, r = 15 mm

Lever arm of hoist rope = 3.143 m

Also check the gate for self closing if minimum seating load required is 500kg/m width of the gate..

Exercise 4

A radial gate is shown in the diagram. The pivot point of hydraulic hoist is located 4100 mm horizontal and 6100 mm vertical distance from trunnion point. The hoist capacity is 40 T. What is the stroke length of the hydraulic hoist and the angle rotated by the hoist cylinder for full gate lift? If the pivot point of is shifted horizontally towards trunnion point by 2m what will be the revised hoist capacity required? Also find out the revised stroke length and angle rotated by hoist cylinder for maximum gate lift. Assume the missing data if required.



राष्ट्रीय जल अकादमी

पुणे स्थित राष्ट्रीय जल अकादमी, केन्द्रीय जल आयोग की एक विशिष्ट संस्था है। जल संसाधन क्षेत्र से जुडे राज्य तथा केन्द्र सरकार में विविध स्तर पर कार्यरत अभियंताओं के प्रशिक्षण के क्षेत्र में राष्ट्रीय जल अकादमी एक “उत्कृष्ट केन्द्र” के रूप में कार्य कर रही है। राष्ट्रीय जल अकादमी जल संसाधन के विकास एवं प्रबन्धन के क्षेत्र में अल्प एवं मध्यम अवधि के पाठ्यक्रमों के नियमित आयोजन के साथ-साथ केन्द्रीय जल अभियंत्रण (वर्ग ‘क’) सेवा के अंतर्गत चयनित अधिकारियों के लिए लम्बी अवधि का प्रवेशन कार्यक्रम भी आयोजित करता है।

राष्ट्रीय जल अकादमी की वेबसाइट http://nwa.mah.nic.in से इस संबंध में अधिक जानकारी प्राप्त की जा सकती है।