The constructive calculations of flat and radial gates inhydropowers of Slabinj and Koman, Albania

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Abstract

In order touse the rich water resources in Albania last two decades have been built about 136 small hydro power plants ranging from 1,000 to 20,000 kWh , which provided about 24.1% of the generated power in the country[1]. In Albania, the small hydropowers arebuilt with intake structures, which are of two types:the side intake and drop intake (Tyroless). Large hydropower plants and a part of small hydropower are built with dams (mostly uprights dams).
In three cases, the water passes through the trap which prevents the penetration of impurities like stones, woody, debris etc. The measures of the side windows or galleries are calculated to obtain the maximum amount of water needed to supply hydro turbine.
In the first two cases, excess water, in case of flooding or high water discharged into the river flow through the gates, because the basins are too small by capacity and do not capture water resources, while in the third case (HPP withdam) the gallery captures the plan water quantity and the rest of water remains at the lake.
In case of flooding or over floodingthe discharging gates opened to maintain the maximum quota in the lake. In small HPP the water passes to desander through the intake structures to be cleaned from solid waste.Fromdesander the water passes to pressure basin where fluid provides the required potential energy and through penstock enters the hydro turbines.In case of dam hydropower plant, the water enters into the pipes with pressure and passes through the turbine.Dam hydropower plants have priority over the two previous onesbecause the lakes created by the damkeep huge water reservesand generated power is better align with market demand.

KEYWORD: Desander, Design flat gate, Hydro-mechanic elements, Intake structure, Pressure basin,Radial gate, Trap.

INTRODUCTION

To control the fluid flow rates, rinsing of the alluvium, the excessive discharges in case of flooding or over flooding,it is necessary to use valves and gates in a hydricintake structure[2].
These hydro-mechanical elements have a functional importance in the construction and exploitation of the hydropower plants.A hydric structure cannot operate without them.
Gates manufactured and installed in HPPs built in Albania are of different types, from the simplest to those automatic gates.
Based on the methods of control we have:gate with manual control, with electrical and hydraulic-electric control.
Based on their form we have: flat and radial gates (Segment)
Based on their measures they are classified into light, medium and heavy gates.
The basic elements of a gate are:
The gate skeleton which is fixed (or as often called gate framework)

Moving parts which makes closing (or leaf gate)
The moving mechanism (up-down)
Avoiding of the leakage is made by waterstop
To carry out their function, the gates have some auxiliary accessories such as sensor, signal sensor etc.
Gates design, hydraulic-mechanical calculations, manufacture and installation of all the hydro-mechanic elements is carried out according to the standards of acceptable in order to have a secure exploitation.This requires that the designer, manufacturer and installer must have a high technical skills and responsibility.
This project in its universal meaning is:the most optimal way for creation of any new product.In this process we distinguish these stages: Planning - Conceptualization - Design & Calculation – Manufacture & installation.

The investor draws up the design task in written where he defines his requirements and desires.
He provides drawings of all hydropower structures as: intake structures or dams; channels; tunnels, galleries; desander; pressure basin; penstock etc.
He provides the technical data of the hydropower plant as; water flow, type of turbine, installed power, type of control etc.
After providing this information the designer begins his work to carry out the gate design according to the stages.
This process goes through these main steps:

- Clarify and define the problem;
- Functional study and their structures;
- Determine the solving principles and their structures ;
- Finding achievable modules;
- Define the optimal modules;
- Formation of the overall product;
- Processing of the achievable and usable data.

Here should be clarify all the questions that belong todesign and the results should be left in writing.These include all the requirements and desires of the investor, for example, data on the size, power, installation, service and maintenance, costs and deadlines.These requirements will be divided into main and secondary, which areneeded later in the assessment of the final version and will enable decision-making.

METHOD

All the data are part of the engineering assessment duringthe gate designing of two hydropower plants in Albania.To control the stability of the Flat and Radial gate, the engineering methods are applied to calculate the metal construction[2]. Reactions and the lifting force on each port, is carried out by balancing the respective forces and moments.
Below are two examples of the gates calculation of the HPPSlabinjePogradecand HPPKomanShkoder– Albania.

THE AIM OF THE STUDY

The HPP gates are part of very important hydro-mechanical elements for operation of hydro powers. By means of gates and valves we control the water to the required directions. Gates are installed on intake structures, in desander, in the pressure basin and at the exit of the turbine. Gates are manually-commanded by electric and hydraulic control, pneumatic, etc. Their size depends on the flow and pressure. They are subject to engineering calculations in order to ensure that they meet the forces of pressure and movement control according the determined speed. Below are given calculations for two types of gates: flat and Radial gates. The flat gate is installed in the HPP Vlusha,Albania while the radial gate is installed in one of the biggest HPP in Albania, HPP of Koman. These calculations intendnot only to assure their solidity but also to determine the exact lifting mechanisms

CALCULATION AND INTERPRETATION

Flat Gate

TECHNICAL CALCULATIONS

1. Cargo Action

1.1Weight of flat gate$\mathbf{P_{fg} = 24820\ N}$

1.2 Water pressure force acting on the surface of gate is

$$\mathbf{F_w = \rho \cdot A = \rho \cdot g \cdot \left(H_w - \frac{B}{2}\right) \cdot A \cdot B = 1000 \cdot 9.81 \cdot 11.5 \cdot 2.5 \cdot 3 = 846112.5N}$$

1.3 Friction force in waterstop&guide

$$\mathbf{F_f = F_W \cdot \mu = 846112.5N \cdot 0.64 = 541512N}$$

1.4 Generalized force acting on lifting mechanism is

$$\mathbf{F_t = P_{fg} + F_f = 846112.5 + 541512 = 1387624.5N}$$

1.5 Friction momentum of the screw fillet

$$\mathbf{M_{fs} = \frac{F_t}{2}\left[\frac{D_1}{2} \cdot tg(\beta + \rho) + \frac{D_k}{2} \cdot \mu\right]}$$

$$\boldsymbol{tg\beta = \frac{S}{(\pi \cdot D_2)} = \frac{16}{(3.14 \cdot 42)} = 0.1213, \quad \beta = 6.9°}$$

For our materials we take the angle offriction $\mathbf{\rho = 6.7°}$

$$\mathbf{M_{fs} = \frac{F_t}{2}\left[\frac{D_1}{2} \cdot tg(\beta + \rho) + \frac{D_k}{2} \cdot \mu\right]}$$
$$\boldsymbol{= 693812.25\left[\frac{0.06}{2} \cdot tg(6.9° + 6.7°) + \frac{0.08}{2} \cdot 0.64\right]}$$

$$\boldsymbol{M_{fs} = 22777.85Nm}$$

External diameter D_1 = 60 mm

Inner diameter D_2 = 42 mm

Surface of the section a = 1519.76 mm^2

2. Calculation Screw

2.1 Choosing building screw

Primitive diameter D_0 = 51 mm

Step fillet S = 16 mm

Number of fillet origin n = 2

The lifting screws are Tr 60 x 16 P8

2.2 External torsion strength calculation

$$\mathbf{M_{pd} = F_1\left[\frac{D_1}{2}\cdot tg(\beta+\rho)+\frac{D_k}{2}\cdot\mu\right]}$$

$$\boldsymbol{tg\beta=\frac{S}{(\pi\cdot D_2)}=\frac{16}{(3.14\cdot 42)}=0.1213,\quad \beta=6.9^\circ}$$

We take the angle of friction $\boldsymbol{\rho = 6.7^\circ}$

Force acting on a screw

$$\mathbf{F_1=\frac{F_t}{2}=\frac{1387624.5N}{2}=693812.25N}$$

$$\mathbf{M_{pd} = F_1\left[\frac{D_1}{2}\cdot tg(\beta+\rho)+\frac{D_k}{2}\cdot\mu\right]}$$

$$\boldsymbol{=693812.25\left[\frac{0.06}{2}\cdot tg(6.9^\circ+6.7^\circ)+\frac{0.08}{2}\cdot 0.64\right]=}$$

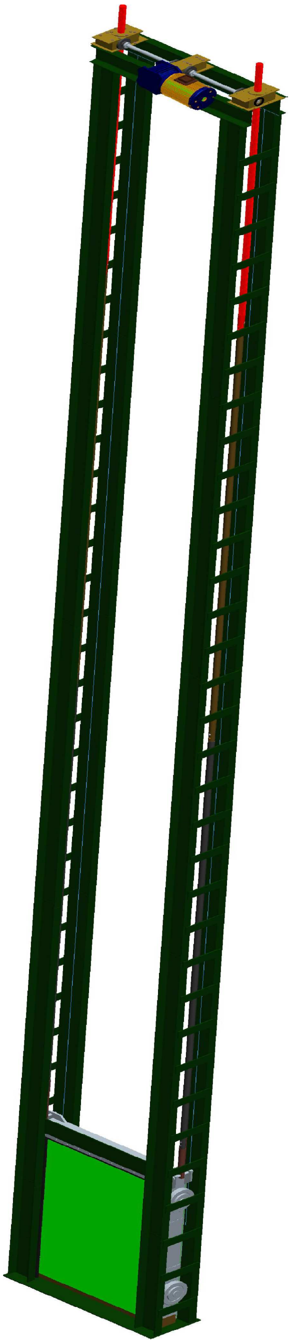
$$\boldsymbol{M_{pd}=22777.85Nm}$$

2.3 Controlling the sustainability of the screw (Material X5NiCrTi26-15) inox accountability:

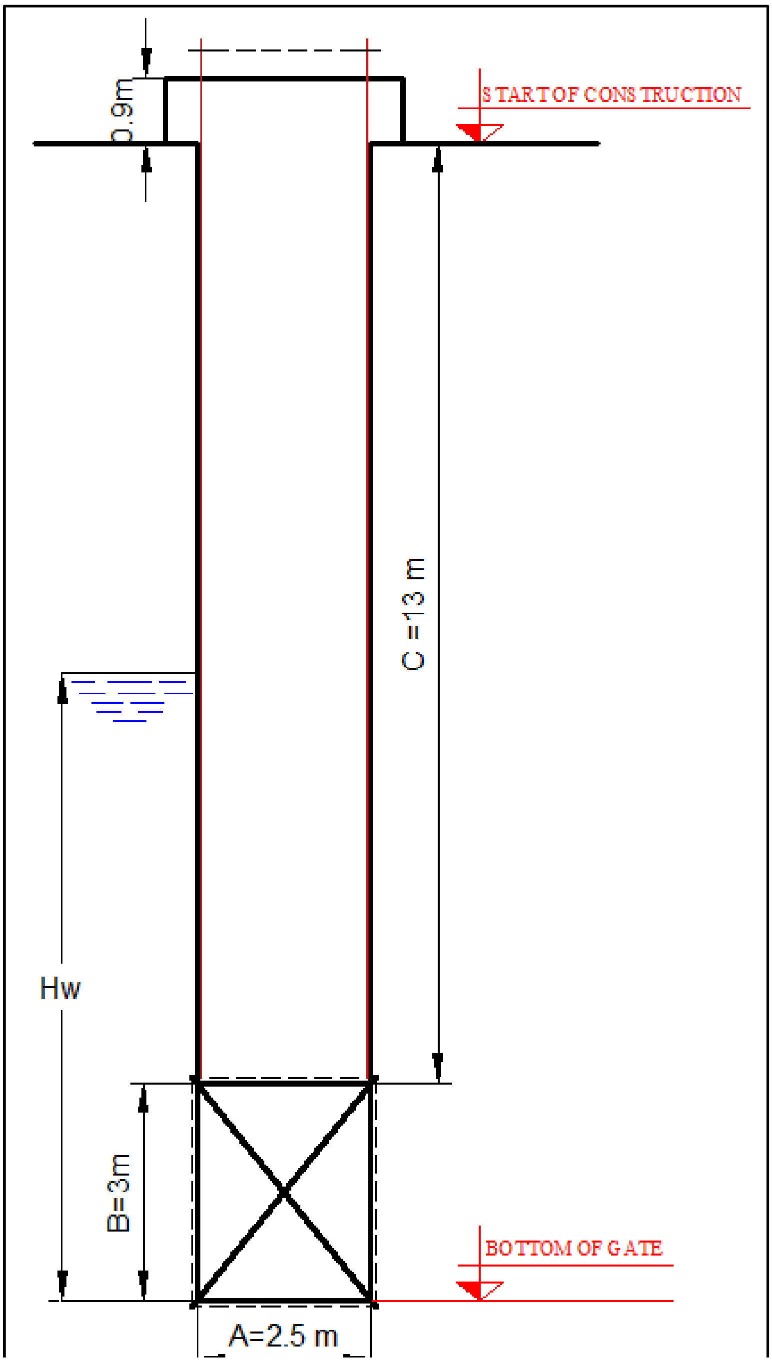
$$\boldsymbol{\sigma_{red}=\sqrt{\sigma^2+3\tau^2}\sigma=\frac{F_1}{a}=\frac{693812.25}{0.001520}=456455427.6N/m^2}$$

$$\boldsymbol{\tau=\frac{M_{pd}}{0.1\cdot D_2^3}=\frac{22777.85}{0.1\cdot 0.042^3}=3078087837.8N/m^2}$$

results that: $\boldsymbol{\sigma=5350908880N/m^2<[\sigma]=960000000N/m^2}$



a)



b)

Fig 1a; Manifactured gate for HPP Slabinje . b) Calculated scheme for gate of HPP Slabinje

2.4 Check the height of the nut

$H_1 = F_t \cdot S/(l_1 \cdot d_1 \cdot \pi \cdot [p])$ [3] Tab 8.3

2.5 Time for the screw attachment
Accept 30 rpm movement crank
Rotation of the screw Nv = P ·n = 16 · 30 = 480 mm/min
Gate openingB= 3 m = 3 000 mm /480 mm/min = 6.25 min

3. Calculations of the Gate

3.1 Water pressure force on the surface of gate$\mathbf{F_w}$**= 846112.5 N**
The average pressure:

$$q = \frac{F_w}{A} = \frac{846112.5}{2.5 \cdot 3} = 112815 N/m$$

3.2 Maximum Momentum on the plate of the gate

$$\mathrm{M_{max}} = \frac{q \cdot B^2}{8} = 126916.9 \mathrm{Nm}$$

3.3 Resistent momentum of the gate in flexureW_o= 412cm^3

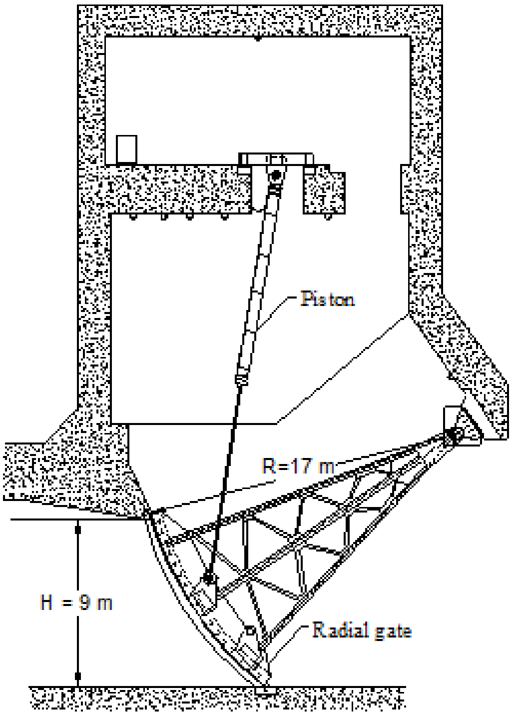
W_1 = 21 cm^3
W_2 = 34.1 cm^3
W_3 = 64.6 cm^3
ΣW = 531.7 cm^3

3.4 Flexural strain

$$\sigma_{pk} = \frac{\mathrm{M_{max}}}{\sum \mathrm{W}} = \frac{126916.9 \mathrm{Nm}}{0.0005317} = 238700206.9 \mathrm{N / m^2}$$

allowed strain $[\sigma_{pk}] = \sigma_{rpkj} \cdot 1.4 = 238700206.9 \mathrm{N}.1.4 = 334180289.6 \mathrm{N / m^2}$

Radial Gate ,HPP Koman (Fig. 2)



H = 9 m

B = 8 m

R = 17 m

$$l = \frac{2\pi R\varphi}{360} = 0,01745R\varphi$$

Fig. 2. Installed gate in HPP Koman

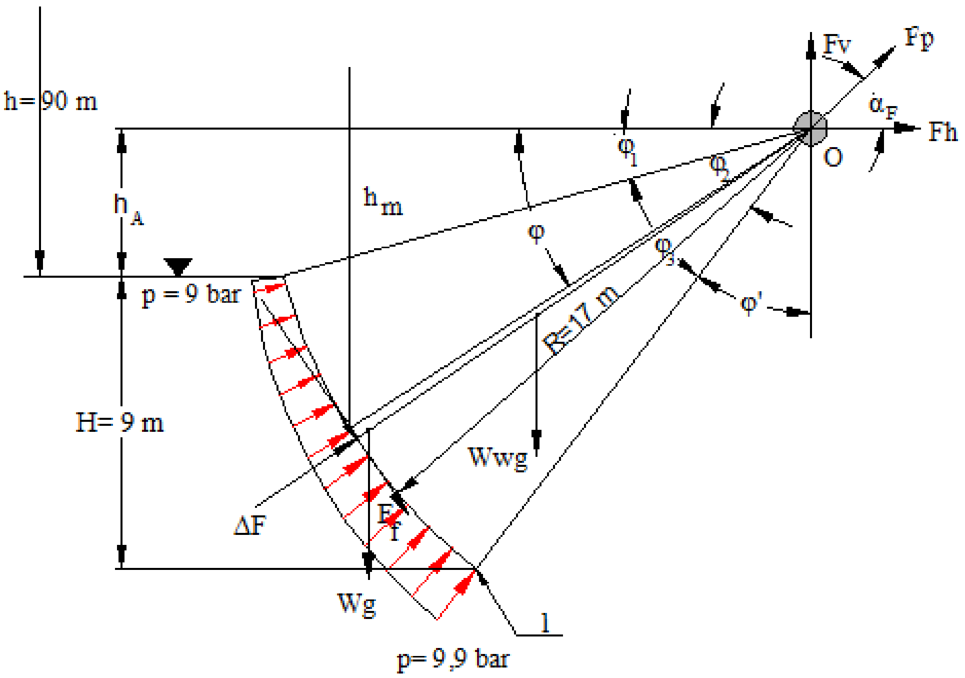


Fig.3.a) Scheme of distribution of pressure forces in gate of HPP Koman

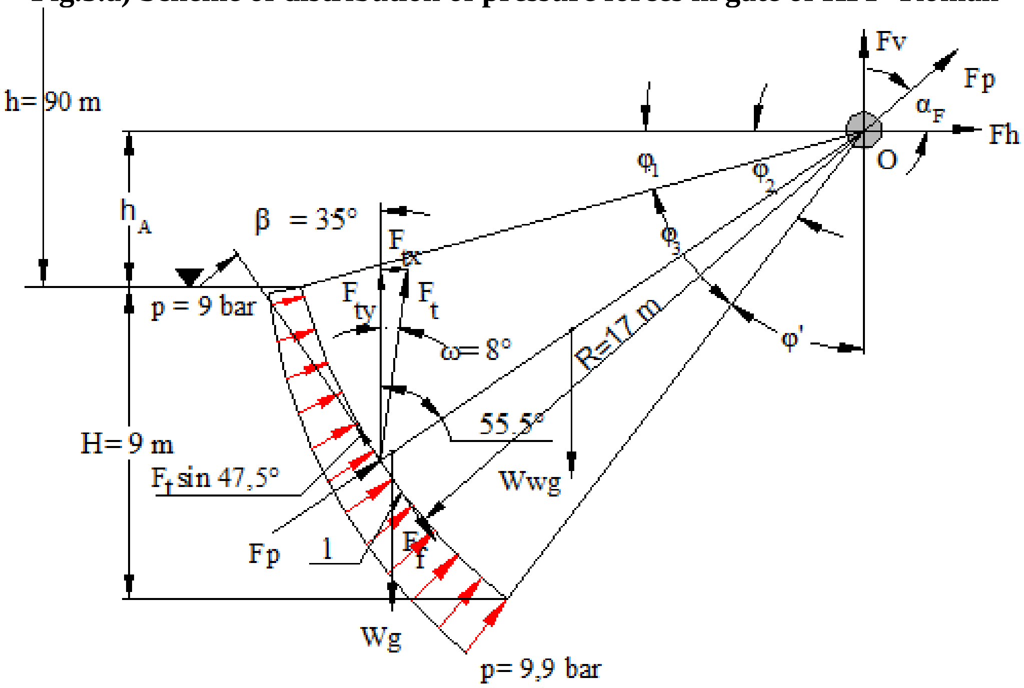


Fig.3. b) Force distribution and reaction happening in the gate, force in the lifting piston.

l-length of the plate body **$\varphi_1 = 16^\circ$, $\varphi_2 = 53^\circ$**

φ_1,φ_2, φ- anglesof radial gate**$\varphi_m = 34.5^\circ$**

S – surface of radial gate

Ft – Lifting pressure (piston)

Fp - Pressure force

F_f - Friction force

W_g– Weight of the plate body of radial gate

Ww_g - Weight of the wings of radial gate

R - Gate Radius

H- Gate Height

B- Gate Width

l_{wg}– Wg distance from trunnion

Calculation of Radial Gate

1. Water Pressure Force calculation[3]

$$\Delta F = P_{\varphi} dA = \rho \cdot g \cdot h_{\varphi} \cdot B \cdot Rd_{\varphi}$$

$$\varphi_1 = 16° \quad , \varphi_1{}^{rad} = \frac{16° \cdot \pi}{180°} = 0,28$$

$$\varphi_m = \varphi_1 + \frac{\varphi}{2} = 16° + \frac{37°}{2} = 34,5° \varphi_m{}^{rad} = \frac{34,5° \cdot \pi}{180°} = 0,60$$

$$h_A = 90m - R \cdot \sin 16° = 90m - 17 \cdot \sin 16° = 85,31m$$

$$h_{\varphi} = 85,31m + R \cdot \sin\varphi$$

$$\Delta F = \rho \cdot g \cdot B \cdot R(85,31 + R \cdot \sin\varphi) d_{\varphi}$$

$$Fp = \int_{\varphi_1}^{\varphi_2} \Delta F = \rho \cdot g \cdot B \cdot R \; [85,31(\varphi_2 - \varphi_1) - R\,(\cos\varphi_2 - \cos\varphi_1)]$$

$$Fp = 1000 \cdot 9.81 \cdot 8 \cdot 17 \; [85,31(\varphi_2 - \varphi_1) - 17\,(\cos 53° - \cos 16°)] =$$

$$Fp = 81,652,443.384\ N$$

2. Direction of Pressure force

$$\sum \mathbf{F_v} = \mathbf{F} \cdot \sin \alpha_F$$

$$= \int_{\varphi_1}^{\varphi_2} \Delta \mathbf{F} \cdot \sin \varphi = \int_{\varphi_1}^{\varphi_2} \rho \cdot g \cdot B \cdot R\,(85,31 + \sin \varphi) \sin \varphi \, d_\varphi =$$

$$= \rho \cdot g \cdot B \cdot R\,(-85,31 \cos \varphi) + \frac{R}{2}\left(\varphi - \frac{\sin^2 \varphi}{2}\right) \Big|_{\varphi_1}^{\varphi_2} \qquad \text{kujtese: } \sin^2\varphi = \frac{1 - \cos 2\varphi}{2}$$

$$= \rho \cdot g \cdot B \cdot R\left[-85.31\,(\cos \varphi_2 - \cos \varphi_1) + \frac{R}{2}(\varphi_2 - \varphi_1) - \frac{R}{4} \cdot (\sin 2\varphi 2 - \sin 2\varphi 1)\right] =$$

$$= \rho \cdot g \cdot B \cdot R\left|-85.31\,(\cos 53° - \cos 16°) + \frac{R}{2}(53° - 16°) - \frac{R}{4}[(\sin 2x53° - \sin 2x16°)]\right| =$$

$$\mathbf{F} \cdot \sin \alpha_F = 50680284.29$$

$$\sin \alpha_F = \frac{50680284.29}{81,652,443.384} = 0.621 =$$

$$\alpha_F = 38.366\,°$$

3.Minimal constant pressure

$$\sum \mathbf{M_O} = W_{w\,g} \cdot 0.6 \cdot R \cdot \cos 34,5\,° + W_g \cdot 0.97\,R \cdot \cos 34.5\,° - \int d\,A_g \cdot p_f \cdot R = 0$$

$$p_f = \mu \cdot p_N \qquad \mu - friction\ coefficient \qquad p_N - normal\ pression$$

$$W_{w\,g} + W_g = W = 51990\ kg$$

$$W_{wg} = 13,260\ kg$$

$$W_g = 38,730\ kg$$

$$\int d\,A_g \cdot \mu \cdot p_N \cdot R = p_N \cdot \mu \cdot R \cdot A_g = p_N \cdot 0.64 \cdot 17 \cdot 1.53 = 16.6464 \cdot p_N$$

$$p_N = \frac{W_{w\,g} \cdot 0.6 \cdot R \cdot \cos 34,5\,° + W_g \cdot 0.97\,R \cdot \cos 34.5\,°}{16.6464} = 3.831 \cdot 10^4$$

$$\sum \mathrm{F_{i\ x-x}} = \mathrm{F_H} + \mathrm{F}\cos\alpha_F + 2\ p_N(2\,\mathrm{R}\sin 18,5^\circ \cdot 0.045)\cos 34.5^\circ + \mathrm{B} \cdot 0.045\ p_N \cos 16^\circ + \mathrm{B} \cdot 0.045 \cdot p_N \cdot \cos 53^\circ = 0$$

$$\sum \mathrm{F_{i\ x-x}} = \mathrm{F_H} + \mathrm{F}\cos\alpha_F + 2\ p_N \cdot 0.399 + 8 \cdot 0.045\ p_N \cos 16^\circ + 8 \cdot 0.045 \cdot p_N \cdot \cos 53^\circ = 0$$

$$\sum \mathrm{F_{i\ x-x}} = \mathrm{F_H} + \mathrm{F}\cos\alpha_F + 2\ p_N \cdot 0.399 + 0.346\ p_N + 0.216 \cdot p_N = 0$$

$$\mathrm{F_H} + \mathrm{F}\cos\alpha_F + 2\ p_N \cdot 0.399 + 0.346\ p_N + 0.216 \cdot p_N = 0$$

$$-\mathrm{F_H} = \mathrm{F}\cos\alpha_F + p_N(0.798 + 0.346 + 0.216) = \mathrm{F}\cos\alpha_F + 1.36\ p_N$$

$$\mathrm{F_H} = -64,526,110.6\ N$$

$$\sum \mathrm{F_{i\ y-y}} = \mathrm{F_V} + \mathrm{F}\sin\alpha_F - W_{w\,g} - W_g + 2\ p_N(2\ \sin 18,5^\circ \cdot 0.045) + \mathrm{B} \cdot 0.045\ p_N \sin 16^\circ + \mathrm{B} \cdot 0.045 \cdot p_N \cdot \sin 53^\circ + 2\,F_{t1y} + F_{t2y} + F_{t4y} = 0$$

$$\sum \mathrm{F_{i\ y-y}} = \mathrm{F_V} + \mathrm{F}\sin\alpha_F - W_{w\,g} - W_g + 0.057\ p_N + 0.099\ p_N + 0.287 \cdot p_N + 2\,F_{f1y} + F_{f2y} + F_{f4y} = 0$$

$$d\,F_f = \mu \cdot p_N \cdot 0.045 \cdot \mathrm{R}\,d_\varphi$$

$$d\,F_{fx} = \mathrm{d}\,F_f \cdot \sin\varphi$$

$$F_{f3x} = F_{f1x} = \int_{\varphi_2}^{\varphi_1} \mathrm{d}\,F_{fx} = \mu \cdot p_N\,0.045 \cdot R\,(\cos\varphi_2 - \cos\varphi_1)$$

$$F_{f1y} = \int \mathrm{d}\,F_{fy} \cdot \cos\varphi_2 = \mu \cdot p_N\,0.045 \cdot R\,(\sin\varphi_2 - \sin\varphi_1) = F_{f3y}$$

$$F_{f1y} = \mu \cdot p_N\,0.045 \cdot R\,(\sin\varphi_2 - \sin\varphi_1) = 0.64 \cdot 3.831 * 10^4 \cdot 0.045 \cdot 17(\sin 53^\circ - \sin 16^\circ)$$

$$F_{f1y} = 9,809.69$$

$$F_{f2x} = -F_{f2} \cdot \sin\varphi_1 = -F_{f2} \cdot \sin 16^\circ$$

$$F_{f2y} = F_{f2} \cdot \cos 16^\circ = \mu \cdot p_N\,0.045 \cdot B \cdot \cos 16^\circ = 4,482.4$$

$$F_{f4} = 0.045 \cdot B \cdot p_N \cdot \mu$$

$$F_{f4x} = -F_{f4} \cdot sin\, 53°$$

$$F_{f4y} = F_{f4} \cdot cos\, 53° = 0.045 \cdot B \cdot p_N \cdot \mu \cdot cos\, 53° = 5,313.63$$

$$\sum \mathrm{F_{i\ y-y}} = \mathrm{F_V} + \mathrm{F}\sin\alpha_F - W_{w\,g} - W_g + 0.057\ p_N + 0.099\ p_N + 0.287 \cdot p_N + 2\,F_{f1y} + F_{f2y} + F_{f4y} = 0$$

$$\mathrm{F_V} = W_{w\,g} + W_g - \mathrm{F}\sin\alpha_F - 0.057\ p_N - 0.099\ p_N - 0.287 \cdot p_N - 2\,F_{f1y} - F_{f2y} - F_{f4y} =$$

$$\mathrm{F_V} = -50,651,254.3\ \mathrm{N}$$

4.Ft – Lifting pressure(piston)[4]

$$\sum \mathrm{M_O} = -F_t \cdot R \cdot sin(55,5° - \omega) + 2\,(W_g \cdot 0.97\,R \cdot cos\, 34,5° + W_{w\,g} \cdot 0.6 \cdot R \cdot cos\, 34,5°) = 0$$

$$F_t = \frac{2\,(W_g \cdot 0.97\,R \cdot cos\, 34,5° + W_{w\,g} \cdot 0.6 \cdot R \cdot cos\, 34,5°)}{R \cdot sin(55,5° - \omega)} =$$

$$F_t = 997,522.68\,N$$

CONCLUSIONS

The HPP gate design should be assessed with due importance by the designer , manufacturer and installer. Safety coefficients selected during the design and gate calculations under high pressure should reflect not only the force pressures, but also the influence that the major forces and particularly earthquakes have on the chemical composition of the fluid to determine protective measures against corrosion etc.Accurate calculations serve to select a lifting mechanisms functioning without problem..

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