Design Modification of Sedimentation Tank

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Abstract— Sedimentation is the perhaps the oldest and most common water treatment process. Sediment is one of the biggest enemy of hydro power project might make project unfeasible due to increase in high cost of project. Although, Nepal has huge potential for hydro power due to glacier in the Himalayas, regular monsoon rain and local topography. There are much no of hydro power plant in the Himalayan River are affected by excessive sediment which will decrease the capacity of reservoir, Sedimentation basin was conducted using both experimental and numerical model simulation. Two important effect or necessary or specific effect to be considered were the effect of wind action and the effect of density stratification. The aim was to confirm that these effects are detrimental to the ability of a basin to remove particle from a suspension by the gravitational settlement process.

Key words: Sedimentation, Water Treatment Process, Hydro Power

I. INTRODUCTION

In a hydro power plant development, sedimentation is a biggest problem. Reservoir in hydro power plants losing their capacity due to sedimentation process. Detailed knowledge of sedimentation removal technique and methodology should be known to combat this problem. There is need of detail knowledge of the rate of supply, size and shape of the sediment particles, characteristic of the sediment particles. Sedimentation basin or settling basin is the most important hydraulic structure in any hydropower plant for its better performance.

Settling basins are mainly used for removing excess sediment entering irrigation or power canals taking off from an alluvial river. The principle which used here is simply to provide a wide and long enough section for the resulting reduced flow velocity to allow the sediment to settle down. Every settling basin has to better efficiency due to which, the hydro power generation is at better rate. With a better hydraulic structure of sedimentation basin, we can get better efficiency of removal. The main objective of study of design modification in sedimentation tank is for better removal efficiency of settling basin. Sedimentation basin will extract water free from sediment at a maximum extant. For better removal of sediment from incoming water from intake, removal efficiency must have better value. At many variation of length having breadth and depth constant, ratio of length and width having constant depth, ratio of breadth and depth having constant length, having these information we can design a better settling tank which will have a better efficiency with the specific dimensions.

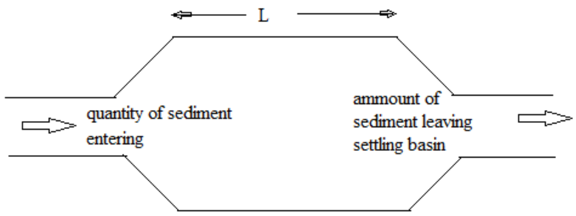


Fig. 1.1: layout of settling basin

The amount of sediment load deposited in a settling basin is expressed in terms of the removal efficiency of the basin, which is defined as follows

$$\eta = \frac{q_{si} - q_{se}}{qsi}$$

$$\eta = 1 - \frac{q_{se}}{q_{si}}$$

II. DESIGN ELEMENT OF SETTLING BASIN

Following are important elements of design continuous flow sedimentation tank

- Detention period and displacement efficiency
- Overflow rate and surface loading
- Basin dimensions
- Inlet and outlet arrangement
- Sludge removal device

A. *Detention period and displacement efficiency*

It is a theoretical time taken by a particle of water to pass between entry and exit of a settling tank

$$t_0 = \frac{V}{Q} = \frac{lbh}{Q}$$

Where V is volume of the basin and Q is discharge rate.

The detention period value depends upon the type of suspended impurities in water ant it may vary from 4 to 8 hours in plain sedimentation tank.

1) *Flowing through period*

Average time required for a batch of water to pass through the settling tank. It will always less than the detention period due to short circuit effects. How close this will approximate the detention period will depend upon the design of the tank.

2) *Displacement efficiency*

It is defined as the ratio of flowing through period to the detention period

$$\eta_d = \frac{\text{flowing through period}}{\text{detention period}} = \frac{t_d}{t_0}$$

It will vary from 0.25 to 0.5 in plain sedimentation tank

B. *Overflow rate and surface loading*

Overflow rate is, the quantity of water passing per hour/ or per day per unit horizontal area is known as the overflow rate or surface loading**.** We know that, $v_s = \frac{Q}{A}$, thus the surface loading rate and settling velocity are numerically equal

C. Basin dimensions

The surface area of the basin is determined on the basis of the overflow rate

The surface area = volume of water in liters hour/ surface loading rate in liters hour/m^2

A flow of 5 million liters per day and surface loading rate of 20,000 liters / day per m^2will require a surface area of

$$\frac{5,000000}{20000} = 250\ m^2$$

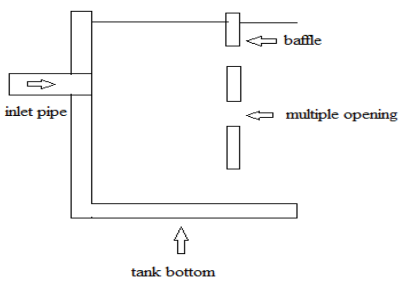
The length to width ratio of rectangular tank should preferably be from 3:1 to 5:1. The depth of basin is kept between 2.5 to 5m, with a preferred value of 3 m, inclusive of the allowance for sludge storage. The cross sectional area is such as to provide a horizontal velocity of flow of 0.2 to 0.4 meters per minute, and normally about 0.3 meters per minute.

D. Inlet and outlet arrangement

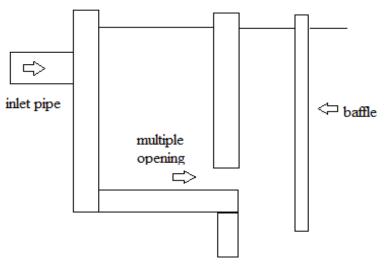
Arrangement of inlet and out should be such that minimum disturbance is caused due to influent and effluent streams. Because of greater weight due to turbidity, there is tendency for the incoming water to sink, move along the bottom and rise at the outlet. This will cause backward flow towards the inlet at the surface thereby reducing the effective detention period. An ideal inlet structure should have

- Uniformly distribute the water as uniformly as possible across the width and depth of tank
- Mix it with the water which are already in the tank
- Minimize large scale turbulence
- Initiate longitudinal or radial flow so as to achieve high removal efficiency

To achieve above requirement, each inlet opening must face a baffle



(a) Perforated baffle



(b) Submerged orifice

Fig. 2.1: Different type of inlet

Outlet arrangement consist of

- Weirs, notches or orifices
- Effluent trough or launder
- Outlet pipe

Weir loading rates are limited to prevent high approach velocities near the outlet

III. PRESENT MODIFICATION

If we suppose the standard value of length, width, depth, settling velocity, flow velocity, discharge, manning's coefficient like as

L= 36m, W= 12m, D= 3m, ω=.002m/sec, U= .039 m/sec, Q=1.41m^3/sec

A. Length vs. Efficiency

Then we have to find out the efficiency at this standard value. First of all we have to calculate the value of shear velocity

We know that shear velocity $u_* = \frac{Un\sqrt{g}}{D^{1/6}}$

After putting these values we get $u_* = 1.423 \times 10^{-3}$ m/sec

The sediment transport function $\beta = \frac{\omega}{ku_*}$

Putting these values we get $\beta = 3.513$

The mean rate λ at which particles settle out of suspension as a function of $\beta = \frac{\omega}{ku_*}$

From the curve between λ and β

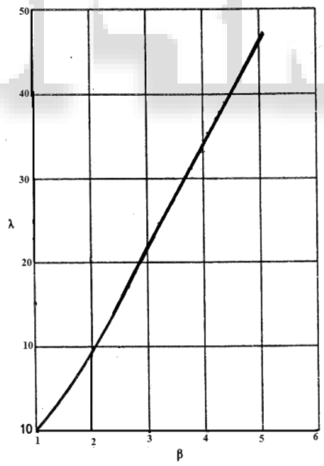


Fig. 3.1

We get the value of λ=40, The relation of efficiency$\eta = 1 - e^{-\left(\frac{k\lambda}{6}\right)\left(\frac{Lu_*}{UD}\right)}$, in which k is a constant which has value 0.4. After putting these all value in efficiency formula, we get the efficiency 68.87%. Now the main target to see the variation in efficiency after variation of length and having constant value of other parameter. The given chart below shows

L (length in meter)	Efficiency In %
36	68.87
37	69.85
38	70.79

39	71.71
40	72.61
42	73.44
44	75.05
46	76.58
48	78.01
50	79.36
53	81.21
56	82.89
65	87.83
70	89.65
72	90.30

Table 3.1: Efficiency variation with length

Feeding these values in a form of graph we get

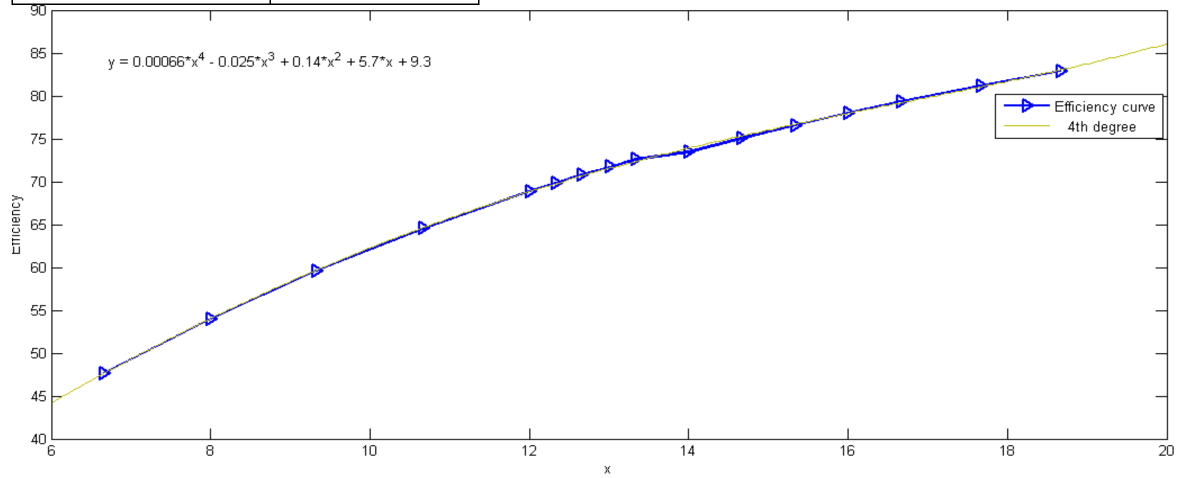


Fig. 3.2: Lengths vs. Efficiency

We get a relation between length and efficiency which is

$$y = 9.3 + 5.7x + 0.14x^2 - 0.025x^3 + 0.00066x^4$$

In which y shows the efficiency values and x shows the value of length as like, x = 3L

B. Depth vs. Efficiency

In this case the length and width of basin will be constant and depth is variable. For plotting the graph and relation we will apply same process like as above keeping length and width constant and depth is variable. L=36 m, B=12 m, D=3 m, d=.05 m, U=.039 m/sec, ω=.002 m/sec

We know that $u_* = \frac{Un\sqrt{g}}{D^{1/6}}$, from this relating we will get the value of u_*. After this we have to find out the value of $\beta = \frac{\omega}{ku_*}$, and from the graph relation between β and λ we will find the value of λ. Putting these values in the relation of efficiency which is

$$\eta = 1 - e^{-\left(\frac{k\lambda}{6}\right)\left(\frac{Lu_*}{UD}\right)}$$

The obtained result given in the below table

Depth of basin (in meter)	Efficiency
1	89.01
1.5	89.90
2	81.47
2.5	75.54
3	68.87
3.1	67.58
3.2	66.11
3.4	63.79

Table 3.2: Efficiency variation with depth

Feeding these values in a form of graph we get

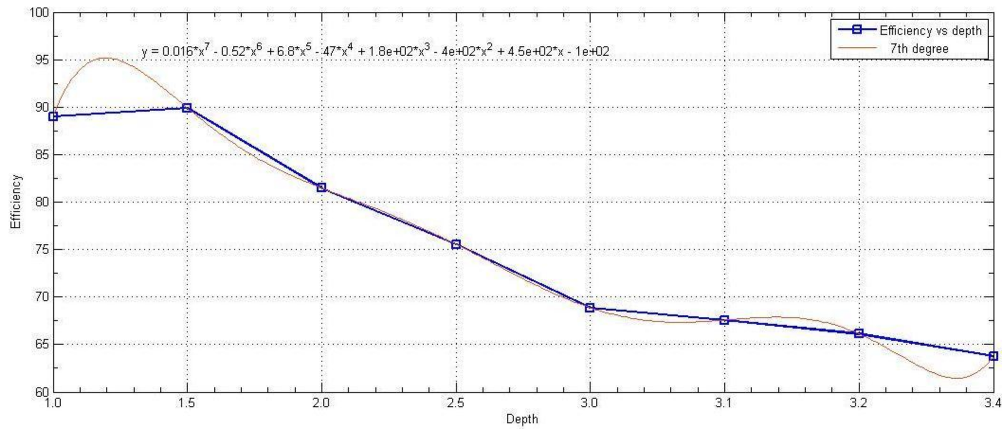


Fig. 3.3: Depths vs. Efficiency

We get a relation between depth and efficiency which is

$$y = 02 - 1e + 02x + 4.5e + 02x^2 - 4e + 02x^3 + 1.8e - 47x^4 + 6.8x^5 - 0.52x^6 + 0.016x^7$$

C. Efficiency vs. ratio of length and breadth

If we choose a fix volume basin having capacity of $1399m^3 \cong 1400m^3$, in which diameter will be constant or fix and the ratio between length and breadth will be variable

In first step when depth is 2.5 m, we will start calculation from the ratio of 3:1 between length and breadth.

Ratio between L & B	Numeric value of L	Numeric value of B	Depth	Efficiency
3:1	40.98	13.67	2.5	82.02
3.3:1	42.98	13.02	2.5	77.28
3.6:1	44.89	12.47	2.5	78.19
3.9:1	46.73	11.90	2.5	78.72
4.3:1	49.07	11.41	2.5	75.40
4.7:1	51.30	10.91	2.5	75.70
5:1	52.91	10.58	2.5	77.29
5.3:1	54.47	10.27	2.5	78.04
5.5:1	55.49	10.09	2.5	75.12
6:1	57.96	9.66	2.5	73.73

Table 3.3: Efficiency variation with ratio of length and breadth

Putting these values for a purpose of graph then we get

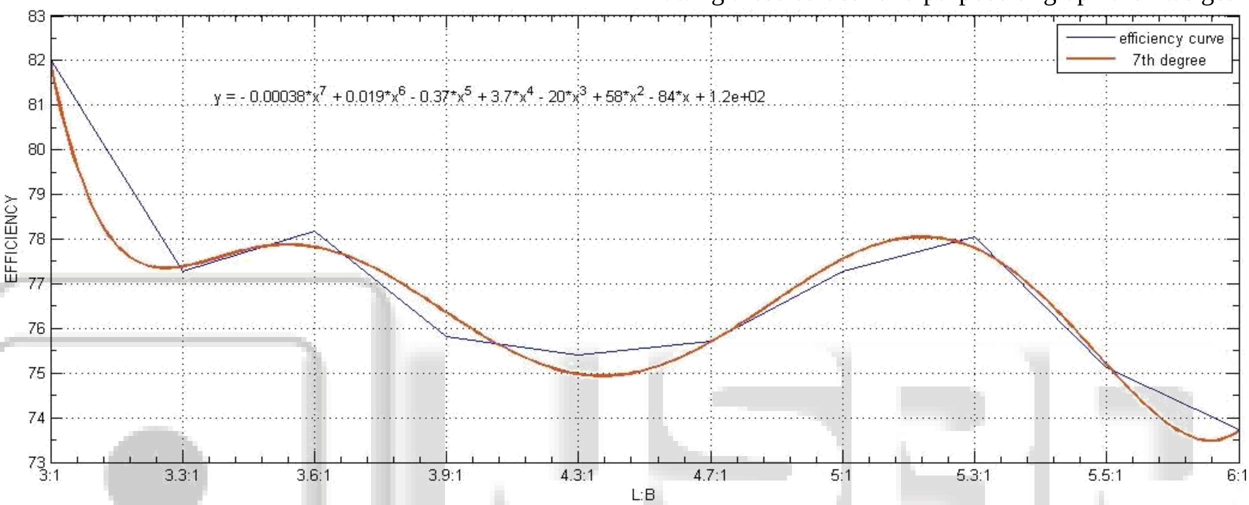


Fig. 3.4: Efficiency vs. ratio of length and breadth

And the relation between ratio of length and width and efficiency as shown below

$$y = 02 + 1.2e - 84x + 58x^2 - 20x^3 + 3.7x^4 - 0.37x^5 + 0.019x^6 - 0.00038x^7$$

D. With change diameter, Efficiency vs. ratio of length and breadth

In second step when depth is 3 m, we will start calculation from the ratio of 3:1 between length and breadth.

Ratio between L & B	Numeric value of L	Numeric value of B	Depth	Efficiency(η)
3:1	40.98	13.67	3	70.73
3.3:1	42.98	13.02	3	71.99
3.6:1	44.89	12.47	3	72.16
3.9:1	46.73	11.90	3	70.69
4.3:1	49.07	11.41	3	69.81
4.7:1	51.30	10.91	3	70.82
5:1	52.91	10.58	3	72.47
5.3:1	54.47	10.27	3	72.42
5.5:1	55.49	10.09	3	70.78
6:1	57.96	9.66	3	69.88

Table 3.4: Efficiency variation with ratio of length and breadth

Putting these values for a purpose of graph then we get

And the relation between ratio of length and width and efficiency as shown below

$$y = 84 - 32x + 29x^2 - 12x^3 + 2.5x^4 - 0.28x^5 + 0.016x^6 - 0.00035x^7$$

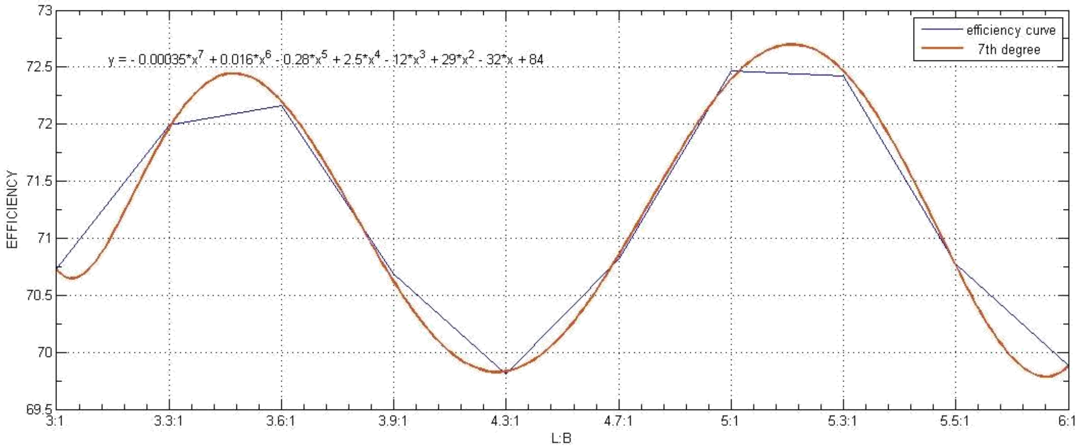


Fig. 3.5: With change diameter, Efficiency vs. ratio of length and breadth

IV. CONCLUSION

There are various way to increase efficiency of settling basin by modification in dimensions of basin. At different different combination of dimensions like length, breadth, width, we will get many variation in efficiency of sedimentation tank. In this thesis work we have calculate the efficiency at varying length with constant breadth and depth at varying ratio of length and breadth with different different depth. We also calculated the efficiency at varying ratio of width and depth. There are many combinations at which we got better efficiency result. Efficiency of basin is mainly depend upon the dimensions of basin, settling velocity of particle, overflow rate etc

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