MODULE – 2

Design of Tank Sluice with a Tower Head

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INTRODUCTION

A ***tank sluice*** is an opening in the form of a culvert or a pipe running through or under the tank bund, and supplying water from the tank to the distributary channel below, to meet the irrigation or other water requirements, as and when needed. Suitable wing walls and other bank connections are also provided as required at the head and tail end of the culvert.

In ordinary medium-sized sluices, masonry culverts with or without arch roofs are generally constructed. The size of the culvert *(i.e.* its cross-section) will depend upon the maximum quantity of water (Q)* it is required to convey, but in no case should be less than **0.6 meter wide and 0.75 meter high**, so as to allow a man to enter it for examination and repairs or removal of obstructions.. The size of the barrel should also be such as to limit the velocity through the sluice barrel to a maximum of **4.5 m/sec*,** under the condition of plug hole being fully open and with the water at full tank level.

In case of very small sluices, earthen ware or cement or cast iron pipes may be used to take the place of masonry culverts. Such sluices are called ***pipe sluices***. They are generally not adopted in tank bunds, where the depth below F.T.L exceeds 2.5 meter or so. This is because, in such cases, the earthen ware pipes may get fractured, or leakage through their joints may take place, resulting in a breach, as the pipes can neither be examined nor repaired easily without cutting open the bund. Moreover, these pipes and especially the cast iron pipes are rarely found to be economical compared to masonry sluices.

Besides the above types of tank sluices, one more type of sluice *i.e.* ***a sluice with a tower head*** is also sometimes provided. This form is sometimes found more economical than the types previously referred to, owing to the saving obtained by avoiding the heavy wing walls of the previous type. Moreover, here there is lesser danger of failure by cracking and bulging which frequently occurs in the wings of the other type. But; on the other hand with such a sluice, additional length of the barrel is required. Tower-heads or wells are generally placed in the water slope of the bund, as thereby, the expanse of a bridge or causeway leading from the bank to the regulation platform is saved. But this has the disadvantage of making it impossible, while the tank .has water, to have access to the portion of the barrel upstream of the well.

Q. Design a sluice taking off from a tank irrigating 200 hectares at 1000 duty. The tank bund through which the sluice is taking off has a top width of 2 meters with 2:1 side slopes. The top level of bank is + 44.00 and the ground level at site is + 34.50. Good hard soil for foundation is available at + 33.50.

The sill of the sluice at off-take is + 34.00. The maximum water level in tank is +38.00. The full tank level is +37.00. Average low water level of the tank is + 35.00. The details of the channel below the sluice are as under :

Bed Level	**+ 34.00**
F.S.L.	**+ 34.50**
Bed Width	**1.25 meters**
Side slopes	**1 ½ to 1 with top of bank at +35.50.**

DESIGN

- Ayacut: 200 hectares
- Duty: 1000 hect./cubic meter/second

$\therefore$ Discharge: $\frac{200}{1000} =$ **0.20 cubic meter/second.**

2.1 VENT-WAY:

The area of the vent-way of the sluice must be such that it can draw normal supplies of water when the tank is at the low water level or a level at which the tank supply will always be available to be drawn during the normal crop period.

The level of the water in the tank is given as +35.00.

Sill of the sluice is +34.00. So the head of water available above the sill level for drawing supplies is 35.00-34.00 = 1 meter.

However, the sluice opening is designed to draw the normal requirements with a driving head of 0.25meters, and when the tank water level is high the vent-way is throttled by means of screw gearing shutters. Assuming a driving head of 0.25m above the centre of the opening, we get the discharge by using the formula

$$Q = C_d * A * \sqrt{2gh}$$

where, C_d is the coefficient of discharge of large orifice usually taken as 0.60.

A is the area of the vent-way and

h is the driving head in meters.

∵ the necessary discharge required is 0.20 cubic meter/second, we have

$$0.20 = C_d*A*\sqrt{2gh}$$

$$= 0.60*A*\sqrt{2*9.81*0.25}$$

$$= 1.328*A$$

$$\therefore A = \frac{0.20}{1.328} = \textbf{0.151 square meters}$$

This gives approximately a diameter of 45cms. for a circular opening. This can be adopted. But the minimum vent-way to be adopted for sluice barrels is about 75 cms.*60 cms., so as to allow room for repair, etc. So, insert a diaphragm stone with 45 cms. diameter opening in it. This will be placed at the entrance to the sluice barrel with regulating arrangements in front of it.

2.2 SLUICE BARREL

The sluice barrel is buried under the tank bund. The barrel will have masonry side walls the roof can be either R.C.Slab laid in situ**,** or pre-cast R.C. slabs with a leveling course of concrete laid over it.

The foundation of the two side walls is continuous in concrete 60 cms. thick, with a wearing coat of richer concrete of 10 cms., thickness serving as floor for the barrel n between the side walls.

2.3 R.C. SLAB

The R.C. slab of the sluice barrel is designed for the clear span of 60 cms. supporting the overburden. So, designing for the maximum possible load, i.e., considering the section of the barrel, at the centre of the bank (**Fig 2.1**), the height of earth supported by the slab is 5.10 meters.

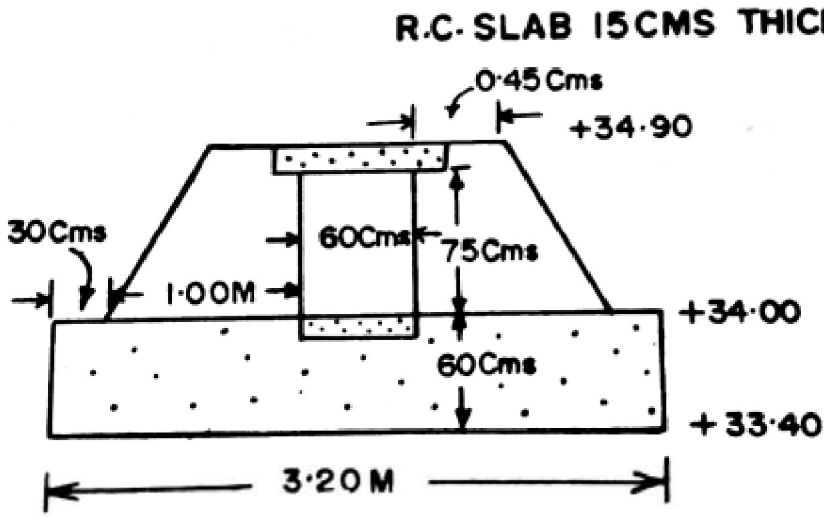


Fig 2.1

The earth will be charged with the percolating water through the embankment. It is designed for saturated earth earth fill.

Height of bank over barrel = 40.00 – 34.90 = 5.10 meters.

Weight of concrete/cubic meter = 2400 kg.

Weight of saturated earth per cubic meter = 2240 kg.

Assume the thickness of slab to be 15cms.

Effective span of slab (60+15) = 75 cms.

Taking a meter width of slab, self-load of slab is :

$\frac{2400*15}{100} * \frac{75}{100}$ = 270 kg.

Weight of earth : 2240*5.10* $\frac{75}{100}$ = 8568 kg.

Add extra = 12 kg.

Total = 8850 kg.

Maximum bending moment $= \frac{WL}{8}$

where, W = 8850 kg, L = 0.75meters. $= \frac{8850*0.75}{8} * 100\ kg.cm.$

= 82,960 kg.cm.

Using 1:2:4 C.C. with stress c= 52.5 kg/sq.cm., and t = 1260 kg/sq.cm., and m = 15, we get an effective depth of 9.7 cms. Adopting a cover of 2 cms, it is enough we adopt a slab having an overall depth of about 12 cms. However, the depth of 15cms. assumed in the deisgn may be adopted.

2.4 SIDE WALLS

The side walls act like abutments. They take the side thrust due to the earth pressure and also the super-incumbent weight of the surcharged earth standing directly on the wall and roof slab. Calculating the earth pressure by *Rankine's Theory*, the stability of one wall is checked by assuming a section as in **(Fig. 2.2)**

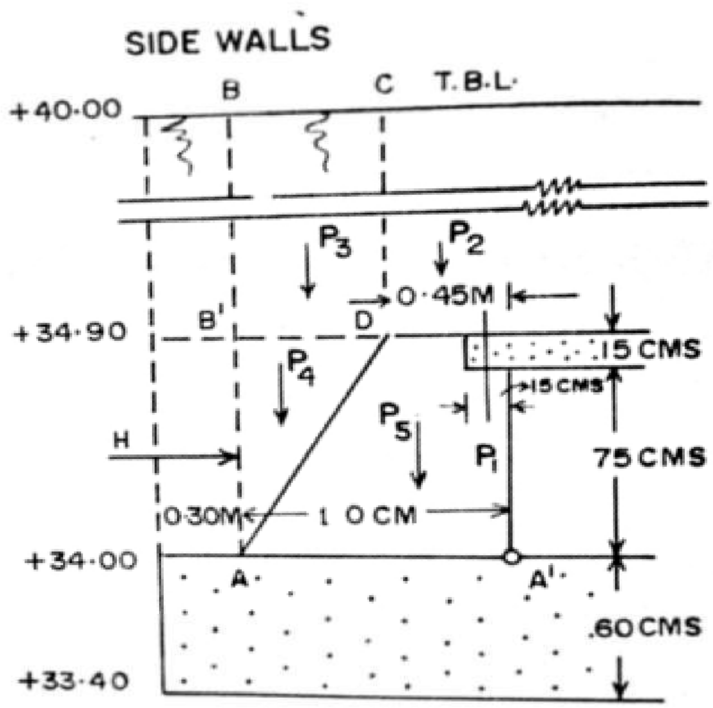


Fig. 2.2

2.5 EARTH PRESSURE

The horizontal pressure acting on the wall at point (A) to be calculated.

Height of earth fill above A = 40.00 – 34.00 = 6.00 meters.

Assuming the weight of earth (saturated) as 2240 kg/m^3 and angle of repose as 30^o.

Earth pressure at A = $\frac{wh(1-sin\theta)}{(1+sin\theta)}$ = 2240 * 6.00 * 1/3 = 4480 kg/m^2.

Earth pressure at D = 2240 * 5.1 * 1/3 = 3808 kg/m2

Total horizontal thrust on the side wall = $\frac{(4480+3808)}{2} * 0.90$ = 3730 kg.

This act at a height of = $\frac{(0.9)}{3} * \frac{(2*3808+4480)}{(3808+4480)}$ = 44 cms. above point A.

Let this force be called **H**.

2.6 WEIGHT TRANSMITTED BY THE ROOF SLAB

Load coming on each side wall (vide art 2.3 where this has been already calculated)

= $\frac{(8850)}{2}$ **= 4425 kg.**

Let this force be called P1. This acts vertically on the side wall at a distance of 7.5 cms. from the vertical face of the abutment.

2.7 WEIGHT OF EARTH ON THE TOP SIDE OF WALL BEYOND THE SLAB

The width of side wall at top is 45 cms.

Deducing the slab bearing, the portion of masonry wall remaining is equal to 45 -15 = **30 cms. or 0.30m**

The weight of earth coming down on this portion = 0.30 * 2240 * 5.1 = **3427 kg.**

Let this force be P2. This acts vertically on the side wall at a distance of 15 + (30/2) = 30 cms. from the vertical face of the abutment.

2.8 WEIGHT OF THE EARTH STANDING ON THE SLOPE OF SIDE WALL

This can be split up into two vertical forces.

(a) The force representing the weight of earth of the rectangular portion.
B' B C D = 5.1 * 0.55 * 2240 **= 6283 kg.**

Let this force be P3 acting vertically at a distance of 45 cms. + (55/2) cms. = 45 + 27.5 = 72.5 cms. from the vertical face.

(b) The force representing the weight of earth standing on the slopping portion AB'D :
= (1/2) * 0.90 * 0.55 * 2240 **= 555 kg.**

Let this force be P4 acting vertically at a distance of {45 cms. + (2/3)*55cms}, i.e., 81.7 cms. from the vertical face.

Weight of masonry per cubic meter is 2100 kg.

2.9 WEIGHT OF MASONRY SIDE WALL

P5 = $\frac{(0.45+1.00)}{2} * 0.90 * 2100$ **= 1370 kg.**

This load P5 acts at a distance of 39 cms. from the vertical face.

2.10 STABILITY ANALYSIS

Taking moments of all forces about the toe (vertical face – A').

FORCE	FORCE IN (kg.)		LEVER ARM (cms.)	MOMENT OF THE FORCE (kg.cms.)
	Horizontal (kg.)	Vertical(kg.)		
P1	...	4425	7.5	33,188
P2	...	3427	30	102,810
P3	...	6283	72.5	455,518
P4	...	555	81.7	45,344
P5	...	1370	39	53,430
H	3730	...	44	(-) 164,120
TOTAL	**3730 kg.**	**16,060 kg.**		**526,170 kg.cms.**

Arm of the resultant from Toe is $= \frac{(526,170)}{16,060}$ = 33 cms.

Eccentricity $= \frac{(100)}{2} - 33$ = 17 cms.

Allowable eccentricity = $\frac{(100)}{6}$ = 16.7 cms.

So, the resultant is just outside middile third.

Maximum compression at toe = $\frac{(16,060)}{100*100}\left(1 + \frac{6*17}{100}\right)$ **= 3.24 kg/cm².**

This corresponds to 3.25 tonnes/sq.m which is within permissible limits of masonry

Tension at the heel A = $\frac{(16{,}060)}{100*100}\left(1-\frac{6*17}{100}\right)$ **= 0.032 kg/cm².**

Hence the section assumed is safe and can be adopted.

2.11 TOWER HEAD

The tower head consists of a masonry well as shown in the drawing in Fig.2.3 into which the shutter operating arrangements are fixed and can be operated from a slab on top of the well.

Generally, these wells are not less than 1.25 meters in internal diameter and have their top taken to at least 30 cms. above MWL of the tank. The bottom of the well rests directly on the foundation concrete of the sluice.

The well steining is designed as a thick cylindrical shell to withstand the radial earth pressure acting on the outer surface. By doing so, the masonry develops hoop compression, which shall not exceed the safe limits of stress the masonry can take.

Assume a section of masonry well as in Fig. 2.3 with inside diameter 1.25 meters.

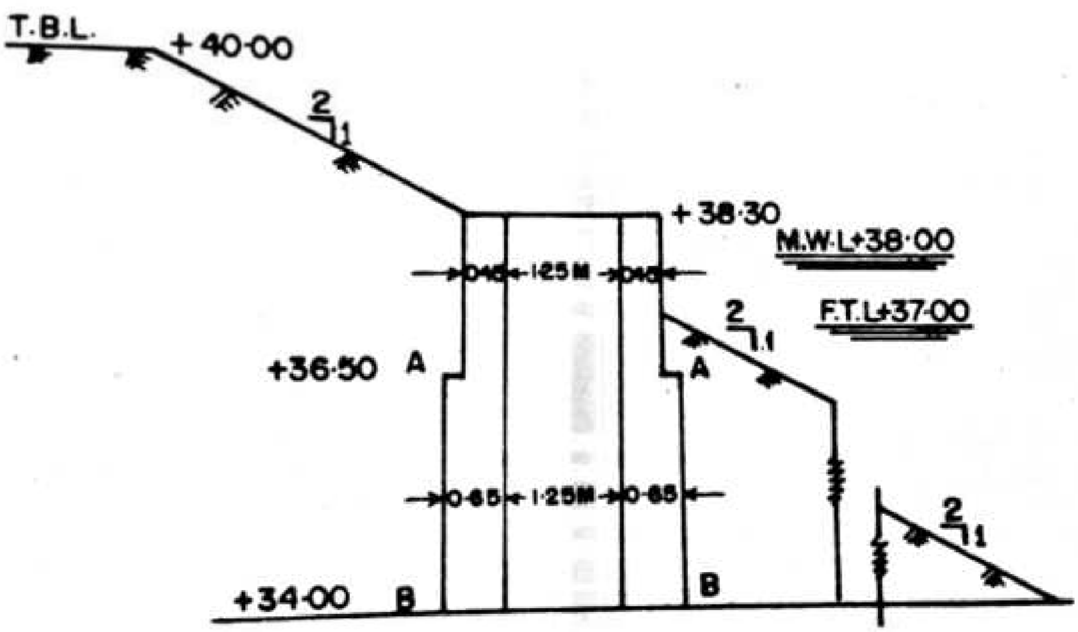


Fig 2.3

The top of well is to be at least 30 cms. above MWL, i.e., keep it at +38.30.

The well is checked for worst condition, i.e., when it is empty.

The total height of well 38.30 – 34.00 = 4.00 meters.

Instead of assuming uniform thickness of well steining right throughout, assume a thickness of shell of 65cms. upto +36.50 and 45 cms. above it up to the top.

Now theck the hoop compression in the steining of the well at level +34.00 where the thickness is 65 cms and also at level +36.50 where the thickness is 45 cms.

The maximum radial presuure is due to the earth standing upto a level +38.30 with a 2:1 sloping surcharge.

In order to check the sections of well at levels +36.50 and at +34.00 it is necessary to ascertain the earth pressure that are actually obtaining at those levels.

The earth pressures are calculated as per *R.C. Designer's Hand Book* by Reynolds

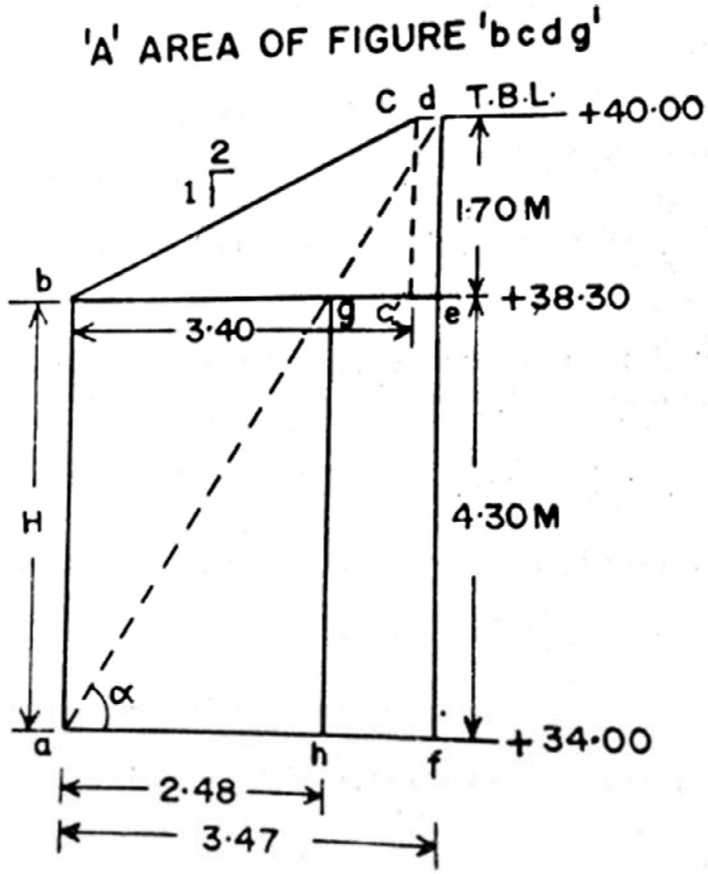


Fig 2.4

Instead of this method, earth pressure can be computed by any of the methods suggested under the " Design of retaining walls", Rebhan's Graphical Method can be conveniently used for obtaining earth pressure with a sloping surcharge as in the present case.

Assuming the angle of repose as 30^o, the pressure on the wall at a depth of h below the top of the wall is given by $P_2 = CK_2wh$, where P_2 is the earth pressure at the point on the wall at a height ***h*** below the top of the wall.

C is a constant given by $C = 1 + \frac{(4.5*A)}{HL}$

where, A = Area of the figure bcdg (**Fig 2.4**)

H = total height of wall

L = horizontal projection of the sloping surcharge, i.e., horizontal projection of '*ad*'

$\alpha = 45 + (\theta/2)$, where θ is the angle of repose.

Assuming angle of repose as 30^o. we have $\boldsymbol{\alpha} = 45 + (30/2) = 60^o$.

In the sketch, the area of the figure '*bcdg*' is to be determined.

Angle *daf* = $\alpha = 60^o$.

∴ $\tan 60^o = \frac{df}{af} = \frac{6.00}{af}$

∴ $af = 6.00*\cot 60^o = 6.00 * 0.5774$

L = 3.466 or 3.47 meters.

Similarly, *ah* = 4.30*cot 60o = 4.30 * 0.5774 = 2.48 meters

cd = *be* – *bc'* or *af* – *bc'*

bc' = 2*1.70 (∵the slope is 2:1) = 3.40 meters.

∴Value of *cd* = 3.47 – 3.40 = 0.07 m.

Similary, *bg* = *ah*

= 2.48 m.

∴ Area of the figure '*bcdg*' $= \frac{(0.07+2.48)}{2} * 1.70$ sq.m = 2.55*0.85 = 2.17 m^2.

Value of the coefficient $C = 1 + \frac{4.5*A}{HL}$

where, A = 2.17 m2, H = 4.30m and L = 3.47 m.

$\therefore$ C = $1+\frac{4.5*2.17}{4.30*3.47}$ = 1+0.65 = 1.65

Calculating the earth pressures by the formula P2 = $CK_2\ wh$

Where the value of $K_2 = \frac{(1-sin\theta)}{(1+sin\theta)}$ with $\theta = 30^o$ is 0.333.

The earth pressure on the well steining at a level of 34.00 = 1.65 * 0.333 * 2240 * 4.30

= 5291 kg/m^2.

The earth pressure on the well steining at a level of +36.50 = 1.65 * 0.33 * 1.80 * 2240

= 2216 kg/m^2.

2.12 CHECKING THE THICKNESS OF THE WELL AT +36.50

Radius of the outer periphery = $\frac{1.25+0.90}{2}$ = 1.08 m.

Now the two conditions are

Fig 2.5

(i) Outside radial pressure is 2216 kg/m2 and radius 1.08 meters.

$\therefore$ 2216 = a + $\frac{b}{R^2}$ where a and b are constants.

$\therefore$ 2216 = a + $\frac{b}{1.08^2}$

= a + $\frac{b}{1.17}$ -------- (1)

(ii) There is no water thrust from inside of the well. This gives the worst condition.

Internal radius $= (1.25/2) = 0.63$ meter

$\therefore 0 = a + \frac{b}{0.63^2}$

$= a + \frac{b}{0.40}$ ----------- (2)

Solving equations (1) and (2), we get

$2216 = \frac{b}{1.17} - \frac{b}{0.40}$

$\therefore 2216 = b * \frac{(0.40-1.17)}{1.17*040} = \frac{-0.77\,b}{0.468}$

$\therefore b = \frac{-2216*0.468}{0.77}$

b = (-) 1347. Substituting this value we get

a = $-\frac{b}{0.40} = \frac{1347}{0.40}$ = **3367**

The hoop compression in the steining is given by

$f = a - \frac{b}{R^2}$

where, a = 3367 and b = - 1347.

The hoop compression in the inner periphery of the well

$f = 3367 + \frac{1347}{0.40}$ = 3367 + 3367

= 6734 kg/m^2.

The hoop compression on the outer periphery of the wall

$f = 3367 + \frac{1347}{1.17}$ = 3367 + 1152

= 4519 kg/m^2.

This shows that no tension is developing in the steining and the maximum compression stress is within the permissible limits for masonry. Hence the section assumed is quite safe.

2.13 CHECKING THE THICKNESS OF WELL AT +34.00

The radial pressure on the outer periphery of the well = **5291 kg/m^2.**

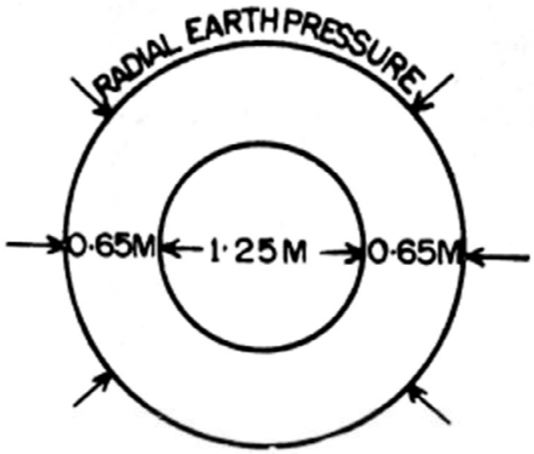
Outer radius = $\frac{(1.25+1.30)}{2}$ = **1.28 m.**

The two considerations are :

(i) $5291 = a + \frac{b}{1.28^2} = a + \frac{b}{1.64}$ ---------(1)

(ii) There is no pressure from inside of the well.

Internal radius = (1.25/2) = 0.63 m.



∴ $0 = a + \frac{b}{0.63^2} = 0 = a + \frac{b}{0.40}$ --------- (2)

Solving equations (1) and (2), we get

$5291 = \frac{b}{1.64} - \frac{b}{0.40} = \frac{b}{0.656}(0.40 - 1.64)$

$= - \frac{1.24*b}{0.656}$

∴ $b = - \frac{5291*0.656}{1.24}$ = **- 2800**

∴ $a = \frac{-b}{0.40}$

∴ $a = \frac{2800}{0.40}$ = **7000**

Hoop compression in the well steining on the inside periphery,

$f = a - \frac{b}{R^2}$

where, R = 0.63 m

$= 7000 + \frac{2800}{0.40}$ = 7000 + 7000 = **14,000 kg/cm^2.**

Hoop compression on the outer periphery

$f = a - \frac{b}{R^2}$

where, R = 1.28 m

$= 7000 + \frac{2800}{1.64}$ = 7000 + 1708 **= 8708 kg/m^2.**

Thus, there is no hoop tension developing and the compressive stresses are all within permissible stresses of masonry. Hence, the assumed sections can be safely adopted.

2.14 CISTERN IN REAR OF THE BARREL

The dimensions of the cistern are fixed arbitrary to suit the earth connections of the channel and tank bund. The cistern enables to take-off more than on channel through separate openings in its side walls. In this case only one channel is proposed in rear and the width of opening is kept as the bed width of the channel. The cistern also functions as a stilling basin for the onrushing waters through the barrel and reduces any possible scours in the channel.

Nominal talus is proposed in the channel in continuation of the cistern.

2.15 SPECIFICATIONS

Foundation: the foundation concrete of the desired thickness can be in 1 : 3 : 6 or in 1 : 4 : 8 with hard broken coarse aggregate.

The wearing coat over the foundation concrete inside the barrel has to be laid along with the foundation concrete. The mix could be in C.C. 1 : 2 : 4 using granite chips and rendered smooth. The purpose of this is to present a hard and smooth surface.

Roof slab: The roof slab is of R.C.C. with a 1 : 2 : 4 mix using 20 mm hard granite chips. If pre-cast slabs are used a leveling course of lean concrete of proportions, say 1 : 4 : 8 of about 15 cms. thickness may be laid to prevent seepage leaking into the sluice barrel.

Masonry: The abutments of the sluice barrel and the cistern walls etc., could be in stone masonry in C.M. 1 : 6. The exposed faces of the masonry walls may be plastered smooth in C.M. 1 : 4.

The steining of the wall also could be in stone masonry, as stipulated above. In this case the stresses in the well steining are of compressive nature only. The well steining should be in reinforced concrete in cases where tension develops in the steining.

REFERENCES:

1. ***Water Resources Engineering – Principles and Practice*** : Satya Narayana Murthy Challa

ASSIGNEMENT

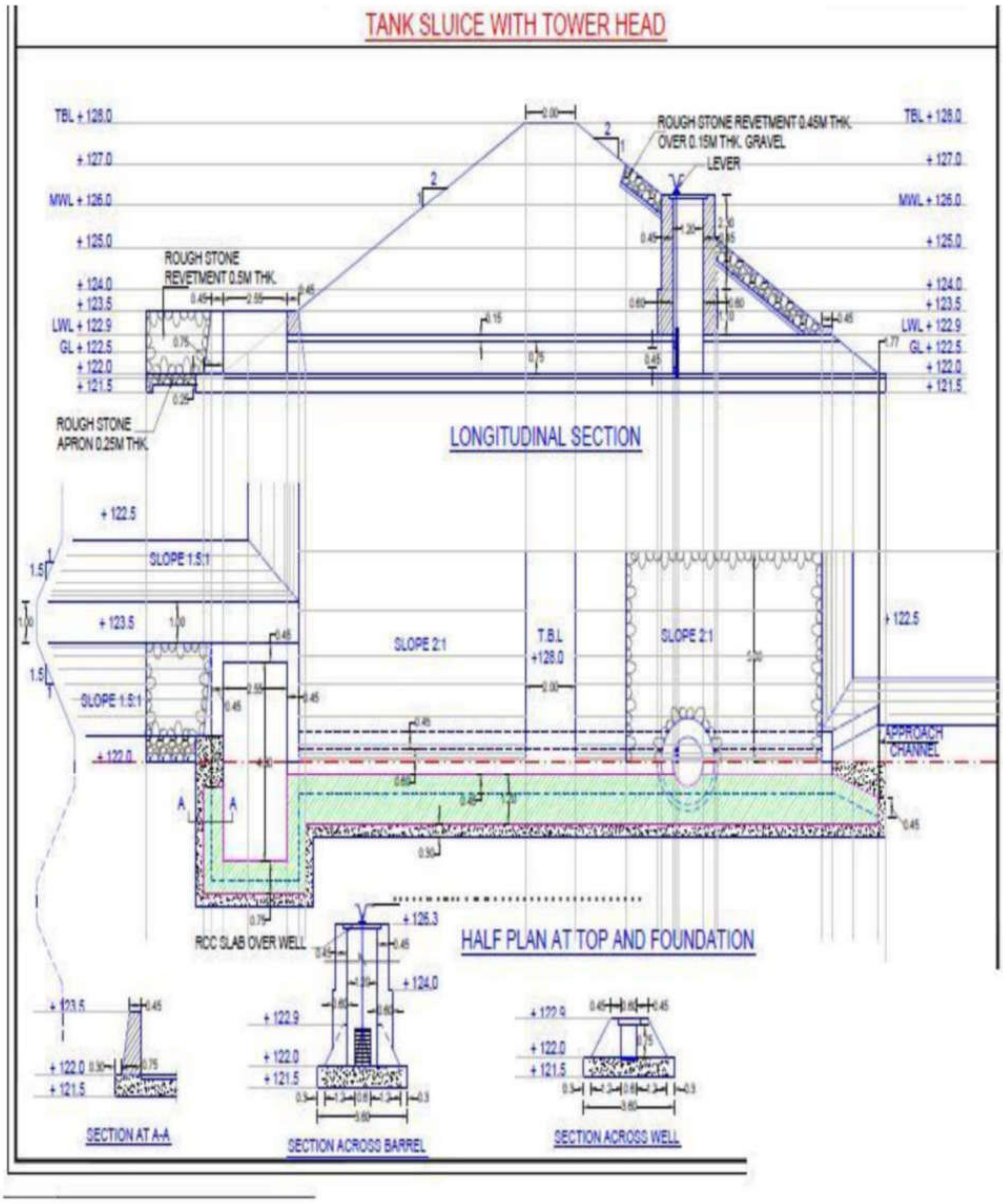
Design a sluice (tank sluice with tower head) takes off from a tank with the following data:

Discharge = 0.25 m^3/sec.
Top width of bund = 2.0 m
Side slopes 2:1
Top level of bank = +100.00 m
Ground level at site = +94.50 m
Sill of the sluice at off-take is = +94.00
Maximum water level in the tank = +98.00
Full tank level is = +97.00
Average low water level is = +95.00
Good hard soil for foundation is available at +93.50

Details of canal below the sluice:

Bed level = +94.00
FSL = +94.50
Bed width = 1.30
Side slopes = 1.5:1 with top of bank at +95.50

Draw longitudinal section. Assume any other suitable data.



TANK SLUICE WITH TOWER HEAD
TBL + 128.0
+ 127.0
MWL + 126.0
+ 125.0
+ 124.0
+ 123.5
LWL + 122.9
GL + 122.5
+ 122.0
+ 121.5
ROUGH STONE REVETMENT 0.45M THK. OVER 0.15M THK. GRAVEL
LEVER
ROUGH STONE REVETMENT 0.5M THK.
ROUGH STONE APRON 0.25M THK.
LONGITUDINAL SECTION
SLOPE 1.5:1
SLOPE 2:1
T.B.L +128.0
APPROACH CHANNEL
RCC SLAB OVER WELL
HALF PLAN AT TOP AND FOUNDATION
+ 126.3
SECTION AT A-A
SECTION ACROSS BARREL
SECTION ACROSS WELL