THE DESIGN OF A SPRINKLING FILTER BED FOR THE EAST LANSING SEWAGE TREATMENT PLANT

THESIS FOR THE DEGREE OF B. S.

Arthur L. Smith

1930

Civil engineering Sanitary engineering

THE DESIGN OF A SPRINKLING FILTER BED

FOR THE EAST LANSING SEWAGE TREATMENT PLANT

A Thesis Submitted to

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By

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Candidate for the Degree of

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THESIS

CONTENTS

ACKNOWLEDGMENT

I wish to express my gratitude to F. R. Thereux for the sincere advice and guidance he has extended to me concerning this problem.

Arthur L. Smith.

INTRODUCTION

The City of East Lansing, Michigan has a sewage treatment plant, located west of Harrison Road near the south bank of the Red Cedar River. The plant consists of a pumping station, Imhoff tanks, and sludge beds.

It is desired to present the design of suitable additional treatment works to accommodate the effluent from the present plant. The additional works are to consist of twin dosing tank feeding to separate nozzled sprinkling filter beds and a secondary settling tank.

The final effluent is to be discharged into the Red Cedar River.

FILTER BEDS IN GENERAL

A sprinkling filter bed may be described as being an artificial bed of broken stone on slag, retained within walls and a smooth watertight floor. The floor is thoroughly drained. The treated sewage is sprayed intermittently but uniformly as possible over the entire surface of the bed.

As the treated sewage is applied to the bed an organic film gradually forms on the filter media where bacteria thrive. The suspended matter in the sewage clings to the organic coatings and is turned into more stable substances by the bacteria.

This type of filter bed undergoes periodical unloading of the organic material in the bed. Due to this, it is necessary to give the bed effluent a secondary settling to clarify and remove the settleable solids.

The solids from the bed effluent may be returned to the preliminary treatment tank for digestion. The liquid may be turned into a nearby stream or body of water.

This treatment with preliminary and final sedimentation has been able to produce an effluent not subject to putrefaction, low in bacterial count and well clarified in appearance. Effluents have been produced having over 90% reduction of bacteria and 80 to 85% reduction of the biochemical oxygen demand of raw sewage.

Sprinkling filters afford a comparatively cheap method of producing a stable effluent. They are inexpensive to operate and seldom give trouble. The beds being assembled of concrete, stone, tile, and cast iron ensures the bed as being permanent and free from excessive maintenance.

COLLABORATORS:
Peterson
Theroux
Smith
Howell
EAST LANSING SEWAGE
AVERAGE DAILY FLOW CURVE
(April 10-11, 1930)
1,000,000 gals. average per 24 hr.
LEGEND
Area-Velocity Method By Surface Floats
Slope-Depth Method
Adjusted Values
FLOW (c.f.s.)
FLOW in thousands of gals. per hr.
HOUR
P.M.
A.M.
2.8
2.6
2.4
2.2
2.0
1.8
1.6
1.4
1.2
1.0
.8
.6
.4
.2
0
75.6
70.2
64.8
59.4
54
48.6
43.2
37.8
32.4
27
21.6
16.2
10.8
5.4
12:00
1:00
2:00
3:00
4:00
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INVESTIGATION

Before attempting any design it is necessary to know the conditions that have to be met and dealt with. To design a treatment plant to serve the present Imhoff tank effluent it is necessary to know the amount of sewage the tank is capable of treating.

I computed the tank capacity using nominal design units of two hours detention period, two cubic feet of sludge storage per capita, effective channel length, and one hundred gallons of sewage per capita per twenty-four hours. I found the tank to be capable of serving ten thousand people without overloading.

As a further check I have taken results of a twenty-four hour gaging of the East Lansing sewer. This is compiled in the accompanying curve. Computations from this curve show the tank to be treating slightly under one million gallons of sewage per twenty-four hours.

The final effluent is to be discharged into the Red Cedar River. It is desirable to try to keep the bottom of the filter bed above the high stages of river flow and to avoid additional pumping. However, there is no particular harm in allowing the river to fill the lower section of the bed for brief and occasional periods when the river is at an unusually high stage.

I referred to Volume XXVI of the Daily Stages of Principal Rivers of the United States for data concerning the Red Cedar River. I obtained the following:

Flood stage of the river - elev.		829.80
Highest " " " "	"	835.70
Bank Full" " " "	"	827.80
Lowest " " " "	"	822.40

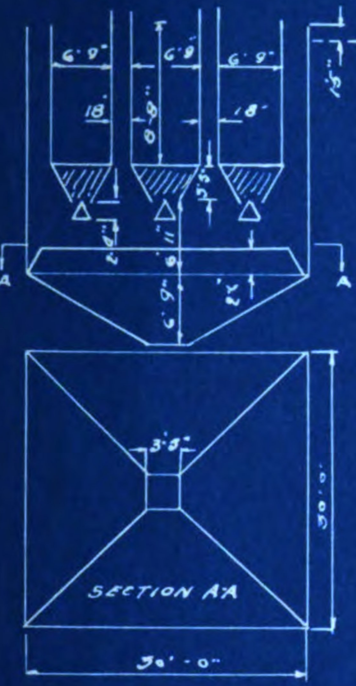
The flood stage of the river is reached during the spring months and periods of excessive rainfall. Comparing these elevations with the elevation of the Imhoff tank effluent which is 839.50, it is readily seen that to avoid pumping a low head filter plant must be built.

Sewage treatment plants are designed to allow for future expansion and plant enlargement to accommodate the future populace. The present tank is located in the northern side of the tract of land obtained for a sewage treatment plant. Sufficient room has been allowed to place a similar Imhoff tank south of the present tank. I believe it advisable to place the additional treatment works in the northwestern part of the land available and quite close to the river. This will allow for future enlargement on the present property. It would be possible to provide for a complete dual system of treatment.

CONCLUSION

I wish to submit the complete construction cost of the filter bed which is the major expense envolved. I have estimated the cost to be $105,393.45.

Computations to determine the capacity of the Imhoff Tank



Line Sketch showing a section thru the Imhoff tank hoppers
The tank has three hoppers of the size shown.
The sedi-channels have webs placed at the third points as the shaded section shows.
The effective channel length is 86'-0"

Data:
Detention period 2 hours
Effective sedi channel length 86'-0"
Gallons of sewage per capita per 24 hours - 100
Sludge storage per capita. 2 cubic ft
The sludge is stored up to 18" below the openings in Sedi-chamber.

The cross sectional area of the sedi chamber.
7.25 x 6.77 = 49.1 sq ft for 1 channel
The Velocity of flow is $\frac{86}{2 \times 60}$ = .716 ft/min.
The total flow for 24 hrs =
.716 x 49.1 x 3 x 60 x 24 x 7.5 = 1,138,000 gallons.
Allowing 100 g.p.d.c. and the sedi-channels will serve 11,380 people.

Sludge storage availiable:
The Volume of one hopper =
$\frac{1}{3}$ x 6.75 x 30 x 30 = 2025 cu.ft.
5.5 x 30 x 30 = 4890 " "
Total 6915 " "
Vol. of 3 hoppers = 20745 cu.ft.
Vol. of 2 trapezoids =
2.5 x 2 x 23.83 x 1.16 138 " "
Total sludge storage availiable = 20983 cubic feet.
Allow 2 cu.ft. sludge storage per capita and the tank is capable of serving 10492 people.

The computations for the determination of the flow in the East Lansing Sewer for twenty four hours.

The results of a twenty four hour gaging of the East Lansing sewer are shown in the form of a curve.

The summ of the total ordinates of the adopted curve is equal to 73.75 (30 Min. ordinates)

$\frac{73.75}{48}$ = 1.535 cubic feet per second. a an average flow.

This reduced to gallons. per. 24 hours
60 x 1.535 x 60 x 24 x 7.5 = 998 000 g.p.d.

The computations for the design of the filter bed and its appliances.
I wish to follow the guidance of Catalog No 30 published by the Pacific Flush Tank Co 4241 Ravenswood Avenue Chicago. Ill.. They advise the selection of head losses and units to be used rather than the computation of them. They advise to design to meet the selected losses.

The total head availiable to use in the dosing tank and filter bed is 11 feet.

Total depth of the bed	5.00'
Total Maximun Net Head	6.00'
Losses	
Entrance loss in dosing tank	0.40'
Dosing tank Loss	0.40'
Syphon loss	0.40'
Distribution loss	0.40'
Maximum net head	4.40'
Net terminal head	1.50'

Max. Number of gallons to be treated in 1 day = 1 M.
Max. Rate of flow 1.5 M.
Rate of application to the filter bed 250,000 g.p.d. A. ft.
Total depth of the bed 5' effective depth 4.5'

Dosing cycle - 5 minute dosing period and 5 minute rest period

The computations for the surface area of the filter bed.

Maximum Number of gallons to be treated in one day = 1,000,000

Rate of application per acre foot per day. 250,000 gal

Effective depth of the filter bed 4.50'

$4.5 \times 250,000 = 1,125000$

$\frac{1.000}{1.125} = .889$ Acres of surface area.

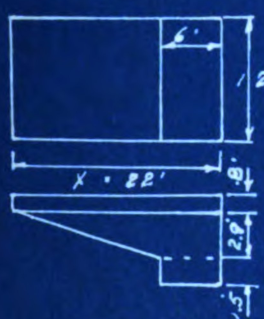
$.889 \times 43560 = 38700$ sq.ft. surface area of the filter bed.

Dimensions of the bed.

$\sqrt{38700} = 196.5'$

Using a divided bed the dimensions of each half of the bed = 196' x 98'

Interior dimensions of the dosing tank



Sketch of one of the twin dosing tanks

Max. Rate of flow 1.5 M.g.d. = 1041 g.p.m.

Each tank must accomodate 5 minutes flow 1041 X 5 = 5205 gal = 694 cu.ft.

Solving for x by equation.

$(.8 \times 12x) + \frac{(12x + 72)}{2} 2.9 = 694$

$27x = 5898$

$x = 21.85' = 22'-0''$

Using the formulas and curves of the catalog No. 30 of the Pacific Flush Tank Co.

Limit of tank inflow P.F.T. Cat No 30 Fig. 18

Not greater than .14 g.p. sq.ft. per min. with 7/8 nozzles being used on the filter bed.

$\frac{1041}{38700} \times 2 = .0538$ The inflow is below the maximum allowable

Net terminal head selected equal 1.50'

Gross terminal head = $\frac{\text{Effective Net head} \times \text{Net Ter. head}}{\text{Max. Net Head}}$

G.T.H. = $\frac{5.2 \times 1.5}{4.4}$

Gross terminal head = 1.775'

Effective SPACING per 7/8" Nozzle = 9.8'
Fig 16 P.F.T.Co. Cat. No 30

square feet. per nozzle of effective bed area =
82 sq.ft. per 7/8" Nozzle.

Number of nozzles required
$\frac{38700}{82}$ = 472 - 7/8" Nozzles for the entire bed.
236 " " " 1/2 the bed.

Syphon diameter
Fig 20 P.F.T.Co Cat. No 30

$d = \sqrt{CN}$ d = diam. of syphon
$d = \sqrt{2.15 \times 236}$ C = coef. from curve.
$d = \sqrt{507}$ N = No of Nozzles
d = 22.5"

24 inch syphon is the nearest commercial size

The 236 nozzles required for each half of the bed are divided into 23 laterals having 10 nozzles each. The head loss designated for distribution loss is equal to 0.40 feet. This is subdivided into 0.20' for the mains and 0.20' for the laterals.

Mains are to be of uniform size.
Page 37 P.F.T Cat. No. 30.

$H = MFN^2C$ H = h/L available = 0.20'
$H = 2.4 \times 4324 \times 100$ C C = coef. for pipe diameter 24" = .0000986
H = 1037 C M = Coef. for M.N.H. + Nozzle diam = 2.4
H = 1037 x .0000986 F = coef for the number of laterals = 4324
H = .1025 N = No. of Nozzels per lateral = 10

Use a 24" Main with the 24" syphon.

The laterals are to be of uniform size
Page 35 P.F.T. Cat. No. 30

h = C m F h = h/L available
h = C 2.8 x .506 c = Coef. for pipe diam.
h = 1.415 C m = coef. for MNH. + Nozzle diam
h = 1.415 x .143 F = Coef. for No. of Nozzles per main
h = .2025 c for 6" diam lateral = .143

This is high but will be balanced by the low head loss of the main

Total h/L of main and lateral	=	0.40
" " " "	=	.1025
" " " lateral available	=	.2975
" " " "	=	.2025
h/L in excess	=	.0950

The computations for the design of the secondary settleing Tank.

Data.

Detention Period = $1\frac{1}{2}$ hours.

Allowable depth of the tank is 6-0". This is dependent on the fact I wish to have the sludge from the tank returned to the wet Well, and pumped with the raw sewage into the digestion tank. No Storage is required.

Maximum Rate of flow is 1.5 M.G.D. = 1042 g.p.m.

$1\frac{1}{2}$ hrs = 90 minutes - the tank capacity
$90 \times 1042 = 93780$ gallon = 12,500 cubic feet.

$\frac{12500}{6} = 2083$ sq ft of tank surface area.

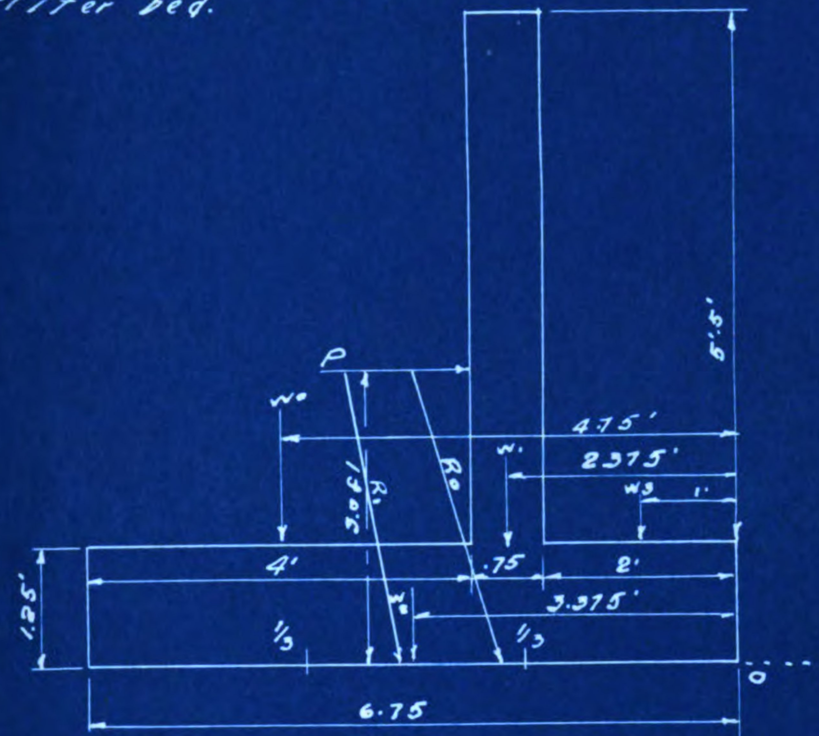
$\sqrt{2083} = 45.7'$

The tank is to be 45' x 45' x 6' with an additional two feet for freeboard depth.

Design Notes.

Provide deep baffle plates in front of the entrance pipes. Place an effluent Weir across the entire width of the tank with a baffle in face of the weir. Give the floor a slight slope towards the center sludge draw off.

The Computations for the design of retaining wall of the filter bed.



The sketch shows the section adopted for the retaining wall. It is a contilever type wall. The wall is to be subjected to various loadings, the center of gravitys are shown and dimensioned from the point of over turning-point O

I considered the bed to be filled with water to test the bed for water tightness before placing the filter media.

Full hydrostatic pressure is considered

$P = \frac{1}{2} wh^2 = \frac{1}{2} \times 6.25 \times 5.5^2 = 945^{\#}$

$W_0 = 6.25 \times 4 \times 5.5 = 1375^{\#}$

$W_1 = .75 \times 5.5 \times 1.50 = 619^{\#}$

$W_2 = 6.75 \times 1.25 \times 150 = 1267^{\#}$

check against overturning.

overturning moment = $P \times 3.081 = 945 \times 3.081 = 2920^{\#/1}$

Resisting "

$W_0 - 1375 \times 4.75 = 6540^{\#/1}$

$W_1 - 619 \times 2.375 = 1467^{\#/1}$

$W_2 - 1267 \times 3.375 = 4280^{\#/1}$

Total $= 12287^{\#/1}$

The wall is safe against overturning

Factor of safty $= \dfrac{12287}{2920} = 4.21$

Solving for the result of forces.

$R_V = \frac{12287}{3261} = 3.37'$ This is combined with P Graphically on the sketch (Fa)
ΣW

The Resultant of forces is in the middle Third

Check the wall against sliding.

Sliding force p is 945#

weight of the wall is 3261#

Coef. of friction .33

Resistant force to sliding is 3261 x 33 = 1080#

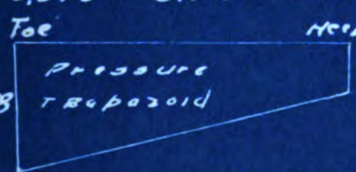
Factor of safty $\frac{1080}{945} = 1.141$

The Wall is safe against overturning.

Foundation pressures = $\frac{W}{b}\left(1 \pm \frac{6x_0}{b}\right)$

$x_0 = ~~3.375~~ \frac{12287 - 2920}{3261} =$

$x_0 = 3.375 - 2.865 = .510$



$\frac{3261}{6.75}\left(1 \pm \frac{6 \times .510}{6.75}\right) =$

$483(1 \pm .44) = 483 \pm 215$

$= 698 + 268$

Consider the bed to be filled with crushed rock and filled with water due to flooding.

Check the ability of the wall to resist the forces created

Data

Using crush stone Weight 130# cubic foot. - 40% voids

The bed is completly filled with water.

Allow full hydrostatic water pressure against the face of the wall. The wedge of crushed stone is small. Full hydrostatic pressure ofsets this value.

Total weight of a cubic foot of stone and water is equal to $130 + (40\% \times 62.5) = 155$# cu.ft.

$P = \frac{1}{2} w h^2 = \frac{1}{2}\ 62.5 \times 5.5^2 = 945$#

$W_0 = 155 \times 4 \times 5.5 = 3420$#

$W_1 = .75 \times 5.5 \times 150 = 619$#

$W_2 = 6.75 \times 1.25 \times 150 = 1267$#

Test the wall for overturning

overturning moment = 2920 #/l

Resisting moment

W_0	3420 x 4.75	=	16250 #/l
W_1	619 x 2.375	=	1467
W_2	1267 x 3.375	=	4280
	5306		21997 #/l

$\frac{21997}{5306}$ = Rv point of action 4.14 This is combined with P graphically on sketch = R. The resultant force is in the middle third of the base

Overturning Moment = 2920 #/1
Resisting " 21997 #/1

The wall is safe against overturning by a factor of safety $\frac{21997}{2920} = 7.48$

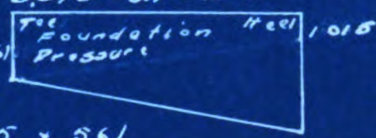
Sliding force on the wall is 945 #

Resistance to sliding is 5306 x .33 = 1750

Factor of safety against sliding = $\frac{1750}{945} = 1.81$

The eccentricity = $3.375 - \frac{21997-2920}{5306} = 3.575 - 3.7 = .325$

Foundation pressure $\frac{W}{b}\left(1 \pm \frac{6 \times e_0}{6.75}\right)$



$\frac{5306}{6.75}\left(1 \pm \frac{6 \times .325}{6.75}\right) = 778 \pm 227 = 1015 + 561$

The design of the steel for the vertical Cantilever.

The Maximum bending moment is equal to 2920 #/1

The thickness of the cantilever = 9"

The effective thickness of the cantilever is 6"

Use $f_c = 550$ $K = 82$ $f_s = 16000$ $j = .887$

The above values are taken from Hools Vol I Reinforced concrete construction. The steel formulas are also taken from this same volume.

$M = bd^2K$ $d^2 = \frac{M}{bK} = \sqrt{\frac{2920 \times 12}{12 \times 80}} = \sqrt{35.65}$ d = 5.95 Use 6" for effective depth.

The ratio of steel to concrete is found by $p = \frac{K}{f_s j} = .00575$

The steel area = $A_s = pbd$

$A_s = .00575 \times 12 \times 6$

A_s = .414 sq in of steel per lineal foot of wall

Select 3/4" ⌀ bars at 12" c to c

Check the bond Stress $u = \frac{V}{\Sigma o j d} = \frac{945}{\frac{12}{12} \times 2.356 \times .89 \times 6"} = 75.2$ #

The bond stress is under the maximum.

Check the shear of the wall

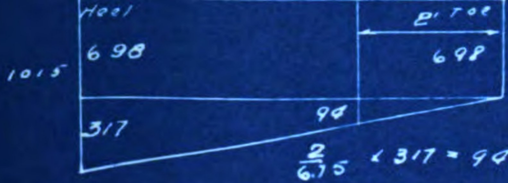
$v = \frac{V}{bjd} = \frac{945}{12 \times .89 \times 6"} = 14.75$

The shear is under the maximum allowable.

The temperature steel for the vertical cantilever

Use .2% = .002 x 9 x 12 = .216

Use 1/2" ⌀ bars spaced 10" c-c and 2" below the surface of the out side face of the wall. Run the steel in both directions on the wall. Use the same for temperature steel in the back face of the wall, that is 1/2" ⌀ bars 10" c to c perpendicular to the cantilever steel and parallel to the face of the wall.



trapozoid of foundation pressures under the wall from the maximum pressures found in previous computations

The bending moment is equal to
$2 \times 698 + \frac{94}{2} \times 2 \times \frac{2}{3} = 1396 + 62.6 = 1458.6$ #/1

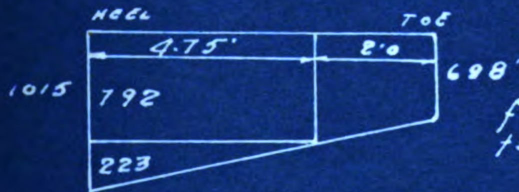
The cantilever is 15" thick. Use an effective thickness equal to 12"
Use $f_c = 550$ $f_s = 16000$ $K = 82.9$ $p = .0058$ $j = .887$
$A_s = pbd = .0058 \times 12 \times 12 = .831$ sq in steel per foot.
Shear of the toe is $v = \frac{V}{b j d} = \frac{698 + 698 + 94 \times 2}{2 \times 12 \times .887 \times 12} = 11.65$ #/□"

Shear of the toe cantilever is O.K.
Select 3/4"○ bars at 6" diam for the steel reinforcing = .88 sq.in. per ft.

Check the bond of the steel. $\frac{V}{\Sigma o j d} = \frac{1490}{\frac{12}{6} \times 2.356 \times .89 \times 12} = 29.6$ #
The bond of the steel is allright 80# is the allowable value.

The temperature steel in the toe cantilever use = .2 %
$.002 \times 12 \times 12 = .288$ 1/2 ○ bars at 8" = .29 sq in. per foot.

The computations for the design of the reinforcing steel in the heel cantilever.



The heel is also 15" thick. Use a 12" maximum effective depth.
$f_c = 550$ $K = 82$ $p = .0058$
$f_s = 16000$ $j = .887$

The bending moment of the heel is equal to
$792 \times 4.75 \times \frac{4.75}{2} + \frac{223}{2} \times 4.75 \times \frac{4.75}{3} \times 2 =$

$8940 + 1675 = 10675$ #/1

$M = bd^2K = d^2 = \sqrt{\frac{M}{bK}} = \sqrt{\frac{10675}{12 \times 82}} = 11.4$ use 12" as the effective depth.

The shearing force on the cantilever $= \frac{1015 + 792}{2} \times 4.75 =$ 4530#
The unit shear is equal to $v = \frac{V}{b j d} = \frac{4530}{12 \times .89 \times 12} = 34.5$#
The shear is under the maximium allowable.

$A_s = pbd = .0058 \times 12 \times 12 = .838$ sq in per foot.
Select 3/4" ⌀ bars at 6" c-c = .88 sq in per foot.

Check the bondstress using 3/4" ⌀ at 6" c-c.

$u = \frac{V}{\Sigma o j d} = \frac{4530}{\frac{12}{6} \times 2.356 \times .887 \times 12} = 87.5\#$ This a high value Hooks may be added to insure the bond.

Temperature steel = .002 bd = .002 x 12 x 12 = .288
Select 1/2" ⌀ bars at 8" = .29 sq in. per foot.

Design of the steel for the floor slab.
The slab is 8" Thick - Temperature steel is all that is required as the slab rests entirely on earth foundations using .002 bd for temperature steel .002 x 12 x 8 = .192 □" per ft.
1/2 ⌀ rods at 12" = .202 sq.in. per sq.ft.
Space 1/2" ⌀ rods 12" apart in both directions parallel to the surface of the floor. Use a depth of 6" below the surface.

Design of the steel for the slab covering the pipe gallery.
The distance between centers of supports = 9.25'
The slab is 8" thick.
The live load is 50#/ft.
Dead load per foot = $\frac{8}{12} \times 150 = 100\#/ft.$
Total load = 150#/ft.
The bending moment is equal to $\frac{1}{8} wL^2 = \frac{150 \times 9.25^2}{8} = 1602\#/l$
$f_c = 550$ $f_s = 16000$ $j = .887$ $K = 82.9$ $p = .00388$

$M = bd^2K = \frac{1602 \times 12}{12 \times 82.9} = d^2 = d = \sqrt{19.35} = 4.4"$ Use 5"

$V = \frac{9.25 \times 150}{2} = 694\#$

Shear $= \frac{V}{bjd} = \frac{694}{12 \times .88 \times 5} = 13.05\#$ This is OK.

Steel for the slab $A_s = pbd = .0058 \times 5 \times 12 = .348$ sq.in. per ft.
Select 5/8" ⌀ bars at 10" c-c = .37 sq.in. steel per ft.

Check the bond of the steel $u = \frac{V}{\Sigma o j d} = \frac{694}{\frac{12}{10} \times 1.96 \times .88 \times 5} = 66.5\#$
The bondstress is o.k.

The temperature steel for the slab = .002 bd
.002 x 5 x 12 = .12 sq in. 3/8" ⌀ bars at 10" = .130 sq.in.

Expansion Joints The coef. of expansion for concrete is .0000065°F
The expansion for 100 ft for 100° is .0000065 x 100 x 100 = .065 ft
.065 ft = .065 x 12 = .78 inches This is slight in excess of 3/4"
There should be one expansion joint one inch in thickness for every 125 feet of concrete.

The computations for the quanity of material required to construct the sprinkling filter bed.

The Wall = Vertical Cantilever - masonry
Total length of the wall independent of the pipe gallery is 828.6 feet
Cross sectional area of the wall = .75 x 5.5 = 4.125 sq ft
overhang on the wall = $\frac{1.5 \times 3}{144}$ = .031 " "

Total sq ft of cross section is 4.156 " "
4.156 x 828.6 = 3443.9 cu ft = 127.55 cu.y.d.

The reinforcing steel in the wall including that bent into the footing 3/4" ∅ bars = 828 x 1 = 828 bars 9' long = 7452' 7452 x 1.50 (wgt/ft) = 11,178 # 3/4" ∅ bars.

1/2" ∅ bars = 7 x 828 = 5796'
+ $\frac{828}{10}$ x 12 x 6 = 5961'

7 x 828 = 5796'
11,7535 ft of 1/2" ∅ bars =
17533 x .67 = 11750.51 # 1/2" ∅ bar steel.
Totals for vertical cantilever = 11178 # 3/4" ∅ steel
11750 # 1/2" ∅ "
127.55 cu yd concrete.

The quanity of material for footings under the wall.

Total length of the footings 804.8' long this is shorter than the wall due to the over lap of wall on the footinge at the corners of the bed.
cross section of the footings = 1.25 x 6.75 = 8.44
$\frac{6 \times 7"}{144}$ = .292
Total = 8.732
8.732 x 804.6 = 7024 cu ft = 260.1 cu.yds. concrete.
Steel in the footings. the length considered here is the same as the wall length = 828.6
3/4" bars 6' long 6" spacing = 828.6 x 6 x 2 = 9943.2'
" " 3'8" " 1' " = 828 x 3.66 = 3030.8'
12974'
12974 x 1.5 = 19461 # 3/4" ∅ bars
1/2" ∅ bars = 828 + 32 (steel lap in the corners) = 860'
860 x 12 = 10320 ft 10320 x .67 = 6914.4 # 1/2" steel.

Totals for the footings = 19461 # 3/4" steel
6914 1/2" "
260.1 cu yds concrete.

Quanity of materials for the pipe gallery.

Roof slab cross section = 10.33 x .66 = 6.82 sq.ft.

" " length = 206.33 $\frac{206.33 \times 6.82}{27}$ = 52.1 cu.yds.

Roof slab steel $\frac{5}{8}$" o bars =

208 x $\frac{12}{10}$ x 12 = 2972' 2972 x 1.04 = 3090 #

$\frac{1}{2}$" o bars = 208.2 x 9 = 1856' 1856 x .67 = 1244.9 #

Side walls of the pipe gallery

length = 206.33' $\frac{2}{27}$ (206.33 x 6.5 x .75) = 74.5 cu.yds

heigth = 6' 6"

Thickness = 8"

steel in the side walls including bars looped into the footing

A bars 28' long 206 x 41 = 844.6 ft

B " 11 long 844.6 x 1.5 = 12669 # $\frac{3}{4}$" steel

39 + 2 end bars = 41

$\frac{1}{2}$" o bars = 32 x 206 = 6592 9742' x .67 = 6517 # $\frac{1}{2}$" steel

15 x 210 = 3150

9742'

Footings.

Total width = 18' 18 x 210.4 = 3785 sq ft

" " = 210'4" 3785 x 1.25 = 4730 cu ft = 175 cu.yd.

Pipe floor = 4.5 x .75 = 3.38 sq ft 4.005 x 202.8 = 811 cu.ft.

$\frac{1}{2}$ x 1.25 = .625 " "

4.005 " "

slab rest = $\frac{6" \times 7"}{144}$ x 2 x 196.2 = 114.2 cu.ft.

The volume of the effluent channel has to be subtracted

2 x (2 x $\frac{1}{4}$ x 201) = 201 cu ft.

4730 + 811 + 114.2 − 201 = 5454 cu ft

$\frac{5454}{27}$ = 202. cu yd concrete.

Steel in the footing

$\frac{3}{4}$ o 4 + 6" − 6' long = 206 x 6 x 2 x 2 = 4944'

4944 x 1.5 = 7416 # $\frac{3}{4}$" o bars.

$\frac{1}{2}$" o steel = 7 x 2 x 210 = 2940 ft

2940 x .67 = 1971 # steel $\frac{1}{2}$" o

The volume of concrete on the end walls of the pipe gallery

6.5 x 8.5 x .75 = 41.4 cu ft − 2 x 3.4 − 3.5 x 2.5 x .75 = 29.4 cu ft.

29.4 cu ft = vol of 1 end wall $\frac{2 \times 29.4}{27}$ = 2.175 cu yd.

Totals for the pipe gallery

$\frac{3}{4}$ o steel	=	20076 #
$\frac{1}{2}$" o "	=	9738 #
cu yds concrete	=	330.78
$\frac{5}{8}$" o Steel		3090 #

Material in the floor slab

1 slab is 8" thick. 196'-10" x 96'-0"

196.83 x 96 x .66 = 12597.12 cu ft for 1 slab

2 x 12597.12 = 25194.24 cu ft for 2 slab

$\frac{25194.24}{27}$ = 933.1 cu. yd.

steel in the slab = 1/2" o bars running two ways:

197 bars 96' long = 18912'

97 " 196' " = 19012'

37924' 1/2 steel for 1 bed

37924 x 2 x .67 = 50,815 # 1/2" o bars

Material for expansion joints

196' 10"	x 6	=	1181.00
96'	x 6		576.00
8	x 12.25	=	98.00
42'	x 2	=	84.00
			1939'

1939' of 16 g. copper sheeting one foot wide + 307 gallons of asphaltic material to pour over the metal expansion joints

The ratio of steel to the concrete in the structure is

133025 #/steel = $\frac{133025}{490}$ = 271.5 cu.ft. steel. Ratio by vol $\frac{271.5}{44590.5}$ = .00609

1651 x 27 = 44590.5 cu ft of concrete

Ratio by wgt = $\frac{133025}{44590.5 \times 150}$ = .0199

The piping in the filter bed.

Each bed has 23 laterals 6" in diam.

" " " 1 main 24" "

" " " 23 24" x 24" x 6" C.I. tees length = 3 1/2'

23 x 3 1/2 = 80.5 ft

length of 24" pipe = 200.5 - 80.5 = 120' - 24" C.I. pipe

23 laterals

12 are 95' long = 1152'

11 are 101' long 1111'

46 1 foot lengths 46'

2309' 6" CI pipe for 1 bed.

Totals for 2 beds using class B pipe

24" CI pipe	240'	233.3 #/'	= 55,992 #
6 " " "	4608'	33.3 #/'	153,774 #
24" x 24" x 6" Ts =	46	1289 #	59,294 #
6" Valve	46		
6" Bends	46		
7/8" Full nozzles	438		
7/8" 1/2 "	44		

The total number of feet of 1/2 - 6" Diam. tile =

2 (271 x 103) + 386 = 55,680 ft.

The number of cubic yards of stone required for filter material in the beds.

204.8 x 104 x 5.5 = 117,145. cu ft in one bed
117,145 x 2 = 234290 " " " two beds
$\frac{234290}{27}$ = 8677.4 cu.yd. of broken stone.

Summation of the quanities of material, their cost per unit in place and total costs

Material	Quanity	Cost per unit in place	Total cost
Concrete.	1651.52 cuyd	$20.00	33,030.40
Reinforcing Steel	133025 #	$00.05	6651.25
Broken Stone 1¼" to 2½"	8677.4 cuyd.	$5.00	43387.00
½ tile 6" diam	55680'	$00.08	4454.40
class B pipe C.I. 24"	240'	$10.50	2520.00
6"	4618'	$1.50	6927.00
24"x24"x6" T's	46	$105.00	4830.00
6" C.I. gate Valves	46	$27.50	1265.00
7/8" Full Nozzles	438	$2.50	1095.00
7/8" - ½ Nozzles	44	$2.50	100.00
Expansion joints	1939'	$00.60	1133.40
Total Cost of	The Filter Bed		$105,393.45

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