DESIGN OF A SEWERAGE SYSTEM AND A PLANT FOR HARRISVILLE, MICHIGAN

Thesis for the Degree of M. S.
MICHIGAN STATE COLLEGE

George R. Grantham

1940

DESIGN OF A SEWERAGE SYSTEM AND A PLANT FOR HARRISVILLE, MICHIGAN

by

GEORGE RICHARD GRANTHAM

A THESIS

Submitted to the Graduate School of Michigan State College of Agriculture and Applied Science in partial fulfilment of the requirements for the degree of

MASTER OF SCIENCE

Department of Civil Engineering

1940

PREFACE

The title, "Design of a Sewerage System and Plant for Harrisville, Michigan" suggests purely a design problem. It is more than a design problem, however, in that it deals with the subject as an engineer engaged by the City of Harrisville would. An engineer, working on a project of this kind, does not merely design the system and draw the necessary plans but also he must plan and act in the best interests of the city as well as to protect the interests of the city by a properly executed contract and complete specifications.

It is the purpose of this paper to incorporate, between two covers, the work of an engineer on a project of this kind with the exception, of course, the inspection and supervision of the actual construction.

The author wishes to express his sincere gratitude to those who gave of their time and experience to help in this undertaking. Special note in this regard should go to Mr. Frank R. Theroux who not only gave of his experience and access to his files but also the data he had previously obtained at Harrisville. Mr. John Patriarche also made suggestions concerning items in the design of the plant which make a better plant from the standpoint of a plant operator.

May 27, 1940 George R. Grantham

PART ONE

PRELIMINARY REPORT

PRELIMINARY REPORT

I. General Information

Harrisville, the county seat of Alcona County, Michigan, is located on the shores of Lake Huron 30 miles south of Alpena. It is strictly a residential community having no factories of any kind. The city is the shopping center for nearby agriculture and resort areas and adjoining the southern border of the city is the Harrisville State Park which attracts many tourists. Passing through the city is the recently completed concrete highway, U.S. 23, which is the main traveled road up the Eastern coast of Michigan. This highway is one of Michigan's scenic routes. To be constructed in the near future is a new highway leading from the State Park along Lake Street to Main Street, thence west across the state. This highway will be hard surfaced. The city is also served by the Detroit and Mackinaw Railroad.

The city has a recently constructed municipally owned water system and is supplied with electrical power. Drainage of the area is taken care of by drains installed where they are needed. The sanitary wastes are taken care of by privately owned septic tank systems.

II. Population

Table I indicates the population data obtained from the United States Census Reports. Several Eastern Michigan Coast cities and villages were investigated in order to try to obtain a general population curve that might suit the Harrisville population curve. See the graph page 1-5, for the curve representing Harrisville.

Table I

City	1850	1860	1870	1880	1890	1900	1910	1920	1930	1940
Harrisville		185	464	596	987	405	444	460	438	437
Lexington	1176	2064	2433	955	712	619	519	378	380	
Harbor Beach*		176	666	534	1046	1149	1556	1927	1892	
Oscoda			476	1951	3595	1109	864	617	642	
Rogers City				375	431	544	705	2109	3278	
Tawas City		102	1381	712	1544	1228	1061	1018	1054	

*Changed from Sand Beach in 1910.

From the data obtained from the figures in Table I and from the graph it is impossible to predict, with any degree of accuracy the future population. The rise around 1890 can be attributed to the rise in the lumbering industry as can the decrease around 1900. It seems logical that the future population will increase gradually in the same proportion as of 1900 to 1950.

In addition to the figures in Table I about 50 persons (approximately 10%) are summer residents of the city for three months of the year.

With an increase in development of real estate and resort areas insured by recent completion of highways and changed modes of travel, it is reasonable to expect a steady increase in population. Installation of the new water supply and a proposed sewer system will further tend to increase the number of permanent homes as well as summer residents within the city.

Taking into consideration these possibilities of population increase, the predictions of Table II are arrived at.

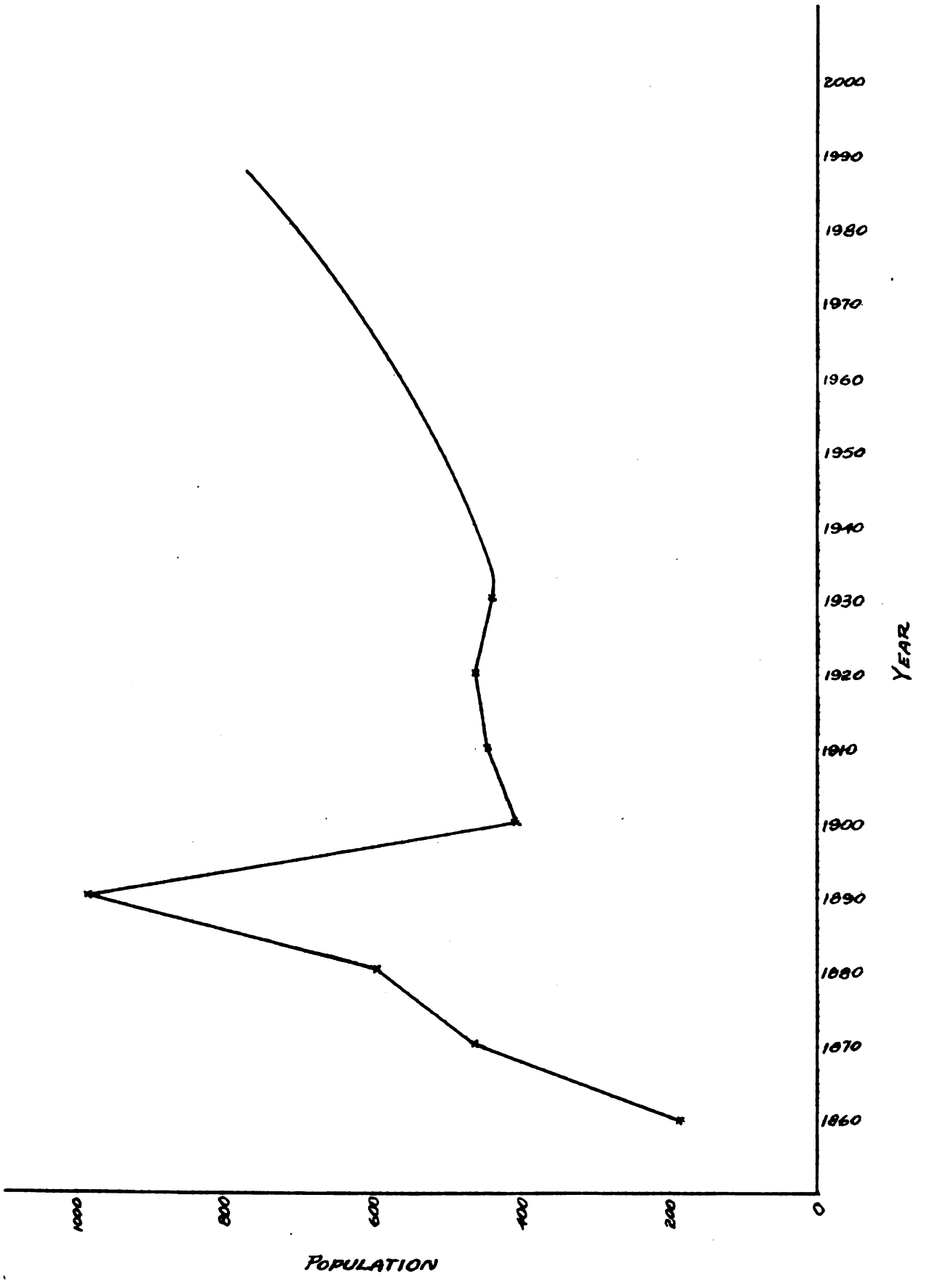

2000
1990
1980
1970
1960
1950
1940
1930
1920
1910
1900
1890
1880
1870
1860
YEAR
1000
800
600
400
200
0
POPULATION

Table II

Year	Winter	Summer
1940	465	512
1950	515	567
1960	570	627
1970	655	700
1980	710	780

The figures in Table II were taken from the curve page 1-5.

The summer population figure for 1980 will be used as the design population in the design that follows.

III. Location of the Treatment Plant

There are four possible locations for the treatment plant. First, the best location geographically is on the lake shore off Lake Street near Spring street. This is the lowest spot and all the wastes could be collected by gravity. This location, however, is very near the State Park and summer resort area and a plant there would be objectional in odor, effluent, and sight.

Secondly, another good location would be off Main Street (north) at the lake front. This location is in the heart of the business district and near the fishing docks. This location would require a small pumping station to take care of the low South Lake Street sewer. The odor and sight would be objectional at this location too.

The third location is at the foot of Dock Street north of the sand spit (see map). This location is further away from (4500 feet) the bathing beach, it is far enough from the center of the city without being outside the city, and it is located on the northside of the sand

spit. It is reasonable to assume that lake currents do not travel south (toward the bathing area) from there because of the sand spit. This location also requires a small pump station to care for the South Lake Street sewer.

Fourth, another location is outside the city limits off north Lake Street north of Washington Street, on property now owned by the county. The property could be obtained at little or no cost to the city. The plant at this location would entail greater costs in laying of the sewer and would require pumping of the raw sewage at the plant in order to obtain sufficient head to discharge into the lake.

The first location, off Spring Street, is, in the mind of the author, impossible. A plant located there would endanger the resort trade which may grow to be the most beneficial enterprise of the city. The fourth location, off Washington Street, would require expense for longer and deeper sewers, and the pumping of raw sewage. In the best interests of the city this location will not be considered. In this preliminary report the remaining two locations will be considered. Hereinafter the location off Dock Street will be known as Design No. I and the location off Main Street as Design No. II.

IV. Sewer System

For small cities spread over large areas, as is Harrisville, it is customary to have what is known as a separate system of sewers. A system of this kind has only a formal layout of sanitary sewers while storm drains to care for the surface water are placed where needed. This type of system greatly reduced costs in that sewers

would have to be made larger to care for the concentrated storm flows in a combined system, catch basins, and extra pipe would be required and in the treatment plant added storm water would be treated and a grit chamber would be needed. Harrisville is located on the side of a slope and inspection of the accompanying map will show that there is natural drainage to the lake. The sewer system will be designed as strictly a sanitary sewer.

A rough idea of the soil conditions may be obtained from the test wells driven in various places in the city.

1. Test well #1 driven in 1903-4 described by the following log:

Formation	Thickness	Total
Yellow loamy soil	12.5	12.5
Quick sand (full of water)	14.0	26.5
Red Clay	6.5	33.0

Beyond this depth we are not interested. The well was driven in the court house grounds. (From U.S. Water Supply Paper No. 185, page 306.)

2. A well driven by J. H. Killmaster at Lake and Main Streets has the following log:

Loose Sand	8.0 Ft.
Hardpan	70.0 Ft.

3. The U.S. Water Supply Paper No. 183 page 309 states "At Harrisville large springs and shallow wells (10 to 40 feet deep - 30 feet common) appear between the elevations of 600 and 640."

4. Inspection of the soil in a cellar being dug at the corner (N.W.) of Main and Third Streets showed that a mucky soil appeared to a depth

of about 4 feet below which a layer of unknown depth of fine water bearing sand was seen. (Nov. 4, 1939)

5. A low mucky spot appears between Lake and First Streets from Jefferson to Church Streets. All of the remaining territory is sandy, judging from the surface soil.

6. Main Street from Lake Street west was an old corderoy road back in the lumbering days and the old road is beneath the present road. Large logs and stumps will hinder excavation. (Overheard from the W.P.A. Supervisor on the water project.)

No serious difficulties due to this ground water are anticipated but it may be necessary to install underdrains for the sewer in the business area of the city.

See the accompanying map for the proposed sewer layout. The system is designed to take care of any property now subdivided whether improved or not. Sewers not needed at the present time are not shown for the sake of clearness. Tables of the tentative design follow:

Table III

DESIGN NUMBER I (Deck 51)

Manhole From	To	Dist. (ft.)	Dia. Pipe (in)	Slope	Vel. ('/sec.)	Surface Elev. (upper)	Fall (ft.)	Invert Elev. (upper)	Invert Elev. (lower)
1	2	400	8	.0040	1.60	594.5	1.60	590.00	588.40
2	3	315	8	.0040	1.60	595.0	1.26	588.40	587.14
3	4	310	8	.0040	1.60	592.7	1.24	587.14	585.90
4	5	340	8	.0040	1.60	599.4	1.40	585.90	584.50
5	6A	338	8	.0040	1.60	599.5	1.28	584.50	583.22
20	21	220	8	.0058	2.00	614.8	1.28	608.82	607.54
21	22	350	8	.0058	2.00	615.5	1.91	607.54	605.63
22	23	315	8	.0058	2.00	616.8	1.83	605.63	603.80
23	24	330	8	.0058	2.00	609.2	1.91	603.80	601.89
24	25	295	8	.0058	2.00	611.2	1.71	601.89	600.18
25	49	340	12	.0030	2.00	615.1	1.02	600.18	599.06
49	6	370	12	.0030	2.00	607.2	1.09	599.06	597.97
6	7	400	12	.0030	2.00	605.5	1.12	597.97	596.85
7	8	390	12	.0030	2.00	607.2	1.12	596.85	595.73
8	9	320	12	.0030	2.00	608.2	.99	595.73	594.74
9	10	320	12	.0030	2.00	606.9	1.05	594.74	593.69
10	11	340	12	.0030	2.00	606.6	1.02	593.69	592.67
11	12	340	12	.0030	2.00	609.5	1.02	592.67	591.65
14	13	360	8	.0130	3.00	612.4	4.68	604.40	599.72
13	12	350	8	.0130	3.00	611.9	4.55	599.72	595.17 (drop)
42	43	300	8	.0090	2.50	645.4	2.70	657.40	654.70
43	44	300	8	.0090	2.50	644.7	2.70	654.70	652.00
44	45	250	8	.0090	2.50	646.5	2.25	652.00	629.75
45	46	250	8	.0294	4.50	646.9	7.35	629.75	622.40
46	47	250	8	.0294	4.50	644.8	7.36	622.40	615.04
47	48	300	8	.0167	3.40	656.6	5.00	615.04	610.04
48	41	240	8	.0167	3.40	627.0	4.00	610.04	606.04
41	25	350	8	.0167	3.40	620.5	5.86	606.04	600.18
50	51	300	8	.0058	2.00	632.0	1.74	622.00	620.26
51	52	300	8	.0058	2.00	632.0	1.74	620.26	618.52
52	53	300	8	.0058	2.00	630.0	1.74	618.52	616.78
53	47	300	8	.0058	2.00	629.0	1.74	616.78	615.04
56	58	220	8	.0058	2.00	617.4	1.28	609.24	607.96
58	41	350	8	.0058	2.00	618.4	1.92	607.96	606.04
86A	79	180	8	.0058	2.00	609.0	1.04	605.35	602.31
79	78	250	8	.0058	2.00	607.6	1.45	602.31	600.86

Manhole From	To	Dist. (ft.)	Dia. Pipe (in)	Slope	Vel. ('/sec.)	Surface Elev. (upper)	Fall (ft)	Invert Elev. (upper)	Invert Elev. (lower)
75	76	160	8	.0206	3.65	626.0	3.30	618.00	614.70
76	77	340	8	.0206	3.65	620.7	7.02	614.70	607.68
77	78	330	8	.0206	3.65	615.3	6.82	607.68	600.86
78	49	300	8	.0058	2.00	607.1	1.70	600.86	599.16
59	60	210	8	.0058	2.00	643.5	1.22	635.00	633.78
60	63	390	8	.0058	2.00	643.5	2.26	633.78	631.52
63	66	400	8	.0138	3.10	642.9	5.53	631.52	625.99
66	69	400	8	.0138	3.10	636.8	5.53	625.99	620.46
69	73	410	8	.0138	3.10	636.6	5.66	620.46	614.80
73	82	330	8	.0138	3.10	629.0	4.56	614.80	610.24
82	85	330	8	.0138	3.10	620.6	4.56	610.24	605.68
85	86	330	8	.0138	3.10	615.1	4.56	605.68	601.12
86	8	380	8	.0138	3.10	610.3	5.29	601.12	595.83
54	55	400*	8	.0075	2.30	645.6	3.00	638.00	635.00
55	56	400*	8	.0075	2.30	646.3	3.00	635.00	632.00
56	45	300*	8	.0075	2.30	648.5	2.25	632.00	629.75
36	38	220	8	.0058	2.00	617.4	1.28	609.24	607.96
38	41	330	8	.0058	2.00	618.4	1.92	607.96	606.04
39	40	230*	8	.0198	3.70	627.5	4.53	619.00	614.47
40	38	330*	8	.0198	3.70	625.0	6.51	614.47	607.96
37	24	240*	8	.0246	4.05	617.2	5.91	608.00	602.09
35	24	260*	8	.0033	1.50	606.8	.86	602.95	602.09
29	28	210*	8	.0224	3.95	626.0	4.70	618.00	613.30
28	22	330*	8	.0224	3.95	622.0	7.37	613.30	605.93
57	58	300*	8	.0095	2.55	646.6	2.91	639.60	636.69
58	60	300*	8	.0095	2.55	646.4	2.91	636.69	633.78
34	23A	240*	8	.0058	2.00	606.6	1.39	601.60	600.21
23A	32	330*	8	.0108	2.70	609.2	3.56	600.21	596.65
32	18	315*	8	.0108	2.70	608.0	3.40	596.65	593.25
18	19	230*	8	.0108	2.70	606.0	2.43	593.25	590.82
19	2	230*	8	.0108	2.70	601.1	2.42	590.82	588.40
33	32	270*	8	.0312	4.80	615.1	8.45	605.10	596.65
31	32	270*	8	.0058	2.00	603.1	1.57	598.22	596.65

*Sewers not included in project which may be constructed when improvements are made.

Manhole From	to	Dist. (ft.)	Dia. Pipe (in)	Slope	Vel. ('/sec)	Surface Elev. (upper)	Fall (ft)	Invert Elev. (upper)	Invert Elev. (lower)
15	16	330*	8	.0250	4.00	625.3	8.25	618.00	609.75
16	17	330*	8	.0250	4.00	618.0	8.25	609.75	601.50
17	18	330*	8	.0250	4.00	614.0	8.25	601.50	593.25
70	71	300	8	.0058	2.00	627.0	1.73	620.00	618.27
71	72	300	8	.0058	2.00	628.0	1.73	618.27	616.54
72	73	300	8	.0058	2.00	629.0	1.74	616.54	614.80
61	62	300*	8	.0123	2.95	647.0	3.74	639.00	635.26
62	63	300*	8	.0123	2.95	646.3	3.74	635.26	631.52
64	65	365	8	.0130	3.00	649.7	4.75	640.00	635.25
65	66	365	8	.0130	3.00	646.0	4.74	635.25	630.51
									Drop
67	68	325	8	.0130	3.00	643.6	4.22	635.60	631.38
68	69	325	8	.0130	3.00	640.0	4.21	631.38	627.17
									Drop
80	81	250*	8	.0068	2.20	620.6	1.71	614.00	612.29
81	82	300*	8	.0068	2.20	621.0	2.05	612.29	610.24
83	84	250	8	.0046	1.80	614.0	1.16	608.00	606.84
84	85	250	8	.0046	1.80	614.0	1.16	606.84	605.68
87	88	450*	8	.0130	3.00	626.0	5.85	618.00	612.15
88	89	320*	8	.0130	3.00	621.2	4.16	612.15	607.99
89	10	400	8	.0200	3.75	615.0	7.99	607.99	600.00
									Drop
94	93	350	8	.0050	1.85	632.3	1.71	624.93	623.22
93	92	350	8	.0050	1.85	932.5	1.71	623.22	621.51
92	91	300	8	.0050	1.85	632.0	1.47	621.51	620.04
91	90	300	8	.0050	1.85	632.0	1.47	620.04	618.57
90	74	400	8	.0050	1.85	632.0	1.96	618.57	616.61
74	73	370	8	.0050	1.85	627.8	1.81	616.61	614.80
95	96	230	8	.0218	3.80	621.1	6.54	613.00	606.46
96	12	400	8	.0130	3.00	618.2	5.20	606.46	601.26
97	98	300*	8	.0058	2.00	618.3	1.74	610.30	608.26
98	96	310*	8	.0058	2.00	618.2	1.80	608.26	606.46
99	100	300*	8	.0122	2.90	628.1	3.67	620.10	616.43
100	88	350*	8	.0122	2.90	621.0	4.28	616.43	612.15
101	102	300*	8	.0058	2.00	618.0	1.74	611.47	609.73
102	89	300*	8	.0058	2.00	616.9	1.74	609.73	607.99
12	103	395	12	.0030	2.00	595.0	1.19	591.65	590.46
103	Plant	175	12	.0030	2.00	596.0	.53	590.46	589.93

*Sewers not included in project which may be constructed when improvements are made.

DESIGN NUMBER II

NOTE: All sewers not listed in Design No. II are the same as in Design No. I.

Manhole From	Manhole To	Dist. (ft.)	Dia. Pipe (in)	Slope	Vel. ('/sec)	Surface Elev. (upper)	Fall (ft.)	Invert Elev. (upper)	Invert Elev. (lower)
14	13	360	8	.0058	2.00	613.7	2.10	608.00	605.90
13	12	350	8	.0058	2.00	612.4	2.04	605.90	603.86
12	11	340	8	.0058	2.00	610.9	1.98	603.86	601.88
11	10	340	8	.0058	2.00	609.4	1.98	601.88	599.90
10	9	350	8	.0058	2.00	606.6	2.04	599.90	597.86
9	8	330	8	.0058	2.00	606.4	2.03	597.86	595.83
8	7	375	12	.0030	2.00	608.2	1.13	595.80	594.67
7	6	375	12	.0030	2.00	607.2	1.13	594.67	593.54
25	49	340	8	.0096	2.60	615.1	3.32	600.18	596.86
49	6	340	8	.0096	2.60	607.2	3.32	596.86	593.54
75	76	160	8	.0200	3.70	626.0	3.20	614.00	610.80
76	77	340	8	.0180	3.50	620.7	6.12	610.80	604.68
77	78	330	8	.0180	3.50	615.3	5.97	604.68	598.71
78	49	310	8	.0058	2.00	607.1	1.85	598.71	596.86
80A	81	275*	8	.0058	2.00	622.0	1.60	614.00	612.40
81	76	275*	8	.0058	2.00	621.0	1.60	612.40	610.80
83A	84	250	8	.0058	2.00	615.2	1.45	607.58	606.13
84	77	250	8	.0058	2.00	615.0	1.45	606.13	604.68
86A	79	180	8	.0058	2.00	609.0	1.04	601.20	600.16
79	78	250	8	.0058	2.00	607.6	1.45	600.16	598.71
75	82	330	8	.0137	3.00	629.0	4.53	614.80	610.27
82	85	330	8	.0137	3.00	620.6	4.53	610.27	605.74
85	86	330	8	.0137	3.00	615.1	4.53	605.74	601.21
86	8	380	8	.0137	3.00	610.3	5.21	601.21	596.00
6	103A	240	12	.0030	2.00	605.5	.72	593.54	592.82
95	96	230	8	.0197	3.60	621.1	4.54	613.10	608.56
96	12	400	8	.0117	2.70	618.2	4.70	608.56	603.86
97	98	300*	8	.0058	2.00	618.3	1.74	610.30	608.56
98	96	310*	8	.0058	2.00	618.2	1.80	608.56	606.76
88	89	320*	8	.0121	2.80	621.2	3.90	608.65	604.75
89	10	400	8	.0121	2.80	615.0	4.85	604.75	599.90
101	102	300*	8	.0087	2.45	618.0	2.62	610.00	607.38
102	89	300*	8	.0087	2.45	616.9	2.63	607.38	604.75

*Sewers not included in project which may be constructed when improvements are made.

A summary of the estimated unit costs is shown as follows:

Table IV

DESIGN NUMBER I

Excavation quantities:

NOTE: Depths are measured 0.2 ft. below invert of the pipe.

Main Street	4985 cu. yds.
Church Street	4264 cu. yds.
S. Lake Street	2368 cu. yds.
N. Lake Street (to plant)	4854 cu. yds.
Second and Third Streets	2627 cu. yds.
State Street	5290 cu. yds.
Jefferson Street	1241 cu. yds.
Fifth Street	573 cu. yds.
Sixth Street	580 cu. yds.
Miscellaneous	989 cu. yds.
	27,771 cu. yds.

Materials and Supplies

Description	Grade	Quantity	Unit	Unit Price	Cost ($)
6" Drain tile	#2	7200	l.f.	0.12	864.00
8" Vit. pipe	std.	17245	l.f.	0.23	3966.35
12" Vit.pipe	std.	3026	l.f.	0.45	1361.70
4" C.I. pipe	150#	25	l.f.	0.70	17.50
Cauking Lead	Std.	60	lb.	0.08	4.80
Asbestos Joint material	std.	11950	lb.	0.03	358.50
Jute	std.	3100	lb.	0.13	403.00
Brick	Common	106	M	15.00	1590.00
Cement	std.	400	bbl.	2.00	800.00
Sand	std.	120	c.y.	1.30	156.00
Gravel	std.	60	c.y.	1.50	90.00
M.H. Frame & Cov.	std.	67	ea.	15.50	1038.50
M.H. Steps	std.	506	ea.	0.20	101.20
Sheeting	#1YP.	100	M	50.00	5000.00
Bracing	#1YP.	30	M	50.00	1500.00
Form Lumber	#1YP.	5	M	50.00	250.00
Pump Lift Sta.		1	ea.	1500.00	1500.00
4" Pipe Stoppers		352	ea.	0.05	17.60
Gasoline (Pumps, etc)		2500	gal.	0.15	375.00
Lubricants		100	lb.	0.50	50.00
Kerosene (Lanterns)		75	gal.	0.10	7.50
Fuel (Heating)		15	ton	9.00	135.00
Gravel (for drains)	pit run	500	c.y.	1.40	700.00
8" x 4" Vit.Y branches	std.	280	ea.	0.92	257.60
12" x 4" "	std.	72	ea.	1.60	115.20
8" Pipe Stoppers	std.	3	ea.	0.20	.60
				Total	$20,660.05

DESIGN NUMBER II

Excavation quantities:

NOTE: Depths are measured 0.2 ft. below invert of pipe.

Main Street	5176 cu. yds.
Church Street	4264 cu. yds.
S. Lake Street	2368 cu. yds.
N. Lake Street (to plant)	3068 cu. yds.
Second & Third Streets	2627 cu. yds.
State Street	5290 cu. yds.
Jefferson Street	1740 cu. yds.
Fifth Street	573 cu. yds.
Sixth Street	580 cu. yds.
Miscellaneous	1005 cu. yds.

Materials and Supplies:

Description	Grade	Quantity	Unit	Unit Price	Cost ($)
6" Drain tile	#2	7200	l.f.	0.12	864.00
8" Vit. pipe	std.	18841	l.f.	0.23	4333.43
12" Vit. pipe	std.	1410	l.f.	0.45	634.50
4" C.I. pipe	150#	25	l.f.	0.70	17.50
Cauking Lead	std.	60	lb.	0.08	4.80
Asb. joint material	std.	10611	lb.	0.03	318.35
Jute	std.	2650	lb.	0.13	344.50
Brick	common	103	M	15.00	1545.00
Cement	std.	395	bbl.	2.00	790.00
Sand	std.	115	cy.	1.30	149.50
Gravel	std.	60	c.y.	1.50	90.00
M.H. cover and frame	std.	68	ea.	15.50	1054.00
M.H. steps	std.	496	ea.	0.20	99.20
Sheeting	#1YP	100	M	50.00	5000.00
Bracing	#1YP	30	M	50.00	1500.00
From Lumber	#1YP	5	M	50.00	250.00
Pump Lift Sta.		1	ea.	1500.00	1500.00
8" x 4" Vit. Y Tees	std.	327	ea.	0.92	300.84
12" x 4" Vit. Y Tees	std.	25	ea.	1.60	40.00
8" x 8" Vit. Y Tees	std.	3	ea.	2.10	6.30
4" pipe stoppers	std.	352	ea.	0.05	17.60
Gas (for pumps)		2500	gal.	0.15	375.00
Lubricants		100	lb.	0.50	50.00
Kerosene		75	gal.	0.10	7.50
Fuel (heating)		15	ton	9.00	135.00
8" pipe stoppers	std.	3	ea.	0.20	0.60
Gravel (under drain)	pit run	500	c.y.	1.40	700.00
				Total	$20,127.62

The estimated cost of each design follows:

Design No. 1

Excavation and Bkfl. 27,771 c.y. at $.60	16,662.60	
Materials and Supplies	20,666.35	
Labor	10,000.00	
		$47,328.95
Engineering and Contingencies		5,000.00
Total -		$52,328.95

Assume $300.00 annually for maintenance, etc.
Annual Expense = Cr + O = (52328.95 x .04) + 300
Annual Expense = $2,393.16

Design No. 2

Excavation and Bkfl. 26,691 c.y. at $.60	16,014.60	
Materials and Supplies	20,127.62	
Labor	10,000.00	
		$46,142.22
Engineering and Contingencies		5,000.00
Total -		$51,142.22

Assume $300 annually for maintenance etc.
Annual Expense = Cr + O = (51142.22 x .04) + 300
Annual Expense = $2,345.69

V. Sewage Flow

The amount of sewage in this case can best be assumed from the assumed water consumption by Mr. Frank R. Theroux. He estimates the average quantity of 55 gal. per capita per day. The sewage flow, then from this water consumption, is estimated at 60 gal. per capita per day. It is assumed that 5 gal. per capita per day above that of the water consumption will flow into the sewers from private and flowing wells in the community. This assumption of 60 gal. per capita per day falls within the average rates for sewage flow as set by Metcalf and Eddy, "Sewerage and Sewage Disposal" page 55 which states "for small towns average rates appear to range from 25 to 60 gallons per capita per day."

Due to the fact that the city is situated on the side of a hill that has ground water near the surface, ground water infiltration

must be taken into account. It is estimated that four miles of sewers come in that area. If the sewers are carefully constructed and the joints are good, a flow of 5000 gal. per mile per day may be expected. (Metcalf and Eddy "Sewerage and Sewage Disposal", page 50). Assume 5000 x 4 or 20,000 gal. per day.

The total flow then, is

780 x 60 + 20,000 = 66,800 gal. per day or

0.1033 sec. ft.

It may be expected that the maximum flow of approximately 200% of the average normal flow will occur between 7 a.m. and 10 a.m. during the day. This maximum flow amounts to

0.1033 x 2.0 = 0.207 sec. ft. or 93 gal. per min.

The minimum flow that may be expected is approximately 50% of the average flow occuring between 2 a.m. and 5 a.m. during the early morning. This minimum flow amounts to

0.1033 x .50 = .052 sec. ft. or 23.3 gal. per min.

VI. Head Available

Fluctuations in Water Level: "The average or normal elevation of the lake surface varies irregularly from year to year. During the course of each year the surface is subject to a seasonal rise and fall, the lowest stages prevailing during the winter months and the highest during the summer months. In the last five years the highest annual stage (taking the maximum monthly mean height of each year) have ranged from 0.52 ft. below to 1.18 ft. above low water datum, and the lowest annual stage (taking the minimum monthly mean height of each year) have ranged from 1.11 ft. below to 0.68 ft. below low water datum

to which depths are referred in the descriptions following. In the 39 years from 1900 to 1938, the difference between the highest (582.31) and the lowest (577.34) monthly mean stages of the whole period is 4.97 ft. The greatest annual fluctuation is shown by the highest and the lowest monthly mean was 2.08 ft. and the least annual fluctuation was 0.59 ft." The mean surface is 579.80 (1900 to 1938). This data was obtained from Bulletin No. 48 "Survey of Northern and Northwestern Lakes," U. S. War Department, Corps of Engineers, U. S. Lake Survey Office, Detroit, Michigan, pages 269 to 270.

For Design No. I: At the entrance of the plant the elevation of the sewer invert is 589.93 ft. The minimum available head considered then is 589.93 - 582.31 equals 7.62 ft. This head is considered as the available head to be used in the plant.

For Design No. II: At the entrance of the plant the invert elevation of the sewer is 592.82. The minimum available head then is 592.82 - 582.31 equals 10.51 ft.

VII. Selection of Type of Plant

There are three major factors that enter into the selection of a type of treatment plant, namely, the degree of purification required, the costs, both initial and operating of the plant, and the physical effect of the plant, that is, odor, insects, and appearance.

The degree of treatment required depends entirely upon local conditions; the strength of the wastes, the type of wastes, and the diluting medium. Reductions that various types of treatment plants are capable of follow in Tables VI and VII.

Table VI

Type of Treatment	% Removal of Susp. Solids	% Removal of 5 day B.O.D.
Sedimentation (Primary Treatment)	56	36
Trickling Filters	84	85
Activated Sludge	91	92
Chemical Treatment	73-91*	58-82*

*Dependent upon amounts of chemicals used.

(From Proc. Am. Soc. of Civil Engineers, April 1938, part 1, page 758.)

Table VII

Removal or destruction of Bacteria of Different Treatment Processes

Process	% Removal of Bacteria
Coarse Screening	0 - 5
Fine Screening	0 - 10
Grit Chamber Treatment	0 - 5
Plain Sedimentation	25 - 75
Septic Tank Treatment	25 - 75
Chemical Precipitation	40 - 80
Contact-Bed Treatment	40 - 80
Trickling Filter Treatment	70 - 85
Activated Sludge Process	90 - 98
Intermittant Sand Filter	95 - 99
Sedimentation and Chlorination	90 - 95
Oxidation and Chlorination	98 - 99

Table VII is taken from "American Sewerage Practice," Vol. III, page 775 by Metcalf and Eddy.

The chemical treatment and trickling filter type plants will not be considered because of the characteristics of that type of plant which makes it undesirable both financially and physically.

During the winter months the city could get along nicely with primary treatment consisting of primary sedimentation and separate sludge digestion. Chlorination equipment could be installed for use during the summer months. Another possibility is the activated sludge type

plant for secondary treatment if it is desired or required. The primary and sludge digestion tanks could be arranged so that in the event that secondary treatment is required in the future, areation tanks and equipment could be added converting the primary treatment plant into an activated sludge plant. It is also possible that the primary treatment be used in the winter and the secondary treatment in the summer when it is needed. This arrangement is very flexible in obtaining any degree of treatment desired.

VIII. Preliminary Design - Primary Treatment

A. Primary Sedimentation Tank

The detention period should be about two hours.

Design Flow - 66,800 gal. per day or .1033 sec. ft.

Try a rectangular tank 4 ft. deep by 6 ft. wide by 30 ft. long. The detention period then is

$$\frac{4 \times 6 \times 30 \times 7.48 \times 1440}{66,800} = 116.2 \text{ min. in 1980}$$

and $$\frac{4 \times 6 \times 30 \times 7.48 \times 1440}{54,020} = 142.5 \text{ min. in 1950.}$$

B. Sludge Digestion Tank

Assume a medium weak strength sewage with 300 p.p.m. suspended solids, 56% removeable, and 95% moisture content. The volume of fresh sludge daily then is

$$\frac{300 \times .0668 \times .56}{.05} = 224 \text{ gal. per day.}$$

Assume a 90 day storage of sludge, with the sludge fully digested in 60 days.

$$300 \times 0.0668 \times .56 \times 8.33 = 93.5 \text{ lbs. per day.}$$

Assume a 25% loss of volume in digestion and 90% average moisture in the digester. All the sludge put in during the first thirty days will be completely digested at 90 days and will have a volume of

$$30 \times 93.5 \times .75 = 2100 \text{ lbs.}$$

All the sludge put in during the second 30 days will have spent an average of 45 days in the digester and would be 75% digested. The volume would be

$$30 \times 93.5 \times (1 - 25 \times .75) = 2279 \text{ lbs.}$$

All the sludge put in during the last thirty days will have spent an average of 15 days in the digester and would be 25 % digested. The volume will be

$$30 \times 93.5 \times (1 - (25 \times .25) = 2630 \text{ lbs.}$$

The maximum amount of sludge in the digester is sum of 7009 lbs. This amounts to

$$\frac{7009}{.10 \times 8.33 \times 1.03} = 8150 \text{ gallons.}$$

For 780 persons, the value in cubic feet per capita per day is $\frac{8150}{7.48 \times 780} = 1.40$ cu. ft. per cap. per day.

The volume necessary for the digester tank then is $\frac{8150}{7.48} = 1090$ cu. ft. Assume a circular tank ten feet deep. The diameter of the tank then is

$$\frac{1090}{10} = \frac{3.14d^2}{4}, \quad d = 11.8 \text{ ft.} \quad \text{Use } 12' - 0''.$$

C. Building

The building should be a neat appearing structure, containing a laboratory in order that control tests may be run, the necessary pumps,

a coal or oil burning furnace, and a lavatory.

D. Sludge Drying Bed

Sludge produced in primary treatment and separate sludge digestion requires approximately one square foot of plan area per capita served.

The area required then is 780 x 1 = 780 sq. ft. Assume a 20' - 00" width: $\frac{780}{20}$ = 39.0 ft. Use 40' - 00".

The bed should have a concrete wall around it projecting at least two feet above the surface of the bed so that a 12" layer of sludge may be drawn and still leave sufficient freeboard. The bed should consist of four lines of 6" open jointed drain tile covered successively with 6" of stone (2" to 6" in size), 6" of graded fine gravel, and finally 6" of graded fine angular sand.

IX. Preliminary Design - Activated Sludge

A. Primary Sedimentation Tank

The detention period should be about an hour to 1½ hours. Design flow is 66,800 g.p.d. or .1033 sec. ft. Try a rectangular tank 4 ft. deep by 5 ft. wide by 25 ft. long. The detention period is $\frac{4 \times 5 \times 25 \times 7.48 \times 1440}{66,800}$ = 80.7 min. in 1980 and $\frac{4 \times 5 \times 25 \times 7.48 \times 1440}{54,020}$ = 99.7 min. in 1950.

B. Areation Tank

It seems best in this case to use mechanical areation due to economy of this type of areation. Assume the detention period of six hours for the primary tank effluent plus 20% return activated sludge. The volume of the tank necessary is $\frac{66,800 \times 6 \times 1.20}{24}$ = 20,040 gal. or

2680 cu. ft. Assume the depth of 10'-0". The necessary tank is $(\frac{2680}{10})^{\frac{1}{2}}$ = 16.38', use 16'-6" square tank.

C. Final Sedimentation Tank

Due to the fact that the activated sludge in the bottom of the final tank is taken out as fast as it settles, the capacity of the tank need be sufficient to care for sewage flow only. Assume a rectangular tank 5 ft. wide by 25 ft. long by 6'-6" deep. The detention period then will be $\frac{5 \times 25 \times 6.5 \times 7.48 \times 1440}{66,800}$ = 131.3 min. in 1980, and $\frac{5 \times 25 \times 7.48 \times 1440}{54,020}$ = 162 min. in 1950.

D. Sludge Digestion Tank

Assume a medium weak sewage with 300 p.p.m. suspended solids, 95% moisture. The primary tank sludge and the excess activated sludge are to be digested together. Assume 96% moisture content. The volume of raw sludge and excess activated sludge daily then is $\frac{300 \times .0668 \times .95}{.04}$ =476 gal. per day. Assume a 90 day storage of sludge with the sludge fully digested in 60 days. Assume a 25% loss of volume in digestion and an average moisture content of 90% in the digester. Solids added per day 300 x .0668 x .95 x 8.33 = 158.7 lbs. per day. All the sludge put in the digester during the first 30 days will have become completely at 90 days and will have a volume of 158.7 x 30 x .75 = 3565 lbs. All the sludge put in the digester during the second 30 days will have been in the digester an average of 45 days and will be 75% digester. The volume then will be 158.7 x 30 x (1 - .25 x .75) = 3868 lbs. All the sludge put in the digester during the third 30 days will have been in the digester an average of 15 days and will be 25% digester having a volume of 158.7 x 30 x (1 - .25 x .25) = 4463 lbs.

The maximum amount of sludge in the digester at any time will be the sum or 11,896 lbs. or

$$\frac{11,896}{.10 \times 8.33 \times 1.03} = 13,880 \text{ gallons.}$$ For 780 persons the value in cu. ft. per capita per day is

$$\frac{13,880}{7.48 \times 780} = 2.38 \text{ cu. ft. per capita per day.}$$

The volume necessary then for the digester tank is

$$\frac{13,880}{7.48} = 1860 \text{ cu. ft.}$$

This figure is under the desired value of 3.00 cu. ft. per capita per day. The volume necessary for the desired value is 780 x 3.0 = 2340 cu. ft. Assume a 12'-0" deep circular tank whose diameter is

$$d = \frac{(4 \times 2340)^{\frac{1}{2}}}{12 \times 3.14} = 15.7' \quad \text{Use } 16'\text{-}00".$$

E. Building

The building should be a neatly appearing building containing a laboratory (including an office desk), an electrical control board, recording gages, raw and return sludge pumps, lavatory, and a coal or oil burning furnace.

F. Sludge Drying Bed

The activated sludge process produces a sludge that contains a large percent of moisture requiring a much larger bed than any other type with the possible exception of the chemical precipitation process and therefore a value of five sq. ft. per capita is chosen.

The area required then is 780 x 5 = 3900 sq. ft. Assume a width of 40'-00", the breadth must be

$$\frac{3900}{40} = 97.5 \text{ ft.} \quad \text{Use } 100'\text{-}00".$$

The bed should have a concrete wall around it projecting at least two feet above the surface of the bed so that a 12" layer of sludge

may be drawn and still have sufficient freeboard. The bed should consist of eight lines of 6" open jointed clay drain tile covered successively with a 6" layer of stone (2" to 6" in size), 6" of graded fine gravel, and finally 6" of graded fine sand.

As the bed will be placed on a sandy beach-like plot of ground, it is likely that the moisture will percolate through the bed and into the sand. A collection pipe system, however, should be provided in case the ground water table or the lake level rises sufficiently to stop the percolation.

X. Cost Analysis - Primary Treatment

A. Primary Tank		
1. Concrete 25.7 c.y. at $26.00	$ 596.00	
2. Mechanical Sludge Collector	1100.00	
3. Misc. Iron	300.00	$1996.00
B. Sludge Digester		
1. Concrete 27.0 c.y. at $26.00	702.00	
2. Gas Relief Valve	25.00	
		727.00
C. Building		
1. Concrete 55.8 c.y. at $26.00	1450.80	
2. Sump Pump	40.00	
3. Plumbing and Fixtures	175.00	
4. Lab. Equipment	620.00	
5. Lab. Furniture	125.00	
6. 2 Raw Sludge Pumps	725.00	
7. C.I. Pipe & Fittings	120.00	
8. Misc. Iron	75.00	
9. Superstructure	1000.00	
10. Electrical Work	500.00	
11. Oil Burner and Tank	150.00	
		4980.00
D. Sludge Bed		
1. Concrete 22.1 c.y. at $26.00	575.00	
2. 6" Drain Tile 101.5' at $.12	12.18	
3. Filter Material	63.62	
4. Labor	250.00	
		900.80
E. Miscellaneous		
1. Excavation 1250 c.y. at $.60	751.20	
2. Landscaping (inc. road, fence,etc)	3500.00	
3. Steel Sheet Piling 97,500# $.035	3412.50	
4. Misc. Conc. 6.4 cy. at $26.00	166.40	
5. Outfall Sewer 500 ft. at $7.50	3750.00	
6. Misc. Iron	50.00	
		11,650.10
		20,234.70
Engineering and Contingencies		5,000.00
Total		$25,234.70

XI. Cost Analysis - Secondary Treatment

A. Primary Tank		
1. Concrete 24.7 c.y. at $26.00	$ 622.20	
2. Mechanical Sludge Collector	1100.00	
3. Misc. Iron	300.00	
		$2022.20

B. Aeration Tank and Outfall Box		
1. Concrete 56.1 c.y. at $26.00	$1458.60	
2. Mechanical Aerator	1200.00	
3. Misc. Iron	200.00	
		2858.60
C. Final Tank		
1. Concrete 36.2 c.y. at $26.00	941.20	
2. Collecting Mechanism	1100.00	
3. Misc. Iron	225.00	
		2266.20
D. Sludge Tank		
1. Concrete 48.2 c.y. at $26.00	1253.00	
2. Gas Relief Valve	25.00	
		1278.00
E. Building		
1. Concrete 55.8 c.y. at $26.00	1450.80	
2. Sump Pump	40.00	
3. Plumbing and Fixtures	175.00	
4. Lab. Equipment	620.00	
5. Lab. Furniture	125.00	
6. 1 Raw Sludge Pump	375.00	
7. 2 Return Sludge Pumps	725.00	
8. C.I. Pipe and Fittings	345.00	
9. Misc. Iron	75.00	
10. Superstructure	1000.00	
11. Electrical Work	800.00	
12. Oil Burner and Tank	150.00	
		5880.80
F. Sludge Bed		
1. Concrete 49.0 c.y. at $26.00	1274.00	
2. 6" Drain Tile 390.5' at $.12	46.86	
3. Filter Material	318.40	
4. Labor	500.00	
		2139.26
G. Miscellaneous		
1. Excavation 1660 c.y. at $.60	996.00	
2. Landscaping (inc. rails, fence)	3500.00	
3. Steel Sheet Piling 97,500#	3412.50	
4. Misc. Conc. 4.4 c.y. at $26.00	114.40	
5. Outfall Sewer 500' at $7.50	3750.00	
6. Misc. Iron	50.00	
7. Misc. Pipe (C.I. and Vit. Pipe)	301.65	
		12,124.53
		$28,569.59
Engineering and Contingencies		3,500.00
Total Cost		$32,069.59

XII. Annual Cost Estimate - Primary Treatment

The Michigan Public Utility rate for power is $22.50 net, or $25.00 gross per active horsepower per year payable monthly plus 1.75 cents per K.W.H. charge for current. The active horsepower is determined on the following basis:

90% of the first 5 H.P. connected m.f.g. rating
80% " " next 5 H.P. " " "
70% " " " 20 H.P. " " "
60% " all over 30 H.P. " " "

Lift Pump Station			
Connected H.P.	1		
Active H.P.	0.9		
Yearly Charge		$22.50	
Hours per Day	6		
K.W.H. per Day	4.5		
Current Cost per Year		28.74	
Primary Tank			
Connected H.P.	.1		
Active H.P.	0.9		
Yearly Charge		22.50	
K.W.H. per Day	18		
Current Cost per Year		114.98	
Sludge Pumps			
Connected H.P.	2		
Active H.P.	1.8		
Yearly Charge		41.00	
Hours per Day	1		
K.W.H. per Day	1.5		
Current Cost per Year		9.58	
Assume the current used in lighting and in the lab. amounts to $10.00 per month. The annual cost is		120.00	

Total Annual Power Costs	$ 359.30
Superintendent	1000.00
Incidental Expense (repairs etc.)	500.00
Insurance	116.00
Annual Operating Expense	$1975.30

Annual Expense = Cr + O = (23,234.70 x .04) + 1975.30
Annual Expense = $2904.69

XIII. Annual Cost Estimate - Secondary Treatment

The Michigan Public Utility rate for power is $22.50 net, or $25.00 gross per active horsepower per year payable monthly plus 1.75 cents charge for current. The active horsepower is determined as follows:

90% of the first 5 H.P. connected M'f'g rating.			
80% " " next 5 H.P.	"	"	"
70% " " next 20 H.P.	"	"	"
60% " all over 30 H.P.	"	"	"

Lift Pump Station		
Connected H.P.	1	
Active H.P.	0.9	
Yearly Charge		$22.50
Hours per Day	6	
K.W.H. per Day	4.5	
Current Costs per Year		28.74
Primary Tank		
Connected H.P.	1	
Active H.P.	0.9	
Yearly Charge		22.50
K.W.H. per Day	18	
Current Costs per Year		114.98
Aeration Tank		
Connected H.P.	3	
Active H.P.	2.7	
Yearly Charge		60.75
K.W.H. per Day	54	
Current Costs per Year		344.93
Final Tank		
Connected H.P.	1	
Active H.P.	0.9	
Yearly Charge		22.50
K.W.H. per Day	18	
Current Costs per Year		114.98
Raw Sludge Pump		
Connected H.P.	1	
Active H.P.	0.9	
Yearly Charge		22.50
Hours per Day	2	
K.W.H. per Day	1.5	
Current Costs per Year		9.58

Return Sludge Pumps		
Connected H.P.	2	
Active H.P.	1.8	
Yearly Charge		$41.00
Hours per Day (1 in use)	12	
K.W.H. per Day	18	
Current Costs per Year		114.98
Assume the current used in lighting and in the lab. amounts to $10.00 per month. The Yearly Cost is		120.00

Total Power Cost (Annual)	$1037.84
Superintendent	1800.00
Incidental Exp. (repairs etc.)	500.00
Insurance	160.00
Annual Operating Expense	$3497.84

Annual Expense = Cr x O
= (32,069.59 x .04) + 3497.84
= 4780.62

The Annual Expense is $4780.62.

EXPLANATION

It is assumed that the City of Harrisville wishes to construct a system of sewers and a secondary treatment plant off Dock Street at the Lake Front. The following Part 2, Part, 5, and the accompanying plans are needed to cause a contract to be let and the work to be done as desired.

PART TWO

ADVERTISEMENT FOR PROPOSALS

FORM FOR PROPOSALS

CONTRACT

PERFORMANCE BOND

MATERIALS AND LABOR BOND

ADVERTISEMENT FOR PROPOSALS

Sealed proposals will be received by the Secretary of the City Council of Harrisville, Michigan until _____M, Eastern Standard Time _____ for furnishing all materials, labor, and equipment necessary for the construction of a sanitary sewer system and a sewage treatment plant for the city and will be publicly opened and read at that time.

Approximate quantities are:

Sewer system

8" Vit. Pipe Sewer (ave. depth 10')	17,785 lin. ft.
12" Vit. Pipe Sewer (ave. depth 14")	3,170 lin. ft.
Manholes	70

One underground lift pump station of 50 GPM. capacity.

Treatment plant

Excavation (sand)	1660.0 cu. yds.
Reinforced Concrete	275.0 cu. yds.
8" C.I. pipe	80.0 lin. ft.
6" C.I. Pipe	38.0 lin. ft.
4" C.I. Pipe	208.5 lin. ft.
12" C.I. Outfall Sewer (into Lake Huron)	485.0 lin. ft.
8" Drain Tile	390.5 lin. ft.
8" Vit. Pipe	56.0 lin. ft.
Steel sheet piling	3250 lin. ft.

One 9' x 16' brick Building containing a laboratory, a lavatory, and office equipment.

Mechanical equipment including two sludge collection mechanisms, one mechanical aerator, 2 50-GPM. variable speed sludge pumps,

two 50 GPM. sludge pumps and electric motors necessary for the equipment.

Plans, specifications, bidding forms, and instructions for bidders are obtainable from the Secretary of the City Council of Harrisville, Michigan with a deposit of $15.00. All plans, specifications, and contract documents must be returned within 30 days after the opening of the bids the deposits being returned on the return of said plans, etc., in good condition.

A certified check of amount equal to 2% of the bid is required of each bidder and a bond of 100% of the amount of the bid shall be required of the successful bidder.

The city reserves the right to waive any informalities and to reject any and all bids. No bidder may withdraw his bid within 30 days after the scheduled time of opening the bids.

_____Mayor

_____Secretary

_____Treasurer

INSTRUCTIONS FOR BIDDERS

Sealed bids endorsed with the title "Sewage System Proposal" and also the name and address of the person or firm making the same will be received at the town hall until _____(date)_____ at (time) Eastern Standard Time at which time the bids will be opened by the city council and publicly read after which the bids will be considered and the award made as soon as practicable.

Proposals must be enclosed in a sealed envelope and addressed to the Secretary of the City Council, Harrisville, Michigan and endorsed with "Sewage System Proposal".

Bids must conform to the accompanying printed forms and any deviation from the said forms and omissions or additions to the same will be treated as informalities and will be rejected as such.

Any bidder may withdraw his bid before the opening time by stating his purpose to the City Council and his bid will, when reached, be returned to him unopened. No bid may be withdrawn within 30 days after the opening of the bids.

The amount of the bid must be written in the bid and also stated in figures so that there will be no doubt as to the amount. Illegible figures will invalidate the bid.

Approximate quantities are:

Sewer System

8" Vit. Pipe Sewer (ave. depth 10')	17,785 lin. ft.
12" Vit. Pipe Sewer (ave. depth 14')	3,170 lin. ft.
Manholes	70

One underground pump lift station of 70 GPM. capacity

Treatment Plant

Excavation (sand)	1660.0 cu. yds.
Reinforced Concrete	275.0 cu. yds.
8" C.I. Pipe	80.0 lin. ft.
6" C.I. Pipe	38.0 lin. ft.
4" C.I. Pipe	208.5 lin. ft.
12" C.I. Outfall (into Lake Huron)	485.0 lin. ft.
8" Drain Tile	390.5 lin. ft.
8" Vit. Pipe	56.0 lin. ft.
Steel sheet piling	3250.0 lin. ft.

One 9' x 16' brick building containing a laboratory, a lavatory, and office equipment.

Mechanical equipment including two sludge collection mechanisms, one mechanical aerator, two 50 GPM. variable speed sludge pumps and motors, two 50 G.P.M. sludge pumps and motors.

Any bidder, if he desires, may enter separate bids for either the sewer system or the treatment plant or both. The bid for the sewers must be for the complete system up to the point clearly designated on the drawings as "Entrance to Plant." The bid for the treatment plant shall include the complete plant and the outfall sewer.

Bidders must have satisfied themselves by personal examination of the site as to the local conditions of soil characteristics, labor conditions, amount of water to be expected and as to the accuracy of the foregoing engineers estimate. Such data will not be given from the Harrisville city offices except that all records of other work which has been done will be freely shown.

The right is reserved to reject any and all bids and to waive any informality in the bids received also to disregard the bid of any failing bidder or contractor known as such.

A certified check payable to the City of Harrisville in amount equal to 2% (two per cent) of the bid entered shall be included with the bid. The check of the successful bidder will be returned to him immediately after he signs the contract. If after two weeks after notice of the awarding of the contract the contractor fails to or refuses to enter into contractural agreement he shall forfeit the check to the City of Harrisville. Checks of unsuccessful bidders will be returned when the contract is signed or the bids rejected.

The successful bidder is required to post a bond as security for the faithful and complete performance of the work under this contract equal in amount to the amount of this bid.

A copy of the instructions for bidders, forms for proposals, contract, specifications, and drawings will be furnished by the Secretary of the City Council of Harrisville, Michigan upon the receipt of a deposit of fifteen dollars ($15.00). The entire deposit will be returned upon the return of the said copies in good condition.

_____Mayor, City of Harrisville

_____Secy., City of Harrisville

_____Treas., City of Harrisville

FORM FOR PROPOSAL

TO THE CITY OF HARRISVILLE, MICHIGAN FOR

THE CONSTRUCTION OF A SEWER SYSTEM AND

SEWAGE TREATMENT PLANT AT HARRISVILLE,

MICHIGAN

The undersigned hereby declares that he has carefully examined the accompanying form of contract and specifications and will provide all necessary materials, labor, tools, equipment, and machinery and do all the work called for by the said contract and specifications in the manner perscribed by them and the requirements under of the engineer for the sum of _____dollars ($). Accompanying this proposal is a certified check for the sum equal to the amount of 2% of the above bid.

No member of the City Council of Harrisville is directly or indirectly interested in this propo sal or any contract which may be made or in expectation of any profits arising therefrom. This proposal is made in good faith without collusion or connection with any other person bidding for the same work.

(Signed)_____

Address _____

_____

CONTRACT

THIS AGREEMENT, made and entered into this _____ day of _____ in the year of _____, by and between _____ duly constituted and elected, herein acting for the Town of Harrisville, Michigan, and without personal liability to themselves, party of the first part, and _____ part_____ of the second part, WITNESSETH, That the parties to these presents, each in consideration of the undertakings, promises, and agreements on the other herein contained have undertaken, promised and agreed, and do hereby undertake, promise, and agree the party of the first part for itself, its successors and assigns, and the part _____ of the second part for _____ and _____ heirs, executors and administrators or successors, as follows:

ART. I

Wherever the words defined in this article, or pronouns used in their stead, occur in this contract and the specifications, they shall have the meanings herein given.

The words "Party of the First Part," above designated shall include the City Council of the City of Harrisville, Michigan, or any Board of Selectmen properly authorized to act for the said party in the execution of the work called for in this contract.

The word "Engineer" shall mean the engineers for the party of the first part, _____ of_____, either acting directly or through agents acting within the scope of the particular duties intrusted to them.

Wherever in the specifications or on the drawings the words "as directed", "as required", or "as permitted" shall be understood that the direction, requirements, or permission of the engineer is understood and similarly the words "acceptable", "satisfactory", or "approved" shall mean approved or acceptable and satisfactory to the engineers.

The word "Contractor" shall mean the party of the second part, above designated, or the legal representative of said party or the agent appointed to act for said party in the performance of the work.

The figures given in the contract and specifications or on the drawings after the word "elevation" or an abbreviation of it shall mean the distance in feet above datum adopted by the engineer, namely Mean Sea Level Datum.

ART. II

To prevent litigations and disputes, the engineer shall in all cases determine the amount, quality, acceptability and fitness of the several kinds of work and materials which are to be paid for under this contract; shall determine all questions in relation to said work and construction thereof, and shall in all cases decide every question which may arise relative to the fulfillment of this contract on the part of the Contractor. His estimate and decision shall be conclusive and final upon said Contractor, and shall in case and question shall arise between the parties thereto, touching this contract, such estimate and decision shall be condition precident to the right of the Contractor to receive any money under the contract.

ART. III

The engineer shall make all necessary explanations as to the meanings and intentions of the specifications, shall give all orders and

directions contemplated therein or thereby and in every case in which a difficulty or unforeseen conditions shall arise in the performance of the work required by this contract.

ART. IV

The Contractor shall do all the work and furnish all the materials, tools, and machinery necessary to performing and completing the work of this contract, in the manner and within the time as hereinafter stated. He shall complete the entire work to the satisfaction of the engineer and in accordance with the specifications and drawings mentioned at the price agreed upon and fixed. All the work, labor, and materials to be done and furnished under this contract shall be done and furnished strictly pursuant to, and in conformity with, the attached specifications and at the direction of the engineer as given from time to time during the progress of the work under terms of this contract, and in accordance with the contract drawings, which drawings and specifications form parts of this agreement. The information for bidders hereto attached and the proposal submitted by the Contractor are also made parts of this contract.

The Contractor shall conduct his work so as to interfere as little as possible with private business and public travel. He shall, at his own expense, whenever necessary or required, maintain fences, provide watchmen, maintain red lights, and take such other precautions as may be necessary to protect life and property, and shall be liable for all damages occasioned in any way by his act or neglect, or that of his agents, employees, or workmen.

The Contractor shall submit, with such promptness as to cause no delay in the work, all shop drawings and schedules required in the work to the engineer for his approval before ordering said work done or material to be ordered.

ART. V

No night work requiring the presence of an engineer or inspector will be permitted, except in case of emergency and then only to such an extent as is absolutely necessary and with the written permission of the engineer.

No Sunday work will be permitted, except in case of emergency, and then only with the written consent of the engineer, and to such extent he may deem necessary.

ART. VI

Whenever the contractor is not present on any part of the work where it may be desired to give directions, orders may be given by the engineer, and shall be received and obeyed by the superintendent or foreman who may have charge of the particular work in reference to which orders are given.

ART. VII

The plans and specifications are intended to be explanatory of each other, but should any discrepency appear or any misunderstanding arise as to the import of anything contained in either, the explanation of the engineer shall be final and binding on the Contractor. Any correction of errors or omissions in the drawings and specifications may be made by the engineer when such a correction is necessary for the proper fulfillment of their intention as construed by him.

ART. VIII

Necessary sanitary conveniences for the use of laborers on the work, properly secluded from the public observation, shall be constructed and maintained by the Contractor in such a manner and at such points as shall be approved and their use shall be strictly enforced.

ART. IX

The Contractor shall not permit nor suffer the introduction or use of intoxicating liquors upon or about the works embraced in this contract.

ART. X

The Contractor shall commence work within twenty-one days after the execution of this contract by the Harrisville City Council at such points as the engineer may approve and shall thereafter continue it at such points and in such an order of precedence as the engineer may from time to time approve.

The rate of progress shall be such that the work shall be performed in accordance with the terms of this contract within 280 days after the contract is awarded to the Contractor.

In case the Contractor fails to satisfactorily complete the entire work contemplated and provided for under this contract, within the stipulated time of the above clause, the party of the first part shall deduct from the payments due the Contractor the sum of ten ($10) dollars for each calendar day of delay, which sum is not as a penalty but as fixed and liquidated damages for each day of delay, to be paid in full and subject to no deductions. If the full amount deducted as liquidated damages is more than payments due the Contractor, the Contractor or his surety shall pay the balance to the party of the first part.

No extention of time will be allowed for ordinary delays and accidents, and the occurrence of such will not relieve the Contractor from the necessity of maintaining the rates of progress.

ART. XI

The party of the first part and the engineer and agents thereof,

for purposes already specified and for any other purpose, enter upon the work and the premises used by the Contractor, and the Contractor shall provide safe and proper facilities thereof. Other contractors of the party of the first part may also, for all purposes which may be required by their contracts, enter upon the work and premises used by the Contractor.

The engineer shall be furnished with every reasonable facility for ascertaining that the work is in accordance with the requirements and intentions of this contract, even to the extent of uncovering or taking down portions of finished work.

The Contractor shall provide the engineer with a building suitably water-tight and provided with heat, light, and ventilation. The building shall contain a desk, chair, and a drawing table.

ART. XII

The inspection of the work shall not relieve the Contractor of any of his obligations to fulfill his contract as herein prescribed, and defective work shall be made good and unsuitable materials may be rejected, notwithstanding that such work and materials have been previously overlooked by the engineer and accepted or estimated for payment. If the work or any part thereof shall be found defective at anytime before the final acceptance of the whole work, the Contractor shall make good any such defect, in a manner satisfactory to the engineer, and if any material brought upon the ground for use in the work, or selected for the same, shall be condemned by the engineer as unsuitable or not conforming to specifications, the Contractor shall remove such materials from the vicinity of the work. Nothing in this contract shall be construed as vesting in the Contractor any right to property in the materials used after they have

been attached to the work or the soil, but all such materials shall, upon being so attached, become the property of the party of the first part.

ART. XIII

The Contractor shall employ enough competent men to do the work. If, in the opinion of the engineer, the Contractor is not employing enough labor to complete this contract within the time specified, the engineer may, after giving written notice, require said Contractor to employ such additional labor as is necessary to enable the work to progress properly. The judgment of the engineer as to whether said work is progressing at such a rate as to enable it to be completed at the time herein specified shall be final and binding.

ART. XIV

The Contractor shall employ only competent men to do the work, and whenever the engineer shall notify the Contractor in writing that any man on the work is, in his opinion, incompetent, unfaithful, disorderly or otherwise unsatisfactory, or not employed with the provision of ART. XV, such man shall be dismissed from the work, and shall not again be employed on it, except with the consent of the engineer.

Any action of the engineer under this article shall not affect the right of the party of the first part to annul this contract as provided for in ART. XX.

ART. XV

The Contractor shall keep himself fully informed of all existing and future State and National laws and local ordinances and regulations in any manner affecting those engaged in the work, or the materials used in the work, or in the conduct of the work, and of all such orders and decrees of bodies having any jurisdiction or authority over the same; and

shall protect and indemnify the party of the first part and their officers and agents against any claim or liability arising from or based on the violation of any such law, ordinance, regulation, or order whether by himself or his employees.

ART. XVI

The Contractor, in the construction of the work, shall give preference in employment to citizens of Harrisville, Michigan and when the same are not available, shall give preference to citizens of the United States of America.

ART. XVII

The Contractor shall give his personal attention to prosecution of the work, shall keep the same under his personal control and shall not assign in any way, or sublet, the work or any part thereof without the previous written permission of the party of the first part, and shall not assign, legally or equitably, any moneys payable or his claims thereto, under the contract unless with some written consent of the party of the first part.

ART. XVIII

The engineer may make alterations in the grade, line, plan, form, dimensions, and materials of the work or any part thereof either before or after the beginning of construction, if the changes decrease the quantity of work to be done without warranting any claim for damages or anticipated profits on the work dispensed with. If the changes increase the work to be done, such increase shall be paid for according to the quantity actually done and at the prices stipulated for such work under this agreement.

ART. XIX

The Contractor shall take all responsibility for the work, and take all precautions for preventing injuries to persons or property in or about the work; shall bear losses resulting to him on account of character of the work or because of the nature of the land in or on which the work is done is different from what was estimated or expected, or on account of the weather, elements or other cause; and he shall assume the defense of and save harmless the party of the first part and their officers and agents from all claims relating to labor and materials furnished for the work; to inventions or patent rights used in doing the work; to injuries to any persons or corporation received or sustained by or from the Contractor and his employees in doing the work, or in consequence of any improper materials, implements, or labor used therein; to any act, omission, or neglect of the Contractor and his employees therein.

The Contractor shall carry and show proof of carrying liability insurance or workmen's compensation insurance and also public liability insurance, together covering bodily injuries to his employees and the public as a consequence of work under this contract.

ART. XX

If the work to be done under this contract shall be abandoned, or if this contract or any part thereof shall be sublet without the previous written consent of the party of the first part, or if the contract or any claim thereunder shall be assigned by the Contractor otherwise than as herein specified, or if at any time the engineer shall be of the opinion and shall so certify by writing to the party of the first part, that the conditions herein specified as to the rate of progress, are not

fulfilled, or if any of the work is unnecessarily or unreasonably delayed, or that the Contractor has violated any of the provisions of this contract, the party of the first part may notify the Contractor to discontinue all or any part of the work and thereupon the Contractor shall discontinue such work as designed by the party of first part and the party of the first pary may thereupon by contract or otherwise as they may determine, complete the balance of such work, and charge the entire expense of so completing the work or part thereof to the Contractor and for such completion the party of the first part for themselves or their contractors may take possession of and use or cause to be used in the completion of the work or part thereof, any such materials, machinery, and tools as may be found on the location of said work.

All expenses charged under this Article shall be deducted and paid by the party of the first part out of the moneys due or to become due the Contractor under any part of this contract and in such accounting the party of the first part shall not be held to obtain the lowest figures for the work of completing the contract or said part or insuring its proper completion, but all sums actually paid therefor shall be charged to the Contractor. In case the expenses so charged are less than the amount due the Contractor, the Contractor shall receive the difference; and in case such expenses shall exceed the said sum, the Contractor shall pay the amount in excess to the party of the first part.

ART. XXI

The Contractor shall pay to the party of the first part all expenses, losses, and damages as determined by the engineer, incurred in consequence of any defect, omission, or mistake of the Contractor or his employees, or the making good thereof.

ART. XXII

The Contractor shall do all work not herein provided for when and as ordered in writing by the engineer or his agents specially authorized in writing to do so, and shall when requested to do so by the engineer, furnish itemized statements of the cost of the work ordered and give the engineer access to accounts, bills, and vouchers relating thereto. If the Contractor claims compensation for extra work not ordered as above stated, or for any damages sustained, he shall, within one week after the beginning of such work or the sustaining of such damage, make a written statement of the nature of the work performed or damage sustained, to the engineer, and shall, on or before the fifteenth day has elapsed succeeding that which any such extra work shall have been done or damage sustained file with the engineer an itemized statement of the details and amounts of such work or damage, and unless such statements shall be made as so required, his claim for compensation shall be forfeited and invalid, and he shall not be entitled to payment on account of such work or damage.

For all such extra work, the Contractor shall receive the reasonable cost of said work plus fifteen per cent of such cost in accordance with Article XXIV.

The decision of the engineer shall be final on all questions of amount and value of extra work, and he shall include in such value the cost to the Contractor of all materials used, of all labor, foremen, and for the rental of all machinery used on extra work, for the period of such use which was on the work before or which shall be required or used until the extra work is finished. If said extra work requires the use of machinery not upon the work, then the cost of transportation of

such machinery to and from the work shall be added to the fair rental but such transportation shall not be in excess of 500 miles. He shall include in the value of extra work the cost to the Contractor of employees liability insurance, and also public liability insurance, covering injuries to his employees or the public resulting from the extra work. The engineer shall not include in the value of such extra work any cost or rental of small tools, buildings, or any portion of the time of the Contractor or his superintendent or any allowance for the use of capital, these items being considered by the fifteen per cent added to the reasonable cost.

ART. XXIII

The party of the first part may keep any moneys which would otherwise be payable at any time and apply the same or any amount necessary, to the payment of expenses, losses or damages incurred by the party of the first part and determined as herein provided and may retain until all claims are settled, so much of such moneys as the party of the first part shall be of the opinion will be required to settle all claims against the party of the first part and their officers and agents, and all claims for labor on the work, and also all claims for the materials used in the work or the party of the first part may make any settlements and apply thereto any moneys retained under this contract. If the moneys under this contract are insufficient to pay the sums found by the party of the first part to be due for said claims, the party of the first part may, at their discretion, pay the same and the Contractor and his surety shall repay the party of the first part such sums paid out. The party of the first part may also, with the written consent of the Contractor, use any moneys retained, due under this contract for the purpose of paying for both

labor and materials for the work, for which claims have not been filed in the office of the party of the first part. While it is understood that the security required be given by the Contractor by giving his bond accompanying this contract, the party of the first part may, if they deem it just and equitable to do so, cause any moneys retained or due, to be held and applied to the payment for labor and materials furnished or supplied by the Contractor for which he has not made payment in full.. The Contractor shall at times that moneys are payable hereunder deliver to the engineer a sworn statement, showing as of that date the amount owed by him for labor and materials.

ART. XXIV

The Town shall pay and the Contractor shall receive as full compensation for everything furnished and done by the Contractor under this contract, including loss and damage arising out of the nature of the work, or any action of the elements, or for any unforeseen obstruction or difficulty encountered in the work and for all expenses incurred by or in consequence of the suspension or discontinuance of the work as herein specified, and for well and faithful completing the work as herein provided a sum of _____ dollars.

For extra work, if any, performed in accordance with Article XXII of this contract the reasonable cost of the work as determined by the engineer, whose determination is final, plus fifteen per cent of such cost.

ART. XXV

The engineer shall, once each month, make an estimate in writing of the amount of work done to the time of such estimates and the value thereof. The party of the first part shall retain fifteen per cent of

such estimated value as part security for the fulfillment of this contract by the Contractor, and shall monthly pay to the Contractor, while carrying on the work, the balance not retained as aforesaid after deducting all previous payments and sums to be kept or retained under provisions of this contract. No such estimate or payment shall be made when, in the judgment of the engineer, the total value of the work since the last estimate amounts to less than three hundred ($300) dollars. Payment at any time may be withheld if the work is not proceeding in accordance to this contract. The party of the first part may, if they deem it necessary, cause estimates to be made more frequently than once each month, and they may cause payments to be made more frequently to the Contractor. The party of the first part may at their option retain temporarily or permanently a smaller amount than aforesaid and may cause the Contractor to be paid temporarily or permanently from time to time during the progress of the work, such portion of the reserve as they think advisable.

The engineer, shall, as soon as practicable after the completion of this contract, make a final estimate of the work done thereunder, and the value of such work, and the party of the first part shall, within sixty days after such a final estimate is made and is approved by the party of the first part, pay the entire sum so found to be due hereunder after deducting therefrom all previous payments and all amounts to be retained under provisions of this contract, including the two per cent of the amount of the contract to be retained as hereinafter provided for making repairs.

It is agreed and understood that any changes made in the plans and specifications for this work, whether such changes increase or decrease

the amount thereof or any change in manner, time, or amounts of payments made by the party of the first part to the Contractor, whether before or after the time specified for completion of this contract, shall in no way annul, release, or in any way affect the liability and surety on bond given by the Contractor.

The Contractor guarantees the work done under this contract, and that the materials used in the construction of the same are free from defects or flaws, and this guarantee is for a term of nine months from and after the date which the engineer's final estimate is approved by the party of the first part.

It is hereby agreed and understood that this guarantee shall not include any repairs made necessary by any causes other than defective work or materials used in the work. The Contractor shall at all times within said term of nine months keep the surface of the ground over this work, or adjacent thereto, in the position and condition required by this contract, and refill any settlement or erosion in the back filling or any surface graded by him due to any cause whatsoever, when so directed by the engineer, should he fail to do so, the party of the first part may have said work done as described below.

ART. XXVI

The party of the first part may retain from moneys payable to the Contractor under this contract, the sum of two per cent and may expend the same in a manner hereinafter provided for in making such repairs of said work as the engineer may deem advisable. If, at any time within the said nine months any of the work contemplated in this contract shall, in the opinion of the engineer require repairing, the engineer shall notify the Contractor in writing to make the required repairs. If

the Contractor shall neglect to make such repairs to the satisfaction of the engineer within three days from the date of mailing or giving such notice, then the engineer may employ other persons to do the same. The party of the first part shall pay the expense of the same out of the sum retained for that purpose. Upon the expiration of the said term of nine months, provided that the work at that time shall be in good order, the Contractor shall be entitled to receive the whole or such part of the sum remaining after the expense of making said repairs is deducted but if said expense is in excess of the sum of two per cent retained, the Contractor shall pay to the Town the amount in excess.

ART. XXVII

Neither the inspection of the party of the first part, nor the engineer, or their agents, nor any order, measurement or certificate by the engineer, nor any order by the party of the first part for the payment of moneys, nor any payment for, nor acceptance of, the whole or any part of the work by the engineer or the party of the first part, nor any extention of time nor any possession taken by the party of the first part or their employees, shall operate as a waiver of any provision of this contract, or of any power herein reserved to the party of the first part, or any right to damages herein provided, nor shall any waiver of any breach of this contract be held as a waiver of any other or subsequent breach. Any remedy provided in this contract shall be taken and construed as cumulative, that is, in addition to each and every other remedy herein provided, and the party of the first part shall also be entitled as of right to a writ of injunction against any breach of any of the provisions of this contract.

IN WITNESS WHEREOF, the parties of these presents have hereunto set their hands and seals the year and day first given above.

_____(Seal)

_____(Seal)

_____(Seal)

_____(Seal)

PERFORMANCE BOND

KNOW ALL MEN BY THESE PRESENTS, that we, the undersigned _____as principal, and _____ as sureties are hereby held and firmly bound unto the _____ _____ in the full and just sum of_____ _____ Dollars ($_____) for payment of which well and truly to be made, we hereby jointly and severally bind ourselves, our heirs, executors, administrators, successors and assigns.

Signed and sealed this _____day of _____ 19____.

The condition of the above obligation is such that if said _____ shall well and faithfully do and perform the things agreed by _____ to be done and performed by the annexed contract, according to the terms thereof, then this obligation shall be void, otherwise the same shall remain in full force and effect.

It is mutually understood and agreed that in cases where changes are required, either by order of the engineer, or owner, or by mutual agreement, such changes shall not modify, discharge or release this bond.

_____(Seal)

_____(Seal)

Signed, Sealed, and Delivered in the presence of

Principal

_____(Seal)

Surety

_____

_____

MATERIALS AND LABOR BOND

KNOW ALL MEN BY THESE PRESENTS, that we, _____ _____ of the _____, hereinafter called the principal, and _____ hereinafter called the Surety, are held and firmly bound unto the People of the State of Michigan in the sum of _____Dollars ($_____), to the payment whereof, well and truly to be made, we bind ourselves, our heirs, executors, administrators, successors and assigns, jointly and severally, firmly by these presents.

Sealed with our seals and dated this _____day of _____ 19____.

WHEREAS, the above named Principal has entered into a contract with the _____ dated the _____day of _____ 19____, wherein the said Principal has covenanted and agreed as follows, to wit:

To furnish all the labor and material _____

_____

AND WHEREAS, this bond is given in compliance with and subject to the provisions of Act No. 187 of the Public Acts of Michigan, for the year 1905, same being sections 14,827 to 14,830 inclusive of the Complied Laws of the State of Michigan of 1915, as amended by Act. No. 384 of the Public Acts of Michigan for 1925 and Act. No. 167 of the Public Acts of Michigan for the year 1927.

NOW, THEREFORE, the condition of this obligation is such that if payment shall be made by the Principal to any subcontractor or by him or any subcontractor as the same may become due and payable of all indebtedness which may arise from him to a subcontractor or a party performing

labor or furnishing materials or supplies or any subcontractor to any person, firm, or corporation on account of any labor performed and materials or supplies furnished in the performance of said contract then this obligation shall be void, otherwise the same shall be in full force and effect.

AND PROVIDED, that any alternations which may be made in the terms of said contract, or in the work to be done under it, or the giving by the party of the first part of said contract of any extention of time for the performance of said contract, or any other forbearance on the part of either party to the other shall not in any way release the Principal and the Surety, or either of them, their heirs, executors, administrators, successors and assigns from any liability hereunder notice to the Surety of any such alternation, extention or forbearance being hereby waived.

Signed, Sealed, and
Delivered in Presence of

_____

_____

_____

_____

Principal

_____

_____

_____

Surety

PART THREE

SPECIFICATIONS

SPECIFICATIONS

ARTICLE 1. EXCAVATION

1. The Contractor shall make all earth excavations to the depths required for the sewers, foundations for appurtenances and structures of the treatment plant as shown on the drawings, clear, and prepare the site of the work under this contract.

2. The earth shall not be plowed or dug with machinery to within six inches of the finished grade, the last six inches to be removed by pick and shovel just before laying the tile. Any excavation carried below the depths as specified by the drawings shall be refilled with material that will render the foundation solid.

3. The material excavated and the materials of construction for the work shall be placed so that street hydrants, water gates, and letter-boxes shall be accessible. Lawns on which excavated material or materials of construction are placed must be protected by planks or canvas. Suitable crosswalks, roadways, and sidewalks shall be provided and the work shall proceed with a minimum of inconvenience to public travel. Safe and convenient access to public and private property shall be provided.

4. Suitable fences, barricades, and lights shall be placed around the excavation, excavated material, and the materials of construction stored on the job.

5. All existing water pipes, electrical conduits, sewers, drains, railroads, roads, and structures which do not require a change in location shall be carefully supported and protected from injury. All roads, curbs, crosswalks, water pipes, drains, sewers, etc., shall be left in good condition. Where pipes, conduits, or sewers are removed

from the trench leaving dead ends in the ground, such ends are to be plugged with brick and mortar, or mortar.

6. Changes in location of the sewer or any structure required or specified by the engineer and not required by the drawings shall be made by the Contractor and shall be paid for as extra work.

ARTICLE 2. SHEETING AND BRACING

1. The Contractor shall furnish, put in place, and maintain such sheeting and bracing as may be necessary to support the sides of the excavation and protect adjacent structures and roads.

2. Sheeting and bracing to be removed shall be removed in such a manner as not to endanger the sewer or adjacent structures and property. All voids left caused by the removal of sheeting shall be filled. Sheeting left in the trench shall not project above a point four feet below the surface.

ARTICLE 3. PUMPING AND DRAINING

1. The Contractor shall remove all water which may accumulate in the trenches or around the work and shall provide all dams and channels necessary to keep them clear of water during construction. The Contractor shall have sufficient pumping machinery ready for immediate use on the job.

2. Newly laid pipe and masonry shall be kept dewatered until permanent set has taken place.

3. Water from trenches shall be disposed of in such a manner as not to cause injury to public health, public or private property, the work completed, nor to interfere with public travel or utilities. The Contractor shall provide temporary channels for surface water flowing along or across the site of the work.

4. When directed by the engineer, the Contractor shall lay open jointed clay pipe, which passes the requirements of Article 6, in a bed of graded gravel in the trench below the subgrade of the sewer. The cost of the materials and the labor shall be paid for as extra work.

ARTICLE 4. BACKFILLING

1. The material used for backfilling shall be free of organic material such as leaves, branches, or mucky soil.

2. Unless otherwise directed the backfilling shall begin as soon as the pipe or masonry has acquired sufficient hardness and shall be completed as soon as possible. The use of water in compacting the backfill material is permitted; the water is to be paid for by the Contractor.

3. No material shall be placed over the newly laid pipe or structure until the pipe is strong enough to support the weight of the material and in no case in less than twenty-four hours.

4. Walking or working on the completed sewer shall be permitted except when necessary in backfilling and tamping until at least two feet of material covers the pipe.

5. The filling of the trench shall be so that the backfill material is placed on both sides of the pipe simultaneously so that the pipe will not be forced out of line.

ARTICLE 5. VITRIFIED PIPE AND SPECIALS

1. Vitrified clay pipe sewer pipe shall fulfill the requirements as to strengths, sizes, and quality of the A.S.T.M. "Standard Specifications for Clay Sewer Pipe," (Designation C-13-35).

2. All pipe will be inspected upon delivery and those not conforming to these specifications will be rejected and shall be removed from the site of the work immediately. Labor necessary for inspection of the pipe is to be furnished by the Contractor. The entire product of any manufacturer may be rejected if the methods of manufacture do not guarantee uniform results and if an excess of the pipe fail to pass the inspection.

ARTICLE 6. DRAIN TILE

1. All drain tile mentioned in Article 5 and on sheet 6 of the drawings shall pass the requirements as to size, strength, and quality of the A.S.T.M. "Standard Specifications for Drain Tile," (Designation C-4-24).

2. All drain tile will be inspected upon delivery and those not conforming to these specifications will be rejected and shall be removed from the site of the work immediately. The cost of aiding the engineer in making his inspection and the removal of the rejected pipe shall be borne by the Contractor.

ARTICLE 7. LAYING VITRIFIED PIPE

1. The pipe lines shall be constructed of the size and on the lines and grades as shown on the drawings.

2. Branch Y's shall be provided and installed where directed and at least one shall be installed for each lot served by the pipe line. The open end of each branch Y shall be covered and sealed with a vitrified stopper made waterproof by a mortar or asphalt joint. The branches are to be laid with the tap at an angle of 50° with the horizontal.

3. The earth shall be removed in such a manner as to make a

uniform supporting bed for the entire length of the pipe except the bell under which a recess shall be dug deep enough to relieve it of bearing pressure and to make the joint. It is forbidden to raise the grade of the pipe by ramming earth under the pipe.

4. The joints are to be made of plastic asphalt compound of recognized and approved quality. The joint is to be thoroughly waterproof and is to be made by calking tightly with a twisted gasket of jute long enough to go around the pipe and overlap and at least three-fourths inch thick and completely filling the remaining space with asphalt jointing material.

ARTICLE 8. BRICK FOR MANHOLES

1. All brick for use in manholes shall pass the requirements in size, strength, and quality of Class C brick of the A.S.T.M. "Standard Specifications for Building Brick (Made from Clay or Shale)" (Designation C-62-30). The brick shall be clear of cracks, warpage, stones, or pebbles.

2. The Contractor shall submit at least three samples of brick which he wishes to use to the engineer at least two weeks before he plans to use them.

3. The brick shall be inspected by the engineer at the site of the work and those not conforming to specifications will be rejected and shall be removed from the site immediately. The labor required in assisting the engineer in this inspection will be furnished by the Contractor.

ARTICLE 9. BRICK FOR BUILDING

1. All brick for use in the plant building shall pass the requirements in size, strength and quality of Class A brick of the A.S.T.M.

"Standard Specifications for Building Brick (Made from Clay or Shale)" (Designation C-62-30).

2. The Contractor shall submit at least three samples of brick which he wishes to use to the engineer at least two weeks before he plans to use them.

3. The brick shall be inspected by the engineer at the site of the work and those not conforming to specifications will be rejected and shall be removed from the site immediately. The labor required in assisting the engineer in this inspection will be furnished by the Contractor.

ARTICLE 10. BUILDING TILE

1. Building tile for use in the plant building shall pass the requirements in size, strength, and quality, and number of cells of the A.S.T.M. "Standard Specifications for Structural Clay Load Bearing Wall Tile" (Designation C-34-36).

2. Wall tile are subject to inspection by the engineer and may be rejected for failure to meet the requirements, number of cells, specified size, workmanship, or finish. Rejected tile must be removed immediately from the site of the work by the Contractor.

ARTICLE 11. MORTAR

1. All mortar shall be composed of one part of Portland cement to three parts of sand by volume, and the proper amount of water for the correct consistency. The sand, water and cement shall conform to related specifications. (Articles 14, 15 and 17B)

2. Retempering of mortar is prohibited.

ARTICLE 12. LAYING OF BRICK

1. All brick to be incorporated in brick masonry shall conform to Article 8 or Article 9 of this set of specifications. Mortar used shall conform to Article 11 of these specifications.

2. All brick shall be thoroughly wetted immediately before being laid by immersion in water that is free from harmful acids or alkalis. Old brickwork shall be cleaned and wetted before new brickwork can be laid on it.

3. Every brick shall be laid in a full and close joint of mortar on its bed, side, and end in one operation. The joints on the face of the work shall not exceed $\frac{1}{4}$" in thickness. Slushing mortar into the joints after the brick is placed is prohibited.

4. All brick masonry shall be thoroughly bonded throughout the structure.

5. All fresh work shall be protected from injury.

ARTICLE 13. MANHOLES

1. Manholes shall be placed at points as shown on the drawings and shall conform in size, shape and type as shown on the drawings.

2. All manholes shall be brought to the proper grade so that the top of the manhole cover is exactly at established grade.

3. Manhole frames and covers shall conform to the drawings and shall be made of approved gray cast iron and shall be painted as specified in Article 21 of these specifications. The standard manhole frame and cover made by a foundry or firm of good reputation may be substituted with the approval of the engineer.

4. Steel steps as shown on the drawings shall be built into the brickwork 15 inches on centers vertically. They shall be painted as

specified in Article 21 of these specifications.

ARTICLE 14. CEMENT

1. All cement shall be of such quality as to meet the specifications of the A.S.T.M. "Standard Specifications for Portland Cement" (Designation C-9-30), and the A.S.T.M. "Standard Methods of Sampling and Testing Portland Cement" (Designation C-77-32). Should high early strength Portland cement be used it shall pass the specifications of the A.S.T.M. "Standard Specifications for High Early Strength Portland Cement" (Designation C-74-36).

2. The cement shall be subject to any tests and inspection by the engineer at the site of the work.

3. The cement shall be delivered in paper or cloth bags containing not less than 94 pounds per bag or in barrels containing the equivalent of four bags. The container shall be plainly marked with the brand and manufacturer's name.

4. The Contractor shall provide adequate watertight storage for all cement delivered on the site. Each shipment shall be placed in separate stacks or piles so that shipments may be distinguished between, and the contractor must furnish the engineer with information he may request about each shipment.

ARTICLE 15. FINE AGGREGATE

1. Fine aggregate shall be clean, washed sand or other approved inert material having similar characteristics; having hard, strong, durable particles.

2. The maximum amount of deliterious substances in the aggregate shall be 5% by weight. All fine aggregate shall be free from injuries

amounts of organic impurities as determined by the colorimetric test for organic impurities. All colors having a color darker than the standard shall be rejected.

3. Fine aggregate shall be well graded from coarse to fine and shall conform to the following requirements:

Passing a 3/8 sieve	100%
Passing a #4 sieve	85% to 100%
Passing a #16 sieve	45% to 80%
Passing a #50 sieve	2% to 30%
Passing a #100 sieve	0% to 5%

4. Fine aggregate from different sources of supply shall not be mixed or stored in the same pile nor used alternately in the same class of concrete or mix without permission from the engineer.

5. Aggregate from each source of supply shall pass such tests as prescribed by the engineer before its use. Aggregates to be tested shall be submitted to the engineer at least 10 days in advance of the time of delivery.

ARTICLE 16. COARSE AGGREGATES

1. Coarse aggregate shall consist of crushed stone, gravel, blast furnace slag or other approved inert material having similar characteristics; having hard, strong, durable pieces free from adherent coatings, alkali materials, laminations, and organic matter.

2. The maximum amount of deliterious material shall not exceed 5% by weight.

3. Coarse aggregate shall be washed and well graded between the limits of the following requirements:

Passing a 1½" sieve	not less than 95%

Passing a ¾" sieve	not less than 40% or more than 75%
Passing a ¼" sieve	not more than 5%

4. In sections less than four inches or less in thickness the maximum size of coarse aggregate shall be ¾ inches.

5. Aggregate from each source must pass such tests as required by the engineer. Aggregates to be tested shall be submitted not less than ten days before the time of delivery.

ARTICLE 17. CONCRETE

A. Forms

1. All necessary forms and supports for forms required shall be furnished by the contractor and erected by him in sufficient quantities to avoid delays.

2. Forms shall conform to the shape and dimension of the member as called for on the drawings. They shall be sufficiently braced or tied together so as to maintain the position and shape intended.

3. Forms shall be made of matched lumber which is surfaced on the side touching the concrete. All forms shall be cleaned thoroughly before erection and shall be well moistened just before placing the concrete.

4. Forms shall be sufficiently tight to prevent leakage of mortar.

5. Moulding or a fillet strip shall be placed in the forms to prevent sharp corners.

6. Forms shall not be disturbed until the concrete has adequately hardened nor shall the permanent shores be removed until the structure has attained its design strength to sustain its own weight plus any additional

construction loads likely to come upon it.

7. The contractor shall build into the concrete, steel reinforcing, expansion joints, pipes, anchor bolts, sleeves, castings, electrical conduits and inserts, and shall leave openings where needed and ordered. Care shall be exercised in keeping said inserts, etc. to the proper grade and line and to thoroughly rod the concrete around them.

B. Water

1. The water used in mixing concrete shall be obtained from the mains of the water system of the City of Harrisville which is of good quality and is to be paid for by the contractor. The City of Harrisville shall supply the meter and shall make such connections as desired by the contractor.

2. The amount of water shall be accurately measured for each batch. The engineer shall specify the amount of water to be used before beginning to mix each day. In no case shall the amount of water added be more than 88% of the cement by volume.

C. Proportioning

1. The proportion of all concrete placed under this contract shall be 1:2:4 by volume. Sand shall be measured when inundated and gravel when loosely thrown into a box.

2. The engineer shall make slump tests using concrete furnished by the contractor in order to determine the workability of the mix. The engineer may alter the proportions of fine and coarse aggregate to secure a better workability but in no case shall the total volume of 1 to 6 (aggregates measured separately) be disregarded.

3. There shall never be less than six bags of cement used per cubic yard of concrete.

D. Mixing

1. Mixing shall be done in a batch mixer of approved type which will insure a uniform distribution of the materials throughout the mass so that the mixture is uniform in color and is homogeneous. The mixer shall be equipped with a charging device, water storage, and a water measuring device.

2. The entire contents of the mixer shall be discharged before recharging. At frequent intervals the mixer shall be cleaned out.

3. Each batch shall be mixed a minimum of 1½ minutes after all the ingredients are in the mixer, at a speed designated as the operating speed of the mixer by the manufacturer.

4. When hand mixing is authorized by the engineer it shall be done on a water-tight platform and shall be turned six times or until the mass is homogeneous in appearance and color after the water has been added.

5. Retempering of concrete which has partially hardened with or without the addition of materials will not be permitted.

E. Placing of Concrete

1. Before beginning a run of concrete, hardened concrete and foreign material shall be removed from the inner surfaces of mixing and conveying equipment.

2. Before placing the concrete, debris shall be removed from inside the forms, the forms shall be thoroughly wetted or oiled, and reinforcing steel shall be securely fastened in its correct position.

3. The concrete shall be transported from the mixer to the place of final deposit as rapidly as possible by methods which shall prevent separation or loss of ingredients. It shall be deposited as

nearly as practicable in its final place to avoid rehandling. It shall be deposited in approximately horizontal layers to prevent any flowing of concrete.

4. Concrete, during and immediately after depositing, shall be thoroughly compacted with rods with special attention being paid to rodding near the forms and reinforcing bars. For thin walls or inaccessible members the concrete shall be compacted by tapping on the forms.

5. The surface of already hardened concrete shall be roughened and cleaned of foreign material and laitance and saturated with water and the forms retightened before depositing the concrete. Keyways for construction joints shall be used, the size of which shall be approved by the engineer.

6. Unless permission is obtained from the engineer no concrete shall be deposited under water nor shall the water be allowed to cover the newly placed concrete until the concrete has set for 24 hours.

7. The concrete shall be deposited as rapidly as practicable and shall continue until the unit is complete.

F. Finishing of Surfaces

1. Immediately after the forms are removed all surfaces of concrete exposed such as the inside of tanks, walls, columns, beams, and slabs shall be finished by vigorously rubbing with carborundum brick and water to insure a true surface.

2. All skin and form marks shall be removed and all voids and cracks shall be filled with a thin cement grout composed of one part of cement and two parts of sand, and scraped.

G. Curing

1. All surfaces shall be kept moistened with water in approved fashion after sufficient set has taken place and shall be kept continually moistened for a period of at least seven days.

2. Concrete poured in freezing weather shall be deposited at a temperature greater than 50°F. and shall be protected from freezing.

ARTICLE 18. STEEL REINFORCING

1. All steel reinforcing bars shall meet the requirements of the A.S.T.M. "Standard Specifications for Billet Steel Concrete Reinforcing Bars" (Designation A-15-59) intermediate grade.

2. All steel used shall be new, clean, free from rust, scale, and defects, and shall have no bends or twists not specified by the drawings. No rerolled or high carbon steel will be permitted. Heating to straighten reinforcing steel will not be permitted. All steel shall be kept free of grease, oil, or dirt and shall be satisfactorily cleaned of scale or rust before being placed.

3. All steel when in storage shall be protected from rusting action. It shall be sorted and placed so that it does not come in contact with the ground.

4. The contractor shall submit detailed drawings and steel schedules showing number, size, length, and bending diagrams of the steel for the steel he proposes to furnish and no steel will be approved unless it conforms to the bending diagrams.

5. All steel shall be of single lengths unless it is unobtainable. In the case of lapping, the joint shall be at the point of minimum stress. Sufficient overlapping shall be provided for transferring the stress.

6. All steel reinforcing bars shall be carefully placed and secured against displacement by wiring with #18 U.S. Standard gage annealed iron wire or with approved clips.

7. All steel shall be of the deformed bar type.

ARTICLE 19. CAST IRON PIPE AND FITTINGS

1. Cast iron pipe shall be used as shown on the drawings and shall conform to the American Water Works Association "Standard Specifications for Cast Iron Water Pipe and Fittings" for class A pipe.

2. Regardless of the type of joint shown on the drawings any cast iron pipe whose joint is in earth shall be of the bell and spigot type and the joint sealed by lead. All cast iron pipe joints inside the tanks or walls shall be flanges type conforming in size and strength to the American Standard Flanged Fittings.

3. All gate valves shall be of the double seat, parallel face, loose disc type and of ample strength to withstand and operate satisfactorily under working hydrostatic. The valves shall be bronze mounted and the gate and seat rings shall be of bronze. All valves shall be manually operated.

4. All pipe shall be inspected by the engineer at the site of the work, the labor required to be furnished by the contractor. All rejected pipe shall be removed from the site immediately. Each piece of pipe shall bear the manufacturer's serial number and shall be certified by the manufacturer to have passed the requirements of the above specifications.

ARTICLE 20. LAYING CAST IRON PIPE AND FITTINGS

1. Care shall be exercised to prevent pipe or fittings from

being damaged during construction; the pipe coating shall be sound especially on the inside of the pipe and fittings.

2. All bell and spigot type pipe shall be laid with a lead joint composed of a ring of twisted jute and soft pig lead.

3. All flanged pipe shall be laid true to line and thoroughly bolted with bolts that meet the specifications of Article 19. A rubber gasket shall be used in all joints.

ARTICLE 21. Lumber

1. The contractor shall furnish all lumber required to make the roof of the building as shown on sheet #5 of the drawings.

2. All lumber shall be new, well seasoned #1 Yellow Pine free from large and loose knots, shakes or other damaging imperfections and shall be sawed square and true.

ARTICLE 22. ROOFING

1. The contractor shall furnish asphalt shingle roofing as manufactured by the Barrett Company or equal. The roofing shall be of the Underwriters Class C rating.

2. The roofing shall be applied in a manner as to obtain the best type of waterproof roof. Suitable flashing and other materials required to make a water-tight joint around the chimney and vent shall be used.

ARTICLE 23. SUMP PUMP

1. The contractor shall furnish and install in the position as shown on the drawings, a sump pump capable of pumping ten (10) gallons per minute against a total head of 18 feet.

2. The equipment shall include a centrifugal pump with motor, float, float switch, starting switch, couplings and bearings necessary for immediate operation. The discharge shall be 1½ inches in diameter.

3. The motor shall be a 110 volt, 1750 RPM motor made by a reputable manufacturer.

ARTICLE 24. PUMP FOR LIFT STATION

1. The contractor shall furnish complete and install one electrically driven vertical ball bearing centrifugal non-clog sewage and trash pump with 4-inch flanged suction and discharge openings.

2. The pump shall be capable of delivering fifty (50) gallons per minute against a head of 200 feet. The pump must be especially suited for pumping raw sewage which has not been screened. All openings shall be large enough to permit the passage of a sphere 2" in diameter including sticks and rags or any other trash that will flow in and around the elbows of a 4" pipe without clogging.

3. The pump shall be driven by a three phase, 60 cycle, 1 H.P., 220 volt, constant speed splash-proof motor of standard make as Westinghouse, General Electric, or Howell equipped with a safety switch at the motor and a magnetic motor starting switch of across-the-line type to be placed on the switchboard.

4. The impeller shall be of the enclosed type with the forward ends of the blades well rounded to avoid catching trash; the blades shall be tapered toward the periphery of the impeller so as to give the maximum possible shut-off head; and the outer tips of the blades shall occupy only a negligible portion of the area of the impeller throat or periphery. The impeller shall be made of cast iron and shall be accurately balanced

before assembling in the pump.

5. The volute shall be made of cast iron and shall be large enough at all points to pass any solids which can pass through the impeller.

6. The casing heads or side plates shall be cast separate from the volute and built so that the entire impeller can be removed by unbolting the suction head.

7. The pump shall run on ball bearings; one of which shall be of the radial type, and one of the radial and thrust type. The bearings shall have a labyrinth disc type seal to prevent any water from entering the bearing and to prevent grease from escaping.

8. The pump shaft shall be 1¼" in diameter or greater and shall be made of manganese alloy steel carefully ground to size. This shaft shall have a tapered fit in the impeller for ease in assembly and maintenance, and shall be fastened with a key and screw. The shaft shall be covered with a chrome stainless steel sleeve, Brinell 450 or greater, where it passes through the stuffing box. The pump is to be packed with rawhide packing to retard wear on the shaft sleeve in event abrasives are handled in large quantities.

9. The pump shall be connected to the motor by one "A" section of flexible shafting with a universal joint connection to the pump and motor shafts.

10. The pump must be of size to fit into the area provided in the lower level of the lift pump station (sheet 10 of the Sewage drawings).

11. All wrenches, greasing equipment, etc., necessary to

service this pump shall be furnished by the contractor.

ARTICLE 25. SLUDGE PUMPS

1. (Pumps #1 and #2). The contractor shall furnish complete two (2) electrically driven horizontal ball bearing, centrifugal, non-clog sewage pumps with 4" flanged suction and discharge openings. These pumps are to be the variable speed type.

(Pump #3). The contractor shall also furnish complete one (1) electrically driven, horizontal ball bearing, centrifugal, non-clog sludge pump with 4" flanged suction and discharge openings. This pump is to be the constant speed type.

2. Each pump shall be capable of delivering 50 gallons per minute against a head of 3.0, 30.0, and 29.5 feet respectively for pumps #1, #2, and #3. The pumps shall be especially suitable for pumping of activated sludge and raw sludge. All openings shall be large enough to permit the passage of a sphere 2" in diameter including sticks and rags or any other trash that will flow through a 4" pipe or around a 4" elbow without clogging.

3. Each pump shall be driven by a three phase, 60 cycle, 1 H.P., 220 volt, constant speed splash-proof motor of standard make as Westinghouse, Howell, or General Electric. Each shall be equipped with a safety switch at the motor and a magnetic motor starting switch of the across-the-line type to be placed on the switchboard.

4. The impeller shall be of the enclosed type with the forward ends of the blades well rounded to avoid clogging; the blades shall be tapered towards the periphery of the impeller to generate the highest shut-off head; and the outer tips of the blades shall occupy only a

negligible portion of the area of the impeller throat or periphery. The impeller shall be made of cast iron and shall be accurately balanced before assembling in the pump.

5. The volute shall be made of cast iron and shall be large enough to pass any size solid which can pass through the impeller.

6. The casing heads or side plates shall be cast separate from the volute, and so built that the entire impeller may be removed by unbolting the suction head.

7. The pump shaft shall run on ball bearings, one of the radial type and one of the radial and thrust type. The bearings shall have a labyrinth disc type seal to prevent any water from entering the bearing and to prevent any grease from leaking out.

8. The pump shaft shall be 1¼" in diameter or greater and shall be made of manganese alloy steel, carefully ground to size. This shaft shall have a tapered fit in the impeller for ease of assembly and maintenance, and shall be fastened with a key and screw. The shaft shall be covered with a chrome stainless steel sleeve, Brinell 450, or greater, where it passes through the stuffing box. Each pump is to be packed with rawhide packing to retard wear on the shaft sleeve.

9. Pump #3 must be provided with a special flexible coupling of the pin and rubber bushing type. The coupling shall be accurately balanced before shipment.

Pumps #1 and #2 must be provided with variable speed pulley and belt arrangements.

10. The workmanship throughout is to be of the highest grade and all parts guaranteed against defects for one year.

11. The pumps shall be of such size as to readily fit into the area of the pump room as shown on sheet #5 of the drawings.

12. All wrenches, greasing equipment, etc., necessary for servicing this equipment shall be furnished by the contractor.

ARTICLE 26. PRIMARY TANK SLUDGE COLLECTOR

1. The contractor shall furnish and install complete one sludge collector mechanism for one tank as shown on sheet #2 of the drawings.

2. The sludge collector mechanism shall be of the straight-line type as manufactured by the Link-Belt Company and the Jeffrey Company. The manufacturer shall submit his specifications for his product which will be examined and subject to approval by the engineer. The manufacturer shall have experience in the design of this type of mechanism and shall have successful installations for three or more years.

3. The manufacturer shall furnish all bolts, anchors, rails for the tank bottom, wall supports, driving chain, etc.

4. The motor shall be of the splash-proof type as manufactured by General Electric, Howell, Westinghouse, or equal. It shall be impregnated against moisture. It shall operate on three phase, 60 cycle, 220 volt alternating current. It shall be equipped with a safety switch at the motor. The reducer shall be the motorized reducer type with anti-friction bearings.

5. All wrenches, greasing equipment, etc. necessary for servicing this equipment shall be furnished by the contractor.

ARTICLE 27. AERATOR MECHANISM

1. The contractor shall furnish and install complete one mechanical aerator as provided for on sheet #3 of the drawings.

2. The aerator shall be capable of diffusing finely divided air bubbles from the bottom of the tank, causing these bubbles to rise the full depth of the tank to the surface. The amount of finely divided air introduced shall be capable of being readily adjusted between the limits of zero to 0.5 cubic feet of air per gallon of sewage treated.

3. The manufacturer of the equipment shall submit his specifications for his product which will be examined and subject to approval by the engineer. The manufacturer shall have experience in the design of this type of mechanism and shall have installations which have been in successful operation three or more years.

4. All material used in the construction of the mechanical equipment shall be of the corrosion resisting type. All plate material shall be of wrought iron, and all fastenings and bolts shall be of steel heavily galvanized. The equipment shall be painted as stipulated in Article 32 of these specifications.

5. The motor to drive the aerator shall be three phase, 60 cycle, 220 volt alternating current motor of reliable manufacture, impregnated with moisture-proof insulation and suitable for operating under all weather conditions. The motor shall be provided with a moisture-proof reversing switch at the motor, a magnetic motor starting switch of the across-the-line type placed on the switch-board, a switch in the cover of the starter marked "hand", "off," "automatic" for either manual

or automatic time switch operation of the equipment, and a time switch provided with an indicating dial for adjusting the "on and off" cycle to any period of operation from zero to 100% of the cycle for automatic operation of the unit.

6. All wrenches, greasing equipment, etc. necessary for servicing this equipment shall be provided by the contractor.

ARTICLE 28. FINAL TANK SLUDGE COLLECTOR

1. The contractor shall furnish and install complete one sludge collector mechanism for one tank as shown on sheet #4 of the drawings.

2. The sludge collector mechanism shall be of the straight-line type as manufactured by the Link-Belt Company and the Jeffrey Company. The manufacturer shall submit his specifications for his product which will be examined and subject to approval by the engineer. The manufacturer shall have experience in the design of this type of mechanism and shall have successful installation for three or more years.

3. The manufacturer shall furnish all bolts, anchors, rails for the tank bottom, brackets, wall supports, driving chain, etc.

4. The motor shall be of the splash-proof type as manufactured by Howell, General Electric, or Westinghouse, or equal. It shall be impregnated against moisture. It shall operate on three phase, 60 cycle, 220 volt alternating current. It shall be equipped with a safety switch at the motor. The reducer shall be the motorized reducer type with anti-friction bearings.

5. All wrenches, greasing equipment, etc., necessary for servicing this equipment shall be furnished by the contractor.

ARTICLE 29. ELECTRICAL EQUIPMENT

1. The contractor shall furnish and install all electrical equipment and make any connections necessary to place all electrical devices provided for in these specifications and on the drawings in full and satisfactory operating condition.

2. All electrical work shall comply with the N.E. Code, 1939 edition as regards to materials, insulation, and limitations.

3. Each motor, including the motor at the pump lift station, shall be provided with a series thermal over-load breaker at the switchboard in the building with an alarm provided to indicate when the breaker has tripped due to overload.

4. Four convenient outlets for the laboratory shall be provided. All ceiling lights provided for on the drawings shall be single, direct light units with a glass enclosing globe and rust-proof base. Two over head lights shall be provided in the basement of the building connected to a switch at the head of the stairs to the basement. Outlets and lights are to be supplied with two phase, 110 volt, 60 cycle alternating current. The contractor shall provide all fixtures, lamps, and fuses to place such equipment in operation.

5. The contractor shall provide and install a line voltmeter and ammeter to be placed on the switchboard.

ARTICLE 30. PLUMBING AND FIXTURES

1. The contractor shall furnish materials necessary and install a $1\frac{1}{2}$" wrought iron water pipe connecting the city mains and the plant as shown on sheet #1 of the drawings.

2. Three-quarter inch water pipe shall be placed as shown on

sheet #5 of the drawings to the laboratory sink and to the lavatory (water closet). There shall be one convenient outlet and a meter in the basement. Valves shall be provided on all branch lines to enable any one or more fixtures to be shut off at one time.

3. There shall be two outlets as shown on sheet #1, one near the sludge tank and one between the primary and aeration tanks. They shall be equipped with self draining valves and boxes.

4. The contractor shall furnish complete and install ready for use one water closet of standard manufacture as made by Crane Company, Kohler, and Company, or equal, in the space provided for. The outlet is shown on sheet #5 of the drawings.

ARTICLE 31. PIPE RAILINGS

1. The contractor shall furnish all the materials for and properly install all pipe railings shown on the drawings and in the locations as shown in the drawings.

2. The posts shall be of standard weight $1\frac{1}{2}$" wrought iron pipe screwed into floor flanges which are firmly anchored into the concrete or to be firmly bolted with no less than 3 - $\frac{1}{2}$" steel bolts to the channels making up the stairway. The rails shall be of standard weight $1\frac{1}{2}$" wrought iron pipe and spaced as shown on the drawings. Slip joints are to be used with the rails and posts firmly pinned.

3. The railings shall be painted as specified in Article 32 of these specifications.

ARTICLE 32. PAINT AND PAINTING

1. All surfaces to be painted shall be thoroughly cleaned of rust, grease, and any other foreign matter by the method approved by

the engineer.

2. No painting shall be done in temperatures below 32°F nor upon wet or damp wood, on damp, frosty metal, nor in foggy and wet weather, nor in basements where the atmosphere is damp.

3. All electrical, mechanical, and other equipment shall be protected from drippings of paint or other materials of construction by suitable coverings.

4. After all equipment and piping are erected and installed they shall be given the final coat of paint as herein specified.

5. All exposed wood and building boardsurfaces shall be painted with three coats of the best quality of lead paint. The first coat shall be a primer coat with the paint thinned with an equal volume of oil. All paint used as specified in this clause shall be thinned with the best quality of raw linseed oil.

6. All pipes, railings, stairs, and other miscellaneous metal equipment, with the exception of the railing on the aerator tank (see sheet #3) shall be painted with at least two coats of asphalt varnish; the second coat of which shall comform to part four of this article.

7. All metal equipment and apparatus in and around the primary tank, aerator tank, the final tank, and the outfall box shall be painted with two coats of chlorinated rubber paint as manufactured by Goodyear Rubber Company and Firestone Tire and Rubber Company. All mechanical equipment shall not receive any paint other than chlorinated rubber paint.

8. Gratings for the channels shall be either painted with two coats of chlorinated rubber paint as in part 7 of this article or

they shall be heavily galvanized.

9. All damaged paint surfaces shall be cleaned and repainted or touched up prior to the final approval of the work.

ARTICLE 33. FENCE

1. The contractor shall furnish and erect fencing as required by sheet #1 of the drawings, and by this article.

2. The fencing used shall be of the diamond-shaped chain-link type with not greater than 2" mesh. It shall be heavily galvanized. Posts shall be at least 2" pipe also heavily galvanized and shall be set in concrete at least 12" in diameter and 4 feet deep. They shall be spaced not greater than eight feet on centers. A railing shall be placed around the top of the fence.

3. A gate ten feet wide made of material similar to the fencing shall be placed in the position as shown on sheet #1 of the drawings. The gate shall swing on hinges that support the weight of the gate so as to eliminate any lifting when opening the gate.

4. The gate shall be provided with a lock and shall be capable of being securely locked.

ARTICLE 34. LABORATORY EQUIPMENT

1. Furniture. The main work table along the front wall (see sheet #5) shall be 7'-6" long, 2'-6" wide and 3'-0" high. Cabinates and drawers shall be provided for the full length of the table. The furniture shall be of copper bearing steel alloy (greater than 0.25% copper) finished with a baked enamel finish. The table top is to be of birch with a carbonized black acid and alkali resisting finish. The sink shall be of stoneware 18" x 24" x 8" deep with a lead waste plug,

and shall be placed as shown on the said drawing.

2. Equipment. The contractor shall provide the following equipment which shall be procured from a reliable manufacturer:

QUANTITY	ITEM	Cat. No. (Central Scientific Co.)
1	Analytical Balance	1514
1	Set Balance Wts.	8100
1	Trip Balance	3370
1	Set Balance Wts.	9100
1	pH Colorimetric Indicator (Phenol Red pH 6.8 to 8.4 and Chloro-phenol Red pH 5.2 to 6.8 slides required)	21600
1	Muffle Furnace	13675
1	Electrical Drying Oven	95000A
1	Electric Water Distiller (one gal./hr. cap.)	12750
1	Electric Water Bath (6 openings)	19920A
2	Beakers 1 liter	14265
6	" 400 ml.	"
6	" 250 ml.	"
6	Bottles glass stoppered 32 oz.	10425
5	" " " 16 oz.	"
24	" " " 8 oz.	"
2	Burettes 50 ml.	15925C
1	Burette support	19005
2	Clamps burette	12105
4	Clamps pinch	12186
1	Corks, bag assorted	12408
12	Crucibles Gooch 25 ml.	18550
1	Crucible tongs 18" handle	19640
1	Dessicator 230 mm.	14550
1	" 250 mm.	"
1	Electric Hot Plate 110 volt	16500A
4	Erlenmeyer Flasks 250 ml.	14905
6	Evaporating Dishes 75 mm.	18575
1	File 3"	88325
1	Funnel Support	19035
1	Glass Tubing 1b. 7 mm.	14100
2	Graduated Cylinders 1 liter	16125
2	" " 100 ml.	"
1	" " 25 ml.	"
1	" " 10 ml.	"
3	Imhoff Cones	29015
2	Pipettes 100 ml.	16355
5	" 1 ml.	"
2	" graduated 1/100 1 ml.	16325B
2	" " 1/10 10 ml.	16325F
2	Iron Rings 4"	18005C

QUANTITY	ITEM	Cat. No. (Central Scientific Co.)
24	Rubber Tubing ft.	18202C
1	Rubber Stoppers 1 lb. assorted	18153A
1	Sampling Can (D.O.) See M.S.C. Bulletin	
2	Spatulas 3"	18750A
2	Suction Flasks 500 ml.	14990
2	Rubber Crucible Holder	18110A
2	Thermometers -10°C to 110°C	19240A
2	Triangles 2"	19720A
1	Tripod	19770B
2	Volumetric Flasks 1 liter	16250
2	" " 100 ml.	"
2	Wash Bottles 1 liter	14810
2	Water Suction Pumps	13195

3. Chemicals. The contractor shall furnish the following chemicals which are to be C.P. unless otherwise indicated.

QUANTITY	ITEM
¼ lb.	Asbestos Fiber
¼ lb.	Chloroform
5 lbs.	Manganous Sulphate crystals
10 gms.	Methylene Blue
25 gms.	O-Tolidine
5 lbs.	Potassium Dichromate
1 lb.	Potassium Iodide
1 lb.	Sodium Bicarbonate
5 lbs.	Sodium Hydroxide pellets
1 lb.	Sodium Thiosulphate crystals
9 lbs.	Sulphuric Acid C.P.
9 lbs.	" " tech.
4 oz.	Starch indicator grade
1 lb.	Copper sulphate crystalls

ARTICLE 35. LANDSCAPING

1. The contractor shall provide all materials and labor necessary for placing the grounds as herein specified.

2. The entire area inside the fence line exclusive of the area of the tanks, troughs, building , sludge bed, etc., shall be covered with at least a 6-inch layer of clay and a 2-inch layer of

loamy top soil approved by the engineer.

3. The final grade after the clay and top soil are put on shall be as indicated on sheet #1 of the drawings.

ARTICLE 36. MISCELLANEOUS ITEMS

1. Cleanup. The contractor shall remove all scraps, rubbish, and debris from in the tanks, pipes, and building and shall place the plant in full running condition before he leaves the work. He shall also remove all rubbish and excess materials of construction from the site.

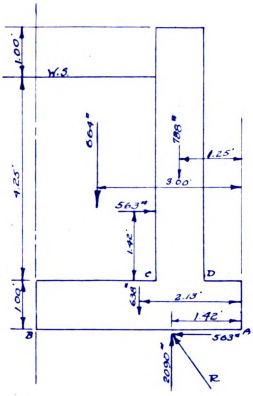
2. Oil Burner and Tank. The contractor shall provide and install ready for use one oil burning furnace of 40,000 B.t.u. per hour capacity in the space provided as shown on sheet #5 of the drawings. The burner shall be one of the common household type with a pleasing appearance and shall approximately fit the space provided. The contractor shall also provide and install (see sheet #1) one 200 gallon capacity oil tank fitted with a gravity feed line to the burner of large enough size to allow the oil to run freely at all times.

3. Measuring gage. The contractor shall provide and install a device complete with a continuous recording gage to measure the head on the measuring weir as shown on sheet #2 of the drawings. The recording gage shall be placed in a convenient place in the building. The engineer shall calibrate the gage to fit the specific conditions of the weir.

Structural Design

I Primary Tank Wall

Design a cantilever wall for a concrete tank, max height 5'-3" and inside width of 6'-0". In order to insure waterproof construction, the wall & footing must be 12" in thickness or more. Assume the thickness of wall 12", footing 12", and a footing width of 4'-0". Assumed that the tank is full and no grading around the tank, the forces present are:



W_1 = wt. of water = $4.25 \times 2.5 \times 62.4 = 664\#$

W_2 = wt. of stem = $5.25 \times 1.0 \times 150 = 788\#$

W_3 = wt. of slab = $4.25 \times 1.0 \times 150 = \underline{638\#}$

$W = 2090\#$

p = water pressure = $\frac{62.4 \times 4.25^2}{2} = 563\#$

$\Sigma M_{toe} = 0$

$-[563(1.42 + 1.0)] + (664 \times 3.0) + (788 \times 1.25)$

$+ (638 \times 2.13) = 2090\ x$, $x = 1.42'$

dist from third point = $\frac{4.25}{3} - 1.42 = 0.0'$

Since the size of the stem & slab are so large that the forces present will not stress the steel or concrete up to design values, assume 1/2"ø bars at 12" ctrs and check stresses. Assume $f_s = 18000$ #/□" and $f_c = 800$ #/□" and $n = 15$. From table, Peabody's "Reinforced Concrete Structures", p 433, $K = 138$, $p = .0089$, $j = .867$, $k = .382$.

Stem Design - Assume $d = 9"$ with a 3" protection.

Max. Resisting moment = $Kbd^2 = 138 \times 12 \times 9 \times 9 = 134{,}000$ in-lbs.

The wall is subject to $563 \times 1.42 \times 12 = 9{,}600$ in-lbs, depth is O.K.

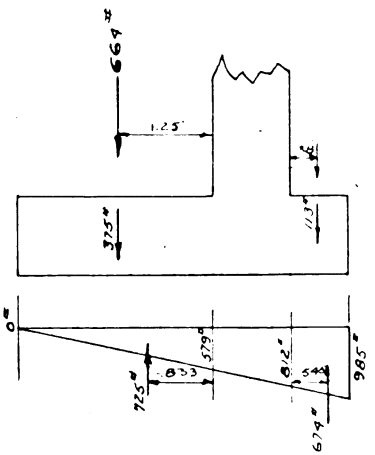
Shear - $v = \frac{V}{bjd} = \frac{563}{12 \times .867 \times 9} = 4.9$ #/□". Allowed .02 f'c = 40 #/□".

Steel - $A_s = \frac{M}{f_s jd} = \frac{9600}{18000 \times .867 \times 9} = .0685$ sq. in. (provided 0.19 □")

Bond - $\mu = \frac{V}{\Sigma_b jd} = \frac{563}{1.57(\frac{12}{12}) .867 \times 9} = 45.8$ #/□". Allowed .05 f'c = 100 #/□".

Slab Design - The eccentricity, $e = \frac{4.25}{2} - 1.42 = .695'$

$p = \frac{W}{b}\left(1 \pm \frac{6e}{b}\right) = \frac{2090}{4.25}\left(1 \pm \frac{6 \times .695}{4.25}\right) = 0$ #/□' or 985 #/□'. This is ok. because the toe pressure is not excessive..



$p_1 = \left(\frac{579+0}{2}\right)(2.5) = 725$ # Acting $\frac{2.50}{3}$' from C.

$p_2 = \left(\frac{812+985}{2}\right)(.75) = 674$ # Acting a dist of

$\frac{(812 \times .75 \times .5) + [(985-812).75 \times .5 \times .67]}{812 \times .75 + [(985-812).75 \times .5]} = .545'$ from D

Heel Slab wt. = $2.50 \times 1.0 \times 150 = 375$ #

Toe Slab wt. = $.75 \times 1.50 \times 1.0 = 113$ #

Assume d = 9".

Heel Slab - Max. resisting moment =

$Kbd^2 = 138 \times 12 \times 9^2 = 134,000$ in-lbs.

Applied Bending Moment =

$+[(664 + 375)(1.25)] - (725 \times .833) = +7250$ in-lbs.

Shear - $v = \frac{V}{bjd} = \frac{664 + 375 - 725}{12 \times .867 \times 9} = 3.4$ #/□" Allowed 40 #/□" O.K.

Steel - Assume 1/2" ϕ bars @ 12" ctr. As = .19 sq. in.

$A_s = \frac{M}{f_s jd} = \frac{7250}{18000 \times .867 \times 9} = .051$ □". Steel is O.K.

Bond - $\mu = \frac{V}{\Sigma_0 jd} = \frac{314}{1.57(\frac{12}{12}) \times .867 \times 9} = 25.6$ #/□" Allowed 100 #/□" O.K.

Anchorage - $l = 40d$.

Toe Slab - Assume a depth of 9". The max. resisting moment = $138 \times 12 \times 9^2 = 134,000$ in-lbs. The bending moment applied = $+(113 \times .38) - (674 \times .525) = -3730$ in-lbs. depth is O.K.

Shear - $v = \frac{V}{bjd} = \frac{674 - 113}{12 \times .867 \times 9} = 6.0$ #/□". Allowed 40 #/□" O.K.

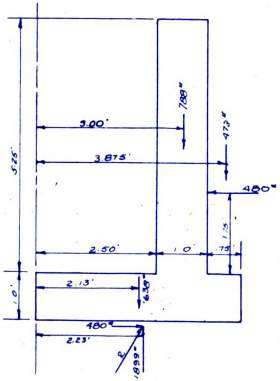
Steel - Assume 1/2" ϕ bars @ 12" ctrs. As = .19 □".

$A_s = \frac{3730}{18000 \times .867 \times 9} = .03$ □". Amount O.K. Anchorage - $l = 40d$.

Bond - $\mu = \frac{V}{\Sigma o j d} = \frac{561}{1.57(\frac{12}{12}) \times .867 \times 9} = 45.8$ #/in" Allowed 100 #/in" O.K.

Assume the tank empty and graded to the top outside.

Use Rankin's method. Wt/cu. ft of fill = 120#. No surcharge.



W_1 = wt. of stem = $525 \times 1.0 \times 150 = 788$#

W_2 = wt. of slab = $4.25 \times 1.0 \times 1.50 = 638$#

W_3 = wt. of earth = $5.25 \times .75 \times 120 = 473$#

$W = 1899$#

$P = C_a \frac{wh^2}{2}$ $C_a = \cos\theta \frac{\cos\theta - \sqrt{\cos^2\theta - \cos^2\phi}}{\cos\theta + \sqrt{\cos^2\theta - \cos^2\phi}}$

θ = angle of surcharge = 0°

ϕ = angle of repose = 40°

$C_a = 1 \frac{1 - \sqrt{1 - .655}}{1 + \sqrt{1 - .655}} = .29$

$P = .29 \times \frac{120 \times 5.25^2}{2} = 480$#

$\Sigma M_B = 0. \quad -[480(1.75 + 100)] + (473 \times 3.875) + (788 \times 3.00) + (638 \times 2.13) = 1899 x$

$x = 2.23'$. Eccentricity = $\frac{4.25}{2} - 2.23 = .105$' to right of center.

Stem Design - Assume d = 9", 3" protective coating.

Max. resisting moment = $Kbd^2 = 138 \times 12 \times 9^2 = 134{,}000$ in-lbs.

Applied Bending moment = $480 \times 1.75 \times 12 = 10{,}080$ in-lbs. depth O.K.

Shear - $V = \frac{V}{bjd} = \frac{480}{12 \times .867 \times 9} = 5.1$ #/in". Allowed 40 #/in". O.K.

Steel - Assume ½" ϕ bars @ 12" ctrs. $A_s = .19$ sq. in.

$A_s = \frac{M}{f_s j d} = \frac{10080}{18000 \times .867 \times 9} = .072$ sq. in. .19 a" provided.

Bond - $\mu = \frac{V}{\Sigma o j d} = \frac{480}{1.57 \times .867 \times 9} = 39.2$ #/in". Allowed 100 #/in" O.K.

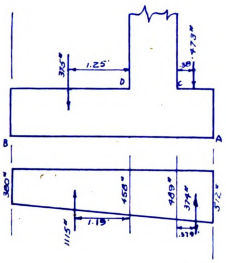
Anchorage - $\ell = 40d$.

Slab Design - $P = \frac{W}{b}\left(1 \pm \frac{6e}{b}\right) = \frac{1899}{4.25}\left(1 \pm \frac{6 \times .105}{4.25}\right) = 380$ #/ft, 512 #/ft.

$380 + \frac{2.5}{4.25}(512 - 380) = 458$#. $\quad 380 + \frac{3.5}{4.25}(512 - 380) = 480$#.

$P_1 = (380 \times 2.5) + [(\frac{512 - 380}{2})2.5] = 1115$,# acting

$\frac{(380 \times 2.5 \times 1.25) + (512 - 380).5 \times 2.5 \times \frac{2.5}{3}}{(380 \times 2.5) + (512 - 380).5 \times 2.5} = 1.19$ ft. from D.



$P_z = (489 \times .75) + [(512-489).75] = 374^{\#}$ acting

$\frac{(489 \times .75 \times \frac{.75}{2}) + [(512-489).75 \times \frac{2 \times .75}{3}]}{(489 \times .75) + [(512-489) 1/2 \times .75]} = .379'$ from C.

Heel slab weight = $2.50 \times 1.0 \times 150 = 375^{\#}$

Toe slab weight = $.75 \times 1.0 \times 150 = 113^{\#}$

Heel Slab Design - Assume d = 9".

Max. resisting moment = $Kbd^2 = 134{,}000$ in-#

Applied moment = $+(375 \times 1.25) - (1115 \times 1.19) =$

10320 in-lbs. depth is sufficient.

Shear - $v = \frac{V}{bjd} = \frac{1115-375}{12 \times .867 \times 9} = 7.9^{\#}/\square''$. Allowed $40^{\#}/\square''$. O.K.

Steel - Assume 1/2" ϕ @ 12" ctrs. $A_s = .19$ sq. in.

$A_s = \frac{M}{f_s jd} = \frac{10320}{18000 \times .867 \times 9} = .074$ sq. in. Steel is sufficient.

Bond - $\mu = \frac{V}{\Sigma_0 jd} = \frac{740}{1.57 \times .867 \times 9} = 60.3^{\#}/\square''$. Allowed $100^{\#}/\square''$ O.K.

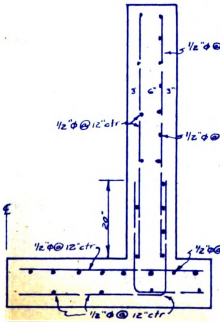
Anchorage - $l = 40d = 20''$.

Toe Slab - Assume depth = 9".

Maximum resisting moment = $Kbd^2 = 134{,}000$ in-lbs.

Applied bending moment = $+(473+113).375 - (374 \times .379) = 950$ "-#

Shear - $v = \frac{V}{bjd} = \frac{473+113-374}{12 \times .867 \times 9} = 1.2^{\#}/\square''$. Allowed $40^{\#}/\square''$. O.K.



Steel - Assume 1/2" ϕ bars @ 12" ctrs.

$A_s = \frac{M}{f_s jd} = \frac{950}{18000 \times .867 \times 9} = .007\square''$. O.K.

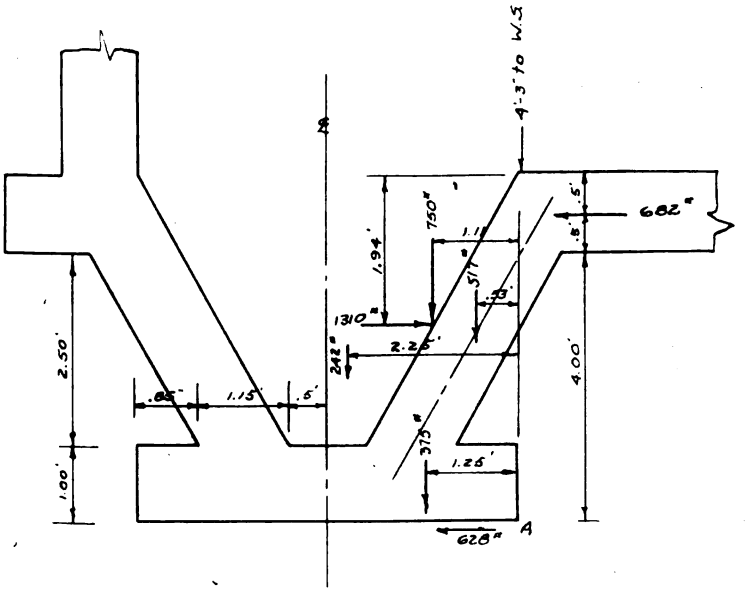
Bond - $\mu = \frac{V}{\Sigma_0 jd} = \frac{112}{1.57 \times .867 \times 9} = 9.1^{\#}/\square''$

Allowed $100^{\#}/\square''$ O.K.

Anchorage - $l = 40d = 20''$.

Temperature Steel - Use .004 bd as area of steel. Place 1/3 in garage face & 2/3 in back face. $A_s = .004 \times 12'' = .57\square''$. $\frac{.57}{3} = .19\square''$ in garage face. $\frac{2 \times .57}{3} = .27\square''$ in back face. 1/2"ϕ@6" ctr

Hopper Design.



Length of stem. $\tan \frac{3.5}{2.0} = 1.75 = 60°11'$ $\quad \sin 60°11' = \frac{3.5}{x_1}$, $x_1 = 4.03$ ft

W_1 = wt. of stem = $\left(\frac{4.17+2}{2}\right)(1)(150) = 517^{\#}$ $\quad \sin 60°11' = \frac{2.5}{y_2}$, $y_2 = 2.88$ ft

W_2 = wt. of slab = $2.5 \times 1 \times 150 = 375^{\#}$ $\quad h_{pc} = \frac{2}{3}\left(\frac{h_2^3 - h_1^3}{h_2^2 - h_1^2}\right) = \frac{2}{3}\left(\frac{(7.75)^3 - (4.25)^3}{(7.75)^2 - (4.25)^2}\right)$

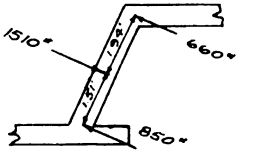
W_3 = wt. of water on heel = $7.75 \times 5 \times 62.4 = 242^{\#}$ $\quad h_{pc} = \frac{2}{3} \times \frac{3882}{41.98} = 6.19'$

$P_H = pA_V = \left(\frac{4.25+7.75}{2}\right)(62.4)(3.5 \times 1) = 1310^{\#}$ $\quad P_V$ = Ht. of water above

$P_V = (4.25 \times 62.4 \times 2) + \left(\frac{3.5}{2} \times 2 \times 62.4\right) = 750^{\#}$

Assume that the tank bottom slab takes its proportional part of the load.

$p = 1310\left(\frac{4.00 - 1.94}{4.00}\right) = 682^{\#}$. The sliding force on the bottom = $1310 - 682 = 628^{\#}$



The resisting force to sliding = $\Sigma F_V \times 1/3$

$F = \frac{1884}{3} = 628^{\#}$. Sliding factor = $\frac{628}{628} = 1.0$

This sliding factor is low but since the soil pressure acting to the left was not considered it is assumed as sufficient.

Bending Moment at Slab - depth = 9"

$R = \frac{1310}{\cos 29°49'} = 1510^{\#}$

Max. Applied Mom. = $660 \times 1.94 \times 12 = 15,380^{in\#}$

Max. Resisting Moment = $138 \times 12 \times 9^2 = 134{,}000$ in-lbs. Depth is O.K.

Shear - $V = \frac{1.94}{3.45}(1510) = 850\#$ $v = \frac{V}{bjd} = \frac{850}{12 \times .867 \times 9} = 9.07\#/\square"$ Allowed $40\#/\square"$.

Steel - $A_s = \frac{M}{f_s jd} = \frac{15380}{18000 \times .867 \times 9} = .11\square"$ Use 1/2" ϕ @ 12" ctr.

Bond - $\mu = \frac{V}{\Sigma_o jd} = \frac{850}{1.57 \times .867 \times 9} = 69.3\#/\square"$: Allowed $100\#/\square"$.

Anchorage - $l = 40d = 20"$.

On the left side of the hopper the moments due to the hydrostatic pressure on the sloping wall and stem wall are such that they add.

$7250 + 15380 = 22{,}630$ in-lbs. Max. Resisting Mom. = 134000 in-lbs O.K.

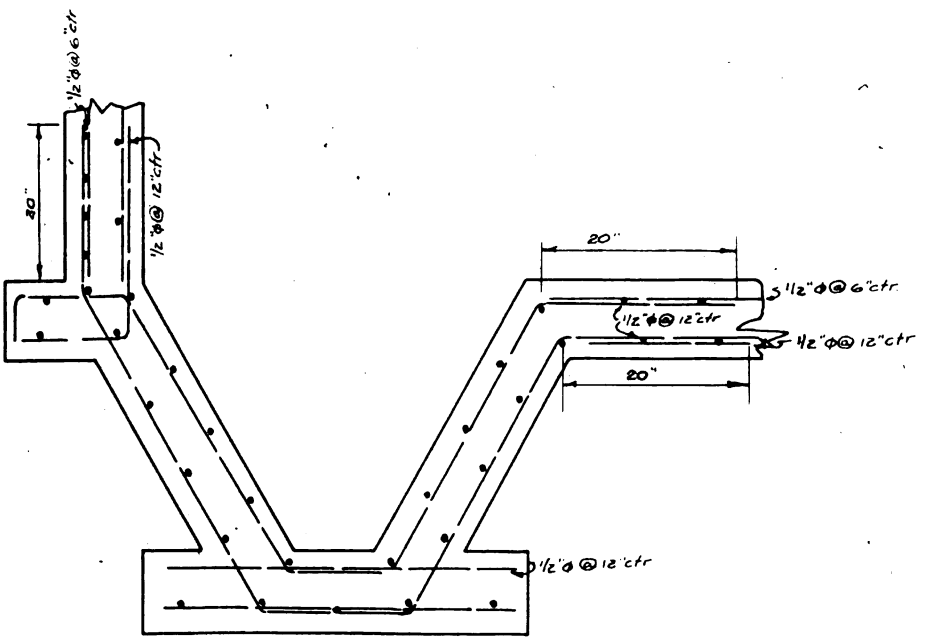
Shear - $V = \frac{1.94}{3.45}(1510) = 850.$ $v = \frac{V}{bjd} = \frac{850}{12 \times .867 \times 9} = 9.07\#/\square"$ Allowed $40\#/\square"$.

Steel - $A_s = \frac{M}{f_s jd} = \frac{22630}{18000 \times .867 \times 9} = .162\square"$ Use 1/2" ϕ @ 12" ctrs. $A_s = .19\square"$.

Bond - $\mu = \frac{V}{\Sigma_o jd} = \frac{850}{1.57(\frac{3}{4})867 \times 9} = 69.3\#/\square"$. Allowed $100\#/\square"$.

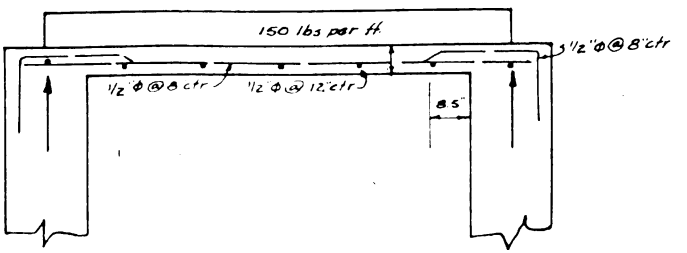
Anchorage - $l = 40d = 20"$.

Temperature Steel - two way steel - no temperature steel needed.



Slab for Primary and Final Tanks

Design a slab to carry a load of 100 lbs. par sq. ft. to corar a small portion of the and of the primary and final sedimentation tanks. The slabs for each tank will be identical. Use a simply supported reinforced concrete slab, span 6.00', width 3.00'. Assume a 4½" slab.



Wt. par foot = $150 * \frac{4.5}{12} + 100 = 157$ lbs par lin.ft. The banding moment for a simply supported slab $M = \frac{wl^2}{8} = \frac{157 \times 6 \times 6 \times 12}{8} = 8480$ in-lbs.

Assume $f_s = 18000$ #/o", $f_c = 800$ #/o", and $n = 15$. From the table page 433 Peabody's "Reinforced Concrete Structures", $K = 138$, $j = .867$, $k = .382$ $p = .0089$.

$d = \sqrt{\frac{M}{Kb}} = \sqrt{\frac{8480}{138 \times 12}} = 2.26$ in. Use $d = 2.5$", 2.0" protection.

Shear - $V = 157 \times 3 = 471$ lbs, $v = \frac{471}{12 \times .867 \times 2.5} = 18.1$ #/o". Allowed 100 #/o"

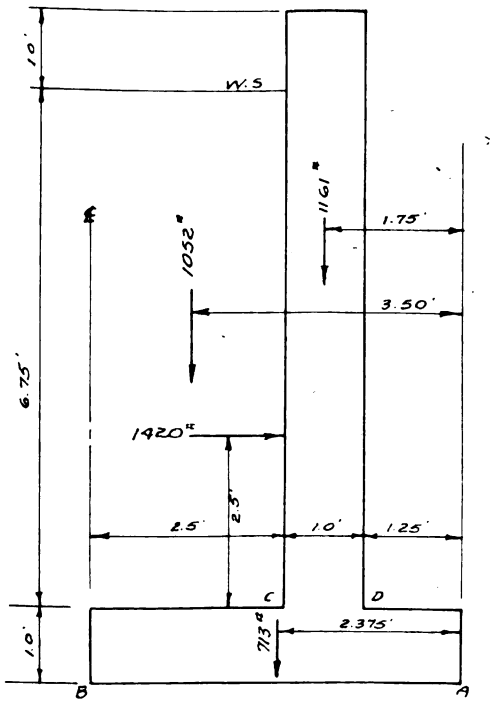
Steel - $A_s = pdb = .0089 \times 12 \times 2.5 = .27$ o" Use ½"ϕ bars @ 8" ctr. $A_s = .28$ o".

Bond - $\mu = \frac{V}{\Sigma o j d} = \frac{471}{157(\frac{2}{8}) \times .867 \times 2.5} = 92.5$ #/o". Allowed 100 #/o".

Temperature Steel - $A_s = .003bD = .003 \times 12 \times 4.5 = .162$ o" Use ½"ϕ bars @ 12" ctr, $A_s = .19$ o".

II Final Tank Wall

Problem - To design a cantilever wall for a concrete tank, maximum height 7'-9" and inside width of 5'-0". In order to insure waterproof construction the wall and footings must be 12" or larger. Assume the thickness of wall 12", footing 12" and a footing width of 4'-9". Assume not filled around the tank with the tank full.



W_1 = wt. of H_2O = 6.75 × 2.5 × 62.4 = 1052 #

W_2 = wt. of stem = 7.75 × 1.0 × 150 = 1161 #

W_3 = wt. of slab = 4.75 × 1.0 × 150 = 713 #

W = 2926 #

$P = \frac{wh^2}{2} = \frac{62.4 \times 6.75^2}{2}$ = 1420 #

$\Sigma M_A = 0$ $\quad 2926\,x = -(1420 \times 3.5)$

$+ (1052 \times 3.5) + (1161 \times 1.75) + (713 \times 2.375)$

x = .838' outside middle third.

Assume a 6'-00" footing with 2.50' heel & toe slabs.

W_1 = wt. of H_2O = 6.75 × 2.5 × 62.4 = 1052 #

W_2 = wt of stem = 7.75 × 1.0 × 150 = 1161 #

W_3 = wt. of slab = 6.0 × 1.0 × 150 = 900 #

W = 3113 #

$\Sigma M_A = 0$ $\quad 3113\,x = -(1420 \times 3.5) + (1052 \times 4.75) + (1161 \times 3.0) + (900 \times 3.0)$, x = 2.00'

which is exactly on the middle third.

Since the size of the stem and slab are so large that the forces present will not stress the concrete or steel up to design values, Assume 1/2" ϕ bars at 12" ctrs and check stresses. Assume f_s = 18000 #/□" f_c = 800 #/□" and n = 15. From tables in Peabody's "Reinforced Concrete Structures" p 433, K = 138, p = .0088, j = .867, and k = .382.

Stem Design - Assume depth, d = 9" and a 3" protection.

Max. Resisting Moment = Kbd^2 = 138 x 12 x 9^2 = 134,000 in-lbs

Moment Applied = 1420 x 2.50 x 12 = 42,600 in-lbs. Depth sufficient.

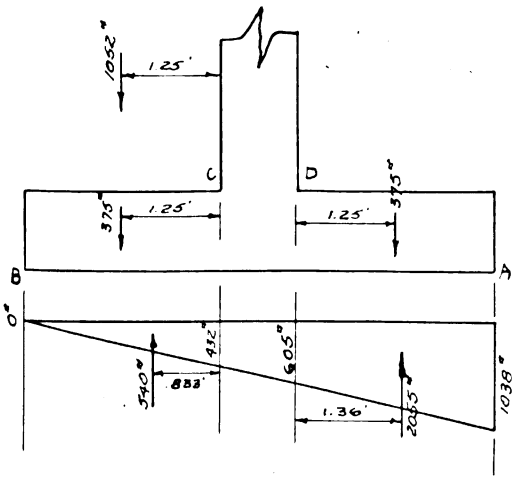
Shear - $v = \frac{V}{bjd} = \frac{1420}{12 \times .867 \times 9} = 15.2$ #/in". Allowed 40 #/in"

Steel - $A_s = \frac{M}{f_s jd} = \frac{42600}{18000 \times .867 \times 9} = .304$ sq.in. Use 5/8" ϕ @ 12" ctrs. $A_s = .31$"

Bond - $\mu = \frac{V}{\Sigma_o jd} = \frac{1420}{1.96(\frac{12}{7\pi}).867 \times 9} = 92.9$ #/in". Allowed 100 #/in".

Anchorage - $l = 40d = 25$":

Slab Design - $a = \frac{6.00}{2} - 2.00 = 1.00'$



$p = \frac{N}{b}(1 \pm \frac{6e}{b}) = \frac{3113}{6}(1 \pm \frac{6 \times 1}{6}) = 1038$ #/in"

or 0 #/in". O.K. as pressures are low.

$P_1 = (\frac{432}{2})(2.5) = 2055$ # acting

$\frac{(605 \times 2.5)(\frac{2.5}{2}) + [(1038-605)(\frac{2.5}{2})(\frac{2.5 \times 2}{3})]}{605 \times 2.5 + (1038-605)(\frac{2.5}{2})}$

= 1.36' from D.

Heel Slab - Assume d = 9":

Resisting Mom. = 134,000 in-lbs

Applied Mom. = 12[+(1035+375)1.25 +

-(540 x .833] = 14690 in-lbs. d = O.K.

Shear = $v = \frac{1052+375-540}{12 \times .867 \times 9} = 9.5$ #/in" O.K.

Steel - $A_s = \frac{14690}{18000 \times .867 \times 9} = .104$ □", use 1/2" ϕ @ 12" ctrs.

Bond - $\mu = \frac{V}{\Sigma_o jd} = \frac{887}{1.57 \times (\frac{12}{7\pi}).867 \times 9} = 72.4$ #/in". Allowed 100 #/in".

Anchorage = $l = 40d = 20$"

Toe Slab - Max. Resisting Moment = 134,000 in-lbs

Bending Moment Applied = 12 [-(2056 x 1.36) + (375 x 1.25)] = 28200 in-lbs

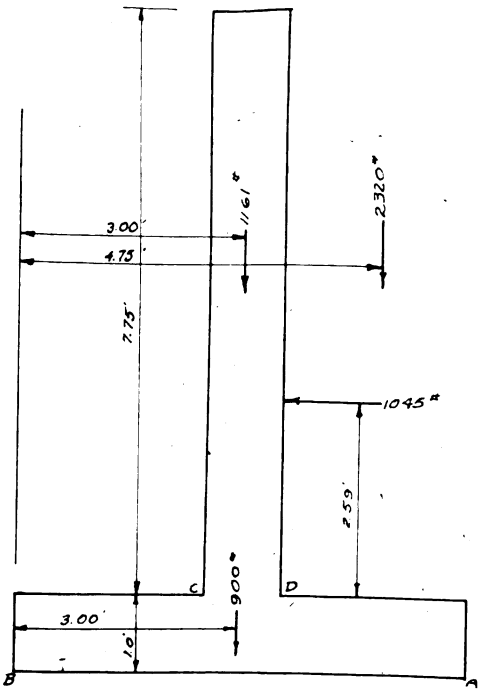
Shear - $v = \frac{V}{bjd} = \frac{2055 - 375}{12 \times .867 \times 9} = 18$ #/in". Allowed 40 #/in".

Steel - $A_s = \frac{M}{f_s jd} = \frac{28200}{18000 \times .867 \times 9} = .201$ □": Use 5/8" ϕ @ 12" ctr to match

steel in stem. Anchorage - $l = 40d = 25$":

Bond - $\mu = \frac{V}{\Sigma_o jd} = \frac{1680}{1.96(\frac{12}{7\pi}).867 \times 9} = 110$ #/in". Use special Anchorage.

Assume the tank empty and outside filled to top. Use Rankin's method in computing the earth pressure, wt. of earth = 120 #/cu.ft, no surcharge and repose angle = 40°.



W_1 = wt. of earth = 2.5 × 7.75 × 120 = 2320 #

W_2 = wt. of stem = 7.75 × 1.0 × 150 = 1161 #

W_3 = wt. of slab = 6.0 × 1.0 × 150 = 900 #

W = 4381 #

$P = C_e \frac{wh^2}{2}$ θ = surcharge = 0°

ϕ = repose ∠ = 40°

$C_e = \cos\theta \frac{\cos\theta - \sqrt{\cos^2\theta - \cos^2\phi}}{\cos\theta + \sqrt{\cos^2\theta - \cos^2\phi}} = .29$

$P = .29 \times \frac{120 \times 7.75^2}{2} = 1045$ # acting $\frac{7.75}{3} = 2.59'$ from footing slab.

$\Sigma M_B = 0$ $\quad 4381\,\bar{x} = -(1045 \times 3.59) + (2320 \times 4.75) + (2061 \times 3.00)$ $\bar{x} = 3.07'$ or .07' to right of the center.

STEM DESIGN - Assume the depth = 9", 3" for protection.

Max. Resisting Moment = Kbd^2 = 138 × 12 × 9² = 134,000 in-lbs.

Applied Bending Moment = 1045 × 2.59 × 12 = 32450 in-lbs. d: O.K.

Shear - $v = \frac{V}{bjd} = \frac{1045}{12 \times .867 \times 9} = 11.1$ #/in². Allowed 40 #/in².

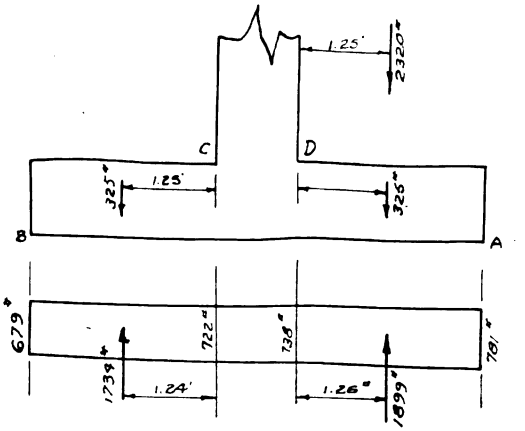
Steel - $A_s = \frac{M}{f_s jd} = \frac{32450}{18000 \times .867 \times 9} = .231$ in². Use ½" ϕ @ 9" ctr, $A_s = .26$ in².

Bond - $u = \frac{V}{\Sigma o\, jd} = \frac{1045}{1.57 \times \frac{12}{9} \times .867 \times 9} = 64.0$ #/in². Allowed 100 #/in².

Anchorage - $l = 40d = 20$".

SLAB DESIGN - $e = \frac{6.00}{2} - 3.07 = .07'$. $p = \frac{W}{b}\left(1 \pm \frac{6e}{b}\right) = \frac{4381}{6}\left(1 \pm \frac{6 \times .07}{6}\right) =$ 781 #/ft' or 679 #/ft'. Soil Pressure O.K.

$p_1 = (679 \times 2.5) + \left[\left(\frac{722 - 679}{2}\right)(2.5)\right] = 1734$ # acting $\frac{(679 \times 2.5^2/2) + \left[\left(\frac{722-679}{2}\right)(2.5^2)(1/3)\right]}{(679 \times 2.5) + \left[\left(\frac{722-679}{2}\right)(2.5)\right]}$ = 1.24' from C. $\quad p_2 = (738 \times 2.5) + \left(\frac{781 - 738}{2}\right)(2.5) = 1899$ # acting



$$\frac{(738 \times 2.5 \times \frac{2.5}{2}) + [(\frac{781-738}{2})(2.5)(\frac{2.5 \times 2}{3})]}{738 \times 2.5 + (\frac{781-738}{2})(2.5)} =$$

1.24' from D.

HEEL SLAB - Assume d = 9":

Max. Resisting Mom. = 134,000 in-#

App. B.M. = [(1734 × 1.24) − (375 × 1.25)]

× 12 = 20,200 in-lbs. d is O.K.

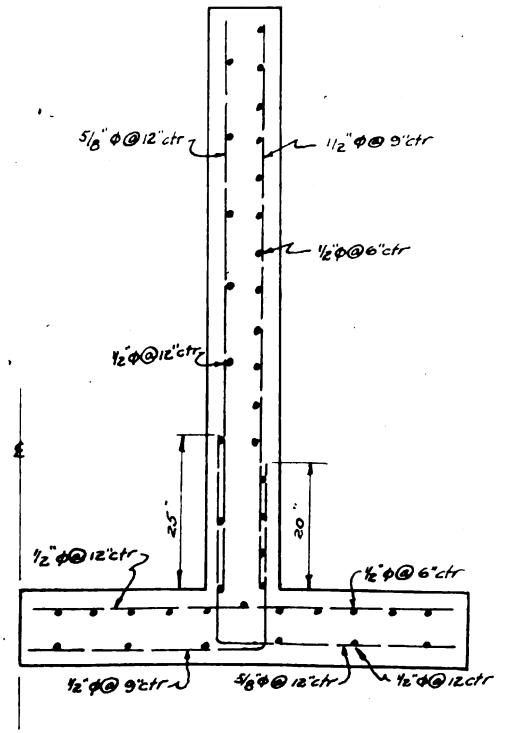
Shear - $v = \frac{1734 - 375}{12 \times .867 \times 9} = 14.5$ #/□"

Steel - $A_s = \frac{20200}{18000 \times .867 \times 9} = .144$ □"

Use 1/2" ϕ @ 9" to match stem steel.

Bond - $\mu = \frac{V}{\Sigma o j d} = \frac{1359}{1.57(\frac{12}{9}) \times .867 \times 9} =$ 83.1 #/□". Allowed 100 #/□"

Anchorage - $l = 40d = 20$":



TOE SLAB -

Max. Resisting Mom. = 134,000 in-lbs

Applied B.M. = [(2320 + 375)(1.25) −

1899(1.25)] 12 = 11600 in-lbs d is OK.

Shear - $v = \frac{796}{12 \times .867 \times 9} = 8.5$ #/□" OK.

Steel - $A_s = \frac{11600}{18000 \times .867 \times 9} = .0830$"

use 1/2" ϕ @ 12" ctr. $A_s = .190$□":

Bond - $\mu = \frac{796}{1.57 \times .867 \times 9} = 65.0$ #/□" O.K.

Anchorage - $l = 40d = 20$":

TEMPERATURE STEEL - Use

$A_s = .004\,bd$. Place 1/3 in inside

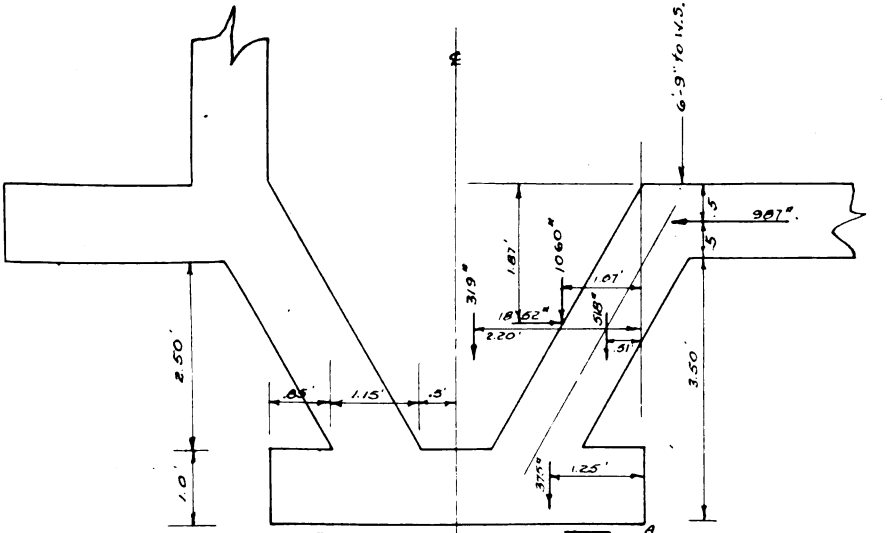
face and 2/3 in outside.

$A_s = .004 \times 12 \times 12 = .57$ □"

$\frac{.57}{3} = .190$□". Use 1/2" ϕ @ 12" ctr.

$\frac{2 \times .57}{3} = .380$□". Use 1/2" ϕ @ 6" ctr.

HOPPER DESIGN



Length of stem - $\tan^{-1}\frac{3.5}{2.0} = 1.75$, $\theta = 60°11'$. $\sin 60°11' = \frac{3.5}{L}$, $L = 4.03'$

$\sin 60°11' = \frac{2.5}{y}$, $y = 2.88'$. Ave. length = 3.45'.

W_1 = wt. of stem = $3.45 \times 1.0 \times 150 = 518$ lbs.

W_2 = wt. of slab = $2.5 \times 1.0 \times 150 = 375$ lbs.

W_3 = wt of water = $10.25 \times .5 \times 62.4 = 319$ lbs

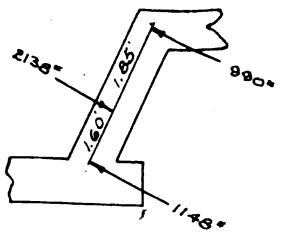
$h_{pc} = \frac{2}{3}\left(\frac{h_2^3 - h_1^3}{h_2^2 - h_1^2}\right) = \frac{2}{3} \times \frac{770}{595} = 8.62$ ft.

$P_H = p\,Av = \frac{(6.75+10.25)}{2}(62.4)(3.5)(1.0) = 1852$#. P_V = wt. of water above = $\frac{(6.75+10.25)}{2}(2.0)(62.4) = 1060$ lbs. Assume that the tank bottom slab takes its proporthonal part of the horizontal load.

$P = 1852\left(\frac{4.00 - 1.87}{4.00}\right) = 987$#. The sliding force on the bottom = 1852 - 987 = 865#. Resisting force to sliding = $\Sigma Fy \times \mu = \Sigma Fy \times 1/3 =$ 757#. Sliding factor = $\frac{987}{865} = .875$ - low but since the soil pressure acting to the left was not considered, it is assumed that this factor is sufficient.

Assume $d = 9"$ & a 3" protection. $R = \frac{1852}{\cos 29°49'} = 2138$ lbs.

Max. Applied Bending Mom. = $990 \times 1.85 \times 12 = 22{,}000$ in-lbs depth OK.



Shear - $V = \frac{1148}{12 \times .869 \times 9} = 12.3$ #/in². Allowed 40 #/in².

Steel - $A_s = \frac{22000}{18000 \times .867 \times 9} = .157$ in² Use ½"φ @ 12" ctr.

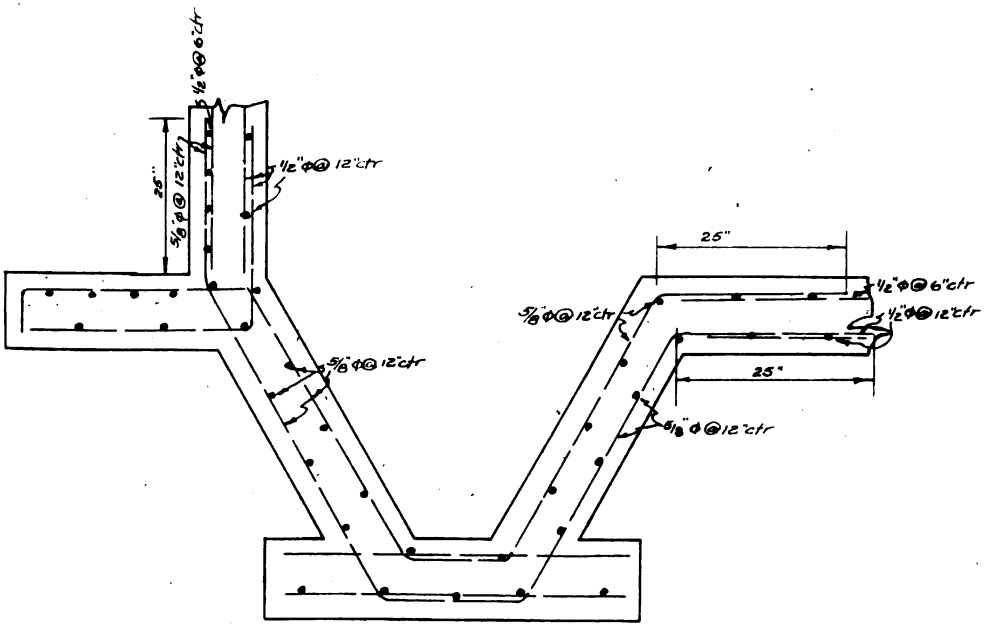
Bond - $\mu = \frac{1148}{1.57(\frac{12}{\pi}) .867 \times 9} = 93.8$ #/in². Allowed 100 #/in².

Anchorage - $l = 40d = 20$".

On the left side of the hopper the moments due to the hydrostatic pressure on the sloping wall and stem are such that they add.

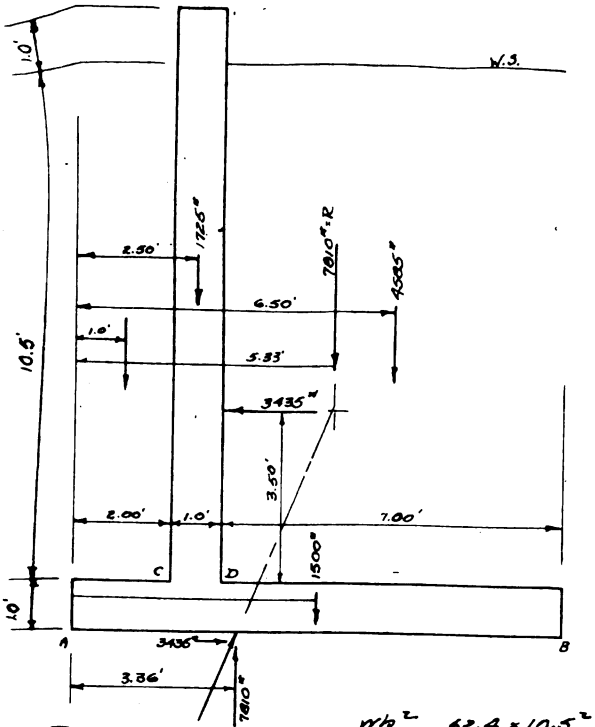
14690 + 22000 = 36690 in-lbs. Max Resist. Mom = 134000 in-lbs

so d is o.k. Steel - $A_s = \frac{36690}{18000 \times .867 \times 9} = .262$ in² Use 5/8"φ @ 12" ctr.



III. Aeration Tank Wall

Problem - To design a cantilever wall for a concrete tank whose max. height is 11'-6" and whose inside width is 16'-6". In order to insure waterproofing, the wall and footing should be 12" or more.



Assume tank full with no fill around outside. Assume the length of slab = 65% of stem height. Assume a 10' footing, 2' toe, & 7' heel. Assume wall & footings 12" thick.

W_1 = wt of water = $7.0 \times 10.5 \times 1.0 \times 62.4 = 4585^{\#}$

W_2 = wt. of stem = $11.5 \times 1.0 \times 150 = 1725^{\#}$

W_3 = wt of slab = $10.0 \times 1.0 \times 150 = 1500^{\#}$

W = 7810 lbs.

P = water pressure = $\frac{wh^2}{2} = \frac{62.4 \times 10.5^2}{2} = 3435$ lbs acting 3.5 ft above top of slab. Resultant of the vertical forces = 7810 lbs acting $x = \frac{(4585 \times 6.5) + (1725 \times 2.5) + (1500 \times 5.0)}{7810} = 5.33'$ from the toe.

$\Sigma M_A = 0$ $\quad 7810x = -(3435 \times 4.50) + (7810 \times 5.33)$, $x = 3.36'$. inside the middle third.

Assume the following reinforced concrete stresses, $f_s = 18000$ #/□", $f_c = 800$ #/□", $n = 15$ from which from tables we get $K = 138$, $J = .867$, $K = .382$, & $p = .0089$.

STEM DESIGN - Assume depth $d = 9"$, with a 3" protection.

Maximum Resisting Moment = $Kbd^2 = 138 \times 12 \times 9^2 = 134{,}000$ in-lbs.

Applied Bending Moment = $3435 \times 3.50 \times 12 = 144{,}000$ in-lbs.

$d = \sqrt{\frac{M}{Kb}} = \sqrt{\frac{144000}{138 \times 12}} = 9.3"$. Use $d = 10"$ with 2" protection.

Max. Resist. Mom. = $138 \times 12 \times 10^2 = 165{,}500$ in-lbs. $d = 10"$ ok.

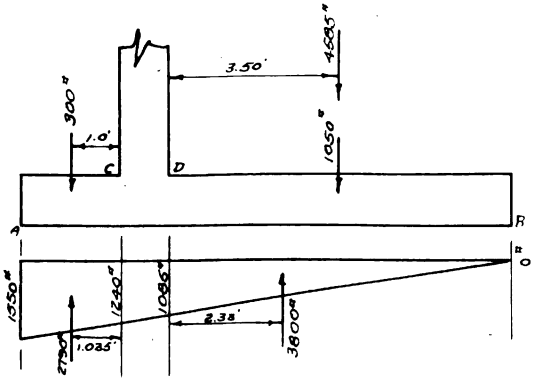
Shear - $v = \frac{V}{bjd} = \frac{3435}{12 \times .867 \times 10} = 33.0$ #/□". Allowed 40 #/□". O.K.

Steel - $As = \frac{M}{fsjd} = \frac{144000}{18000 \times .867 \times 10} = .923$ □". Use 7/8"ϕ @ 7½" ctr.

Bond - $u = \frac{V}{\Sigma o j d} = \frac{3435}{2.75(\frac{12}{7.5}).867 \times 10} = 89.8$ #/□". Allowed 100 #/□".

Anchorage - $l = 40d = 35$".

SLAB DESIGN - eccentricity = $\frac{10}{2} - 3.36 = 1.64'$



$p = \frac{W}{b}(1 \pm \frac{6e}{b}) = \frac{7810}{10}(1 \pm \frac{6 \times 1.64}{10}) = 11.7$ #/□" or 1550 #/□'. Soil pressure o.k. Since the soil pressure diagram is so near a triangle, assume a pressure triangle.

$p_1 = (1240 \times 2) + (\frac{1550 - 1240}{2})2$

$= 2790$ # acting $\bar{x} = \frac{(1240 \times 2 \times 1) + (\frac{1550 - 1240}{2})(2.0)(2 \times \frac{2}{3})}{1240 \times 2 + (1550 - 1240)(\frac{1}{2})(2)} = 1.035'$ from C.

$P_2 = (.085)(\frac{1}{2})(7) = 3800$ # acting $\frac{1085 \times \frac{1}{2} \times 7 \times \frac{2}{3}}{1085 \times \frac{1}{2} \times 7} = 2.33'$ from D

Toe SLAB - Assume d = 10", 2" protection.

Max. Resisting Moment = 165,500 in-lbs

Applied Moment = $[(2790 \times 1.035) - (300 \times 1)]12 = 31,100$ in-lbs. d is O.K.

Shear - $v = \frac{V}{bjd} = \frac{2790 - 300}{12 \times .867 \times 10} = 23.9$ #/□" Allowed 40 #/□". O.K.

Steel - $As = \frac{M}{fsjd} = \frac{31,100}{18000 \times .867 \times 10} = .20$ □". Use 7/8"ϕ @ 7½" ctr to conform to the steel used in the stem.

Bond - $u = \frac{V}{\Sigma o j d} = \frac{2490}{2.75(\frac{12}{7.5}).867 \times 10} = 65.2$ #/□". Allowed 100 #/□". O.K.

Anchorage - $l = 40d = 35$".

HEEL SLAB - Assume d = 10" with 2" protection.

Maximum Resisting Moment = 165,500 in-lbs.

Moment Applied = $\{[3800 \times 2.33] + [(1050 + 4585)(3.5)]\}12 = 180,100$ #-

Shear - $v = \frac{V}{bjd} = \frac{1050 + 4385 - 3800}{12 \times .867 \times 10} = 17.8$ #/□". Allowed 40 #/□".

Steel - $A_s = \frac{M}{f_s jd} = \frac{130{,}100}{18000 \times .867 \times 10} = .835$ □". Use 7/8"ϕ @ 7½" ctr. $A_s = .96$□"

Bond - $\mu = \frac{V}{\Sigma o jd} = \frac{1835}{2.75(\frac{12}{7.5}).867 \times 10} = 48.0$ #/□". Allowed 100 #/□".

Anchorage - $\ell = 40d = 35$"

Assume the tank empty and filled on the outside. Use Rankin's method in computing earth pressure and use wt. of earth = 120 lbs per cu. ft. and angle of repose = 40°

W_1 = wt of earth = $120 \times 2 \times 11.5 = 2760$#

W_2 = wt. of stem = $11.5 \times 1.0 \times 10 \times 150 = 1725$#

W_3 = wt. of slab = $10 \times 1 \times 1 \times 150 = 1500$#

$W = 5985$#

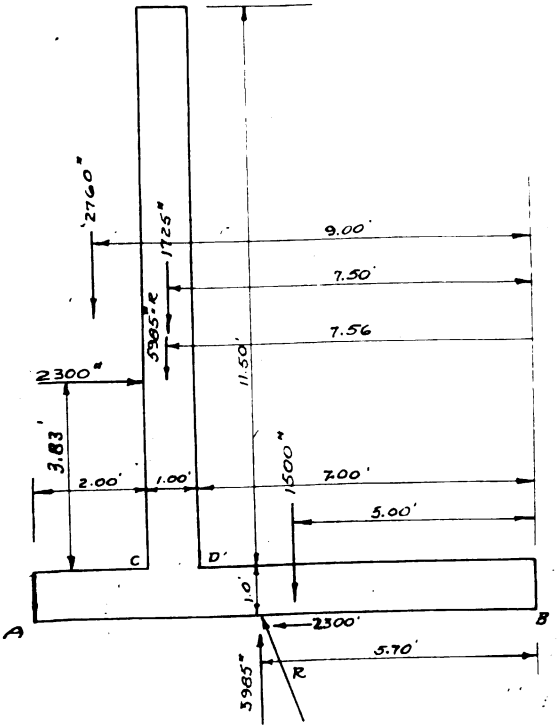
$P = C_e \frac{wh^2}{2}$, $C_e = \frac{\cos\theta - \sqrt{\cos^2\theta - \cos^2\phi}}{\cos\theta \cos\theta + \sqrt{\cos^2\theta - \cos^2\phi}}$

which with ϕ = angle of repose of 40° and θ = angle of surcharge of 0° equals .29.

$P = .29 \times \frac{120 \times 11.5^2}{2} = 2300$# acting $\frac{11.5}{3} = 3.83$' from top of slab.

$\Sigma M_B = 0$ $5985x = -(2300 \times 4.83) + (2760 \times 9) + (1725 \times 7.5) + (1500 \times 5)$.

$x = 5.70$' or .70' to left of center.



The resultant of the vertical forces = 5985 and acts $\frac{(2760 \times 9) + (1725 \times 7.5) + (1500 \times 5)}{5985} = 7.56$ ft from B.

STEM DESIGN - Assume a depth of 10" with 2" protection.

Maximum Resisting moment = $138 \times 12 \times 10^2 = 165{,}500$ in-lbs.

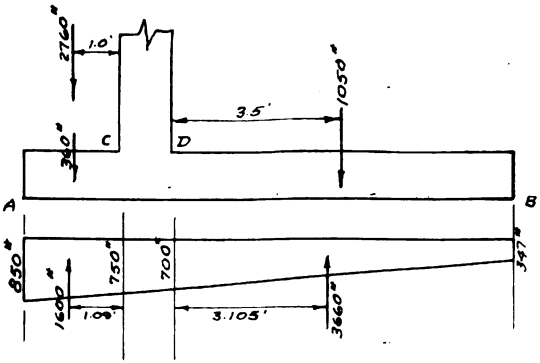
Moment Applied = $2300 \times 3.83 \times 12 = 106{,}000$ in-lbs. depth is O.K.

Shear - $v = \frac{V}{bjd} = \frac{2300}{12 \times .867 \times 10} = 22.1$ #/□". Allowed 40 #/□".

Steel - $A_s = \frac{M}{f_s j d} = \frac{106000}{18000 \times .867 \times 10} = .679$ sq". Use 3/4"ϕ @ 7½" ctr. $A_s = .71$ sq".

Bond - $u = \frac{V}{\Sigma_o j d} = \frac{2300}{2.36(\frac{13}{7.5}).867 \times 10} = 70.2$ #/in". Allowed 100 #/in".

SLAB DESIGN - eccentricity = $\frac{10.0}{2} - 5.70 = -.70'$. $p = \frac{W}{b}(1 \pm \frac{6e}{b})$.



$p = \frac{5985}{10}(1 \pm \frac{6 \times .70}{10}) = 850$ #/in or 347 #/in.

$p_1 = (750 \times 2) + (\frac{850-750}{2})2 = 1600$# at $\frac{(750 \times 2 \times 1) + [(\frac{850-750}{2})(2)(2 \times \frac{2}{3})]}{(750 \times 2) + [(850-750)(\frac{1}{2} \times 2)]} = 1.09'$ from C.

$p_2 = (347 \times 7) + \frac{(700-347)}{2} 7 = \frac{(347 \times 7\frac{1}{2}) + [(\frac{700-347}{2})(7 \times \frac{1}{3})]}{(347 \times 7\frac{1}{2}) + [(\frac{700-347}{2})7]} =$ 3660# at 3.105' from D.

TOE SLAB - Assume d = 10"

Maximum Resisting Moment = $138 \times 12 \times 10^2 = 165,500$ in-lbs.

Applied Moment = $[-(600 \times 1.09) + (3060 \times 10)]12 = 15,800$ in-lbs. depth is O.K.

Shear - $v = \frac{V}{b j d} = \frac{2760 + 300 - 1600}{12 \times .867 \times 10} = 14.1$ #/in". Allowed 40 #/in".

Steel - $A_s = \frac{M}{f_s j d} = \frac{15800}{18000 \times .867 \times 10} = .101$ sq". Use 7/8"ϕ @ 7½" ctr. See Stem.

Bond - $u = \frac{V}{\Sigma_o j d} = \frac{1460}{2.75(\frac{7.5}{7.5}).867 \times 10} = 38.2$ #/in". Allowed 100 #/in".

Anchorage - $l = 40d = 35$".

HEEL SLAB - Assume d = 10" with 2" protection.

Maximum Resisting Moment = 165,000 in-lbs.

Applied Moment = $[-(3660 \times 3.105) + (1050 \times 3.5)]12 = 92600$ in-lbs d is OK.

Shear - $v = \frac{V}{b j d} = \frac{8610}{12 \times .867 \times 10} = 25.1$ #/in". Allowed 40 #/in".

Steel - $A_s = \frac{M}{f_s j d} = \frac{92600}{18000 \times .867 \times 10} = .593$ #/in". Use 3/4"ϕ @ 7½" ctr. See Stem.

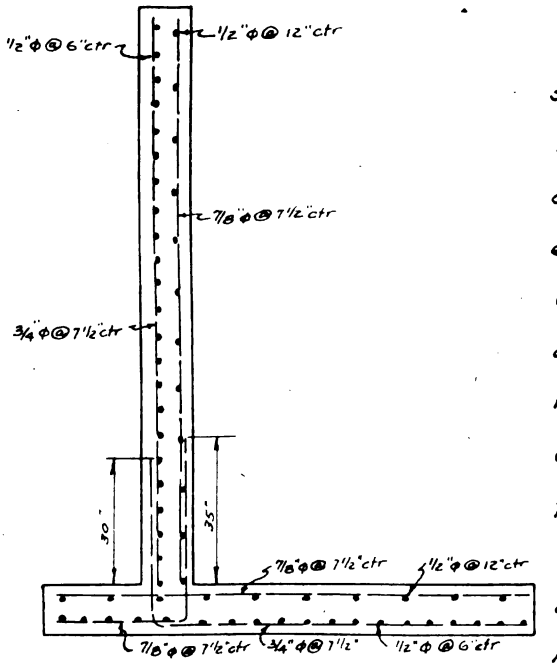
Bond - $u = \frac{V}{\Sigma_o j d} = \frac{8610}{2.36(\frac{13}{7.5}).867 \times 10} = 79.7$ #/in". Allowed 100 #/in"

Anchorage - $l = 40d = 30$".

Temperature steel - Use $A_s = .004 bD = .004 \times 12 \times 12 = .57$ sq"; Place 1/3 of the steel in the inside face and 2/3 in outside face.

$.57/3 = .19$ sq". Use 1/2"ϕ @ 12" ctr, $A_s = .19$ sq" in inside face.

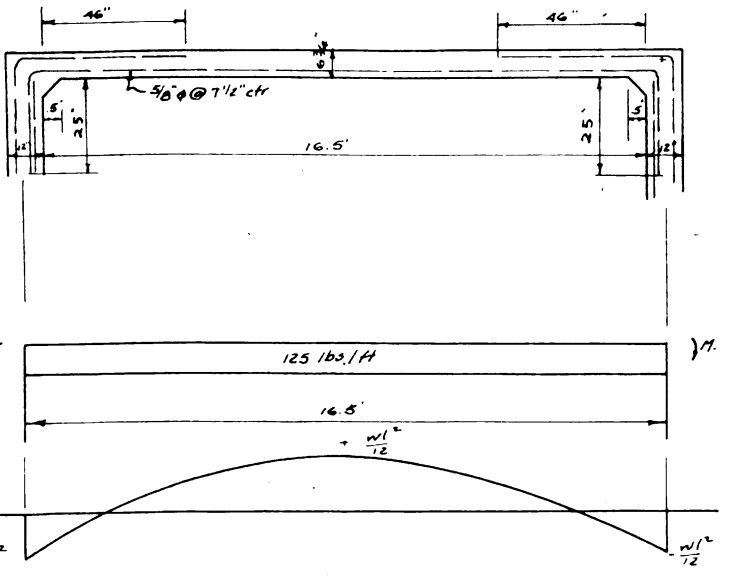
$2 \times .57/3 = .38$ sq": Use 1/2"ϕ @ 6" ctr, $A_s = .38$ sq" in outside face.



DESIGN OF WALK

Problem - to design a slab 2'-6" wide and 18'-6" long to support a live load of 50 #/lin. ft. Assume a 6" slab. Wt per ft = 75 #. W = 125 #/lin ft. Assume a design section of 1'-0" wide and 16'-6" long (see A.C.I. Code Art 706). Max positive moment at center = $\frac{wl^2}{12}$. Max. - moment = $\frac{wl^2}{12}$ at supports.

$M_n = M_p = \frac{125 \times 16.5^2}{12} \times 12 = 34{,}030$ "-#



Assume $f_s = 18000$ #/□", $f_c = 800$ #/□", $n = 15$. From tables page 433 Peabody's "Reinforced Concrete Structures", $K = 138$, $j = .867$, and $K = .382$.

Depth required = $\sqrt{\frac{M}{Kb}} = \sqrt{\frac{34030}{138 \times 12}} = 4.54$". Use $4\frac{3}{4}$" with $6\frac{3}{4}$" = D.

Wt. per foot then is $30 + 150\left(\frac{6.75}{12}\right) = 134$ #/ft. $M_n = M_p = \frac{134 \times 16.5^2}{12} \times 12$

= 36,400 in-lbs. $d = \sqrt{\frac{36400}{138 \times 12}} = 4.7$ Use 4.75" = d.

Shear - $V = 134 \times 16.5 - 1/2 = 1105$ lbs. $v = \frac{1105}{12 \times .867 \times 4.75} = 22.4$ #/□". All. 40 #/□".

Steel - $A_s = \frac{M}{f_s jd} = \frac{36400}{18000 \times .861 \times 4.75} = .498$". Use 5/8" ϕ @ 7 1/2" ctr. $A_s = .498$".

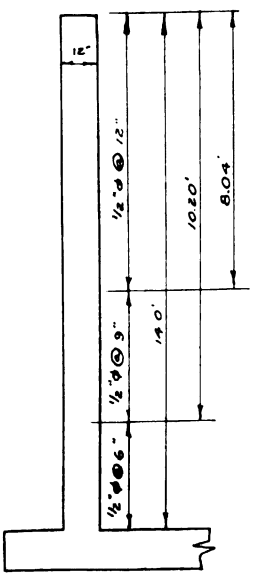
Positive Steel = Negative Steel. Art. 704, A.C.I. Code says the point of inflection is at 1/5 = 39.6". Steel should be carried 10 bar diameters past the point of inflection.

Bond - Art. 901, A.C.I. Code specifies the formula, $\mu = \frac{8V}{7\Sigma od}$:

$\mu = \frac{8 \times 1105}{7 \times 1.96(19+9.5) \times 4.75} = 83$ #/□". Allowed 100 #/□".

Temperature Steel - $A_s = .0035\,bD = .0035 \times 12 \times 6.75 = .283$ □". Use 5/8" ϕ @ 12" ctr, $A_s = .31$ □". See figure p 4-18 for steel Placing.

IV Sludge Tank Wall



Problem - Design a circular reinforced concrete tank 16'-00" in diameter and 14'-00" in height with the liquid surface assumed maximum height 2' below top. The wall shall be 12" thick.

Hoop Tension - for the bottom foot of the wall $p = wh = 62.4 \times 1.03 \times 11.5 = 739$ #/□".

$T = pr = 739 \times 8.83' = 6540$ #/ft. $A_s = \frac{6540}{18000} = .36$□".

Use 1/2" ϕ @ 6" ctr, $A_s = .39$□".

The steel required decreases as the pressure decreases for smaller depths of

sludge. The depth at which 1/2"@ 9"ctr, As = .26 □" can be used is -

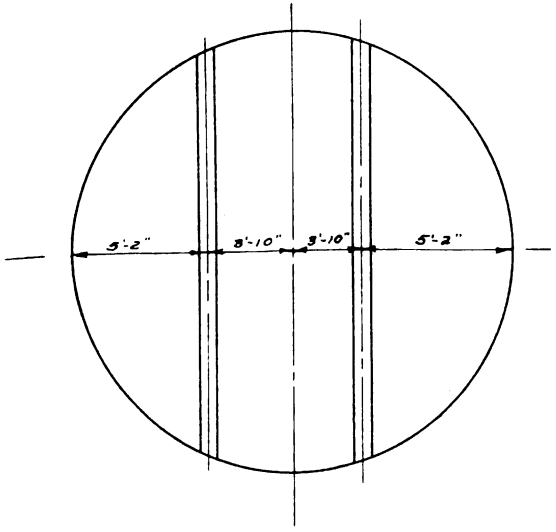
$.26 \times 18000 = 8.83 \times 62.4 \times 1.03 \times h$, $h = 8.20'$. The depth at which 1/2"ϕ @ 12"ctr, As = .19 □" can be used is - $.19 \times 18000 = 8.83 \times 62.4 \times 1.03 \times h$ $h = 6.04'$.

This steel is placed in the outer face of the wall 3" from the outside. It is customary to place the temperature and shrinkage steel in the inner face. Use 1/2"ϕ @ 12" ctr. Also use temperature steel amounting to 0.3% A in a vertical direction, 1/3 placed in the outer face and 2/3 in the inner face.

As = .003 × 12 × 12 = .432 □". $\frac{.432}{3} = .144$ □". Use 1/2"ϕ @ 16"ctr in the outer face, As = .145 □". $\frac{2 \times .432}{3} = .288$ □", Use 1/2"ϕ @ 8"ctr in the inner face, As = .29 □".

ROOF SLAB

Design a slab for a circular roof for the sludge tank to carry a live load of 50 lbs/□'. The tank is 16'-00" inside diameter and the walls are 12" thick. The slab is to be supported by two beams passing through the center of gravity of each half circle.



The center of gravity for a half circle is .425R from the center of the circle. 9 × .425 = 3.83' = 3'-10".

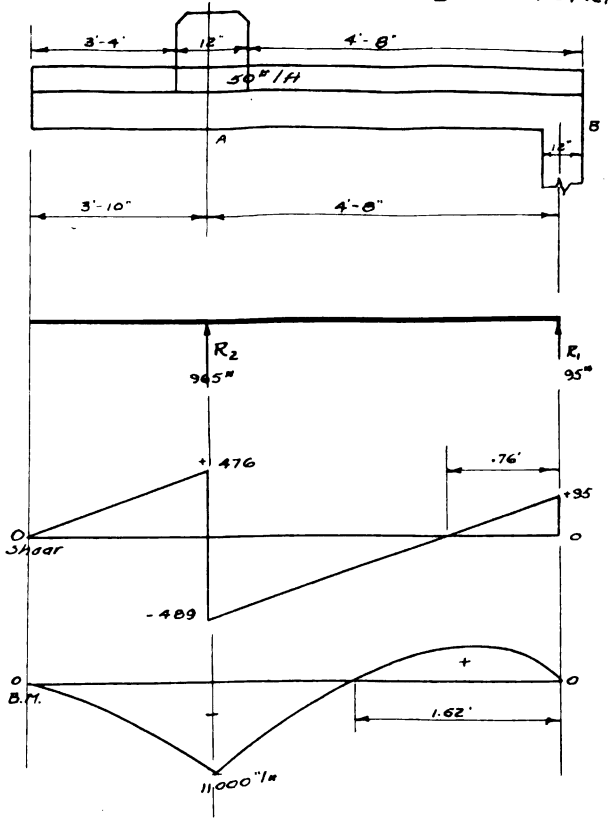
The length of the beam = 2y.

$x^2 + y^2 = r^2$

$(3.83)^2 + y^2 = (9)^2$, $y = 8.15$, $l = 16.30'$.

Assume a 6" slab, wt/ft = 1/2 × 1 × 150 = 75 #/ft. Total wt/ft = 50 + 75 = 125 #/ft.

$\Sigma M_A = 0 \quad 125 \times 3.83 \times 1.92 - \frac{4.67^2 \times 125}{2} + 4.67 R_1 = 0$. $R_1 = 95$ lbs up.



$\Sigma M_B = 0 \quad (125 \times \frac{8.25^2}{2}) - 4.67 R_2 = 0$, $R_2 = 965$#

The maximum mom. is at the point of zero shear. $95 : 584 = x : 4.67$

$x = .76$ ft. The maximum negative moment is at R_2 and $= (\frac{3.83^2}{2} \times 125) 12 =$ 11,000 in-lbs. Max. + moment is .76' from R_1 and $= [-(\frac{.76^2}{2}) \times 125 + (95 \times .76)] \times 12 = 432$ in-lbs.

The point of inflection is at $[-(125 \frac{x^2}{2}) + (95x)] = 0$

$x = 1.52$'.

Negative Steel -

$d = \sqrt{\frac{M}{Kb}} = \sqrt{\frac{11000}{138 \times 12}} = 2.58$

Use $2\frac{5}{8}$" = d, or try a $4\frac{1}{2}$" slab.

Dead wt/ft = $\frac{4.5}{12} \times 150 \times 1 = 56.3$#, Total wt/ft = 106.3 #/ft.

$\Sigma M_A = 0 \quad (106.3 \times 3.83 \times 1.92) - (\frac{4.67^2 \times 106.3}{2}) + 4.67 R_1 = 0$, $R_1 = 81$# up.

$\Sigma M_B = 0 \quad (106.3 \times \frac{8.5^2}{2}) - 4.67 R_2 = 0$, $R_2 = 823$#.

The point of zero shear - $81 : 487 = x : 4.67$, $x = .76$ ft.

The point of inflection - $(81x) - (106.3 \frac{x^2}{2}) = 0$, $x = 1.52$ ft.

Maximum Negative Moment = $(\frac{3.83^2}{2} \times 106.3) 12 = 9370$ in-lbs.

$d = \sqrt{\frac{M}{Kb}} = \sqrt{\frac{9370}{138 \times 12}} = 2.38$". Use $2\frac{1}{2}$" & 2" protection. D = $4\frac{1}{2}$", O.K.

Maximum Positive Moment - $[-(\frac{.76}{2} \times 106.3) + (.76 \times 81)]12 = 326$ in-lbs.

Negative Steel - $A_s = \frac{M}{f_s j d} = \frac{9320}{18000 \times .867 \times 2.5} = .238$ sq.in. Use 1/2"ϕ @ 9" ctr.

Shear - at the left face of the beam - $3.33 : 3.83 = V : 476$, $V = 415^{\#}$

$v = \frac{V}{bjd} = \frac{415}{12 \times .867 \times 2.5} = 15.9^{\#}/\text{in}^2$. Allowed $40^{\#}/\text{in}^2$.

Bond - $\mu = \frac{V}{\Sigma o j d} = \frac{415}{1.57(1\frac{1}{16}) .867 \times 2.5} = 91.0^{\#}/\text{in}^2$. Allowed $100^{\#}/\text{in}^2$.

Bend down half the bars at the point of inflection - 18" from rt. end.

BEAM DESIGN

Design a beam to support the above slab. The live load is 966 lbs per ft., the span is 16.3 ft. Assume a 12" wide beam by 18" deep. The dead load = $\frac{20 \times 12}{144} \times 150 = 250$ lbs per ft. Total load per lin. ft. = $1215^{\#}/\text{ft}$. Assume a simply supported beam,

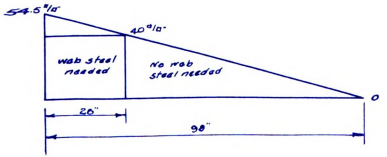
Moment = $\frac{wl^2}{8} = \frac{1215 \times 16.3 \times 16.3 \times 12}{8} = 485{,}000$ in-lbs.

Depth = $\sqrt{\frac{485000}{138 \times 12}} = 17.1"$, Use $d = 17\frac{1}{4}"$, $D = 20"$.

$A_s = \frac{M}{f_s j d} = \frac{485000}{18000 \times .867 \times 12} = 1.80$ sq. in., Use 4 - 7/8"ϕ, $A_s = 1.80$".

Shear - The reaction at one end will be $\frac{12/5 \times 16.3}{2} = 9900^{\#}$

$v = \frac{9900}{12 \times .867 \times 17.25} = 54.5^{\#}/\text{in}^2$. Allowed $40^{\#}/\text{in}^2$. Use 1/2" stirrups.



Max. spacing of stirrups = $\frac{3}{4}"d = 13"$. For minimum spacing, $v = .02f'_c + \frac{a_s f_s}{633 s n_s}$

$54.5 = 40 + \frac{2 \times .20 \times 18000}{12 \times s \times 1}$

$s = 41.3"$

Use 3 - 10" spacings beginning at face of support.

Bond - $\mu = \frac{V}{\Sigma o j d} = \frac{9900}{3 \times 2.75 \times 17.25 \times .867} = 79.9^{\#}/\text{in}^2$. Allowed $100^{\#}/\text{in}^2$ O.K.

Pocket has: 17 Suppls.

109
753
THS

SUPPLEMENTARY MATERIAL

109
753
THS
Suppl.
1

SUPPLEMENTARY MATERIAL