Sewerage

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by

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S E W E R A G E .

Introduction.

A sewerage system for the immediate and efficient removal of sewage from a populous community is demanded on two grounds.

The first and higher one is that of public health.

The second , the more popular one , that of convenience.

The proper meeting of these demands determines the principles of designing, and in so doing each of these purposes must be kept in mind ; the first always being giving predominance over the second , if they conflict in any way.

Requirements of the System.

The two essential requirements of a sanitary sewage system are; First: That all the sewage be removed without delay to a point where it may be properly disposed of . Second: That it be so disposed of as to lose permanently its power for evil; convenience requiring that sewage be collected and disposed of with the least trouble and in the least offensive way.

General Considerations.

In taking up the design of a sewage system for any given city, there are some important preliminary questions to be settled before the location of the mains and the sizes of the pipes can be determined.

Perhaps the first of these questions is as to whether the system shall be the separate system, designed to carry house sewage alone, or the combined system designed to carry both house sewage and storm water combined. The comparative merits of these two systems has been a subject of much discussion, particularly from the sanitary standpoint, and it is still a subject upon which many Sanitary

Engineers differ. A choice of system will most probably be arrived at by mutual concession, although the question is probably best settled by local conditions, such as the financial condition of the community and the means at hand for the disposal of the sewage.

One argument against a combined system is that it must include such large pipes for sewers, some ranging from two or three to as much as fifteen or eighteen feet in diameter ; yet during the larger part of the time the am ount of sewage flowing could be carried By pipes from six inches to two feet in diameter.

Another argument against the combined system is that the storm water might be disposed of at nearer outlets than the presence of the sewage will permit, thereby causing the laying of extra lengthof large pipes all to no purpose.

While the combined system has the advantage of being more easily cleaned out than the small pipes of the seperate system , yet proper flushing will keep the small pipes clean and if there are a sufficient number of man and lamp holes all obstructions to flow can be removed very easily .

As regards the keeping of the large sewer clean, it is claimed that it has the advantage over the small sewer in that it can accumulate a larger amount of sewage for flushing purposes, and on account of a greater hydraulic radius there will be a greater velocity and scouring power for the same grade; and while this will remove all ordinary obstructions , the excessive deposits can easily be removed by hand from a sewer large enough for a man to enter, and with considerable less expense than from a small pipe which must be opened from the surface or cleaned by a rod worked from the man holes.

But in answer to this it is claimed that flushing by automatic flush tanks is sufficient to keep the small pipes clean, if the sewers are properly designed and laid;

and that stoppages are of very rare occurance and easily removed.

The large sewer has the advantage of not being so susceptible to unequal settling or accident to the line, whereas the smaller sewer might be seriously affected by a very slight settlement, so that in the laying of the smaller sewer a less allowance for air is permissable

Another objection to the large sewer in which there is a variable flow, is that it allows floating matter to be carried along in large volume which is often deposited on the walls of the sewer, clinging to the rough and uneven surfaces of the sewer, when the flow grows less, and that this matter so deposited generates noxious gases and fosters the development of bacteria and that these micro-organisims when dried may escape through house traps into houses or through man holes into the street.

This last objection is answered by saying that the volume of air in the large sewers so dilutes these gases as to render them almost harmless.

The combined system is often the more economical one, for in the seperate system the storm sewers must be as large as those of the combined and an additional small sewer must be provided for the house sewage which adds greatly to both the original cost and also to the cost of maintenance; yet the storm drains need not be laid so deep nor carried to so distant an outlet as must the sewage drains.

Ventilation is more rapid in small sewers, and another very important argument in favor of the seperate system and one that is favored by the law in many states, is the absolute necessity for its use where treatment of the house sewage is either immediatly necessary or may become so in time.

There have been many other arguments made for and against the combined system. but after summing them all up there is no sanitary reason why the storm water should be disposed of separately.

Preparatory Maps and Data.

The first necesssity is a good contour map of the district under consideration . This should include the city and all the land over which the city may spread in the course of twenty to twenty five years and also all adjacent areas which shed their waters into or across this territory .

This map should show all streets, lanes, parks, streams and etc., it should also show the position of street-railways. any old sewer lines and the position of all manufacturing establishments.

A second set of maps , to a scale of twenty five feet to the inch should be prepared on which should be shown water- and gas-pipes and also depth of cellars .

The engineer should also make a careful inspection of the section of city covered by the system, noting especially any peculiar or particular demand s that would need to be supplied , such as large factories. penal institutions , asylums etc., which would require sewers entirely out of proportion to those required under ordinary circumstances.

In the making of his maps and profiles the engineer should note all particular conformations of the surface such as small streams gullies, sharp declivities and every thing which would tend to effect the cost of the system in any way whatever either as to grade or cost of construction; the latter being of special importance as regards the nature of the ground as to permeability, hardness and general nature whether of rocky or of ordinary formation.

The determination of the nature of the earth to be excavated may be effected by the use of iron rods pointed at one end and driven down, or by the use of iron pipe sunk by means of the hydraulic jet process.

If the outlet is to be into a stream he should obtain all data as regards high and low water marks , amount of flow and present purity of water, so as to guard against excessive pollution.

The amount of ground water if any should be estimated so as to be able to decide as to the nature of the bedding of the pipes, also to be able to decide as the whether or not extra drains will be needed for the ground water; if not, then to what extent it will increase the sewage flow .

The amount of increase of flow due to ground water depends upon the nature of the joints as well as upon the wetness of the ground; a maximum for the best cement joints being about 20000 gallons per day per mile of sewer, while it may reach even five times this amount in sewers with poorly constructed joints.

Amount of Sewage.

After this preliminary data has been obtained the engineer should next make an estimate of the amount of flow; if for a separate system, this will include house sewage and groundwater alone; if for the combined system it will include both of the above and also the storm water as determined by the run-off formulae mentioned later on.

The amount of sewage per capita varies between sixty gallons and two hundred gallons per day. The amount per capita can be estimated very closely from the water works records, allowing an additional twenty to thirty per cent for future increase of water consumption.

Due allowance must be made for the refuse from factories ~~and~~ etc., which finds its way into the sewers ; every case demanding separate consideration as regards amount and nature of flow.

The population can be estimated very closely by allowing six persons per dwelling and one person per sixty sq. feet. of floor space in factories stores etc., with an allowance for the latter of but twenty five to thirty gallons per capita per day in amount of sewage . The use of this data for designs will be explained later in conection with the accompanying sewer desing diagram for a separate system only.

If the combined system be adopted the amount of storm water run off must be calculated ; and this is usually determined by the use of one of the following formulae:

Bürkli- Zeigler: $Q = Rc\sqrt[4]{\frac{S}{A}}$

c = a constant - 0.75 for paved streets;
0.31 for macadamized roads;

R = average rate during heavist fall in cubic feet per second per acre;

S = the general fall of area per thousand;

Q = cu. ft. per second per acre reaching sewers:

A = drainage area in acres.

Adams: $\log. D = \frac{3 \log. A + \log. N - 3.79}{6}$

A = area in acres;

N = length in feet in which sewer falls one foot;

D = diameter in feet.

(For one inch rainfall , one half running off.)

Hawksley: $\log D = \frac{3\log A + \log N + 6.8}{10}$

D = diameter of sewer in inches;

N = same as Adams';

A = number of acreas to be drained;

(City or suburban surfaces.)

Mc Math: $Q = Rc\sqrt[5]{\frac{S}{A}}$

Terms the same as in Bürkli-Zeigler.

One of these four should be used, probably the Burkli-Zeigler being preferable.

Now the amount of water reaching the sewers depends upon the intensity of the rain fall, permeability of the soil and the slope of the surface. In as much as both the Bürkli-Zeigler and the McMath formulae consider both the condition of the soil and the slope in the values of c and S, they are to be preferred to those formulae which disregard these conditions .

The amount of run off varies greatly according to the roof area, paved area and the nature of the paving or street covering. For roofs, practically all the water runs off . For the best class of pavements about seventy per cent of the total rainfall since they absorb something like thirty per cent because of dust, crevices etc. For second class pavements and macadam roads about twenty five per cent to thirty five percent of the total rain fall reaches the sewer . For ordinary gravel high ways and roads from fifteen to twenty percent

Another formula invloving more variables than any of the above, is:

Kuichling's : $Q = A\,a\,t\,(b - c\,t)$

Q = runoff in cu. ft. per second;

A = drainage area in acres;

t = duration in minutes of the intensity $(b - ct)$;

a = proportion of impervious surface ÷t

$$\left.\begin{array}{l} b = 2.1 \\ c = 0.0205 \end{array}\right\} \text{ for Rochester N. Y.}$$

Kuichling also gives as a formula representing storms of the second class at Rochester; $r = 12 \div t$, in which r = rate in inches per hour.

Design.

There can be no general directions given for the design of a sewerage systems to cover every case . But upon the principles stated care should be taken not to violate any of the requirements of a sanitary sewerage system.

The first question to be decided in preparing the design of a sewer is, how much and what kind of sewage must be disposed of ? The second, what disposal shall be made of it ? And third, what system of disposal shall be employed ?

Local circumstances , such as financial and topographical conditions, will usually decide whether or not the storm water shall be removed by sewers . In closely built up towns or cities the storm water should not flow more than two blocks before finding an inlet to the sewer. As the pavements become more pervious and the buildings more scattered this distance can be greatly increased.

Subdivisions into districts.

After having decided upon the kind of system to be adopted and the manner of disposal of the sewage , the section under consideration is usually divided into sets of districts , one set based upon the population and the other upon the slope of the ground . The former division should be taken as a basis of probable density of population per acre of different sections at some future time, say twenty years, as the system must serve the population at that time as well as at the the present. The latter subdivision , or that into drainage districts, consists of those sections which contain all the territory draining into one main sewer together with that main to its outlet.

Locating the sewer lines.

House and combined sewers should in most cases be located in the centers of the streets or alleys, unless the location is already occupied by gas - or water pipes or by street rail ways. In some cities where the streets are very wide the sewers are located under the side walks, there being a line on either side of the street; as this extra line often costs less than the extra length of house connections. Another advantage of side sewers is that the street paving need not be torn up in making the house connections . Yet a great disadvantage is that the distance from the upper end of the line to where the flow of sewage is self cleaning is double that when a single line is used and also that the roots of trees are apt to cause serious trouble when the double line is used.

The sewer should be laid in continuous straight lines as far as possible. No turns greater than a right angle should be made at any one point by a sewer less than twenty four inches in diameter, and all turns of any consequence should be made in a man hole by means of a curved channel. This channel being usually formed by a concrete semi-circular open water way; in which the course of the sewage is changed by a gradual curve.

Grade. Size and Depth of Sewers.

Use is generally made of the profile of the streets for determining and recording the grades of sewers. In many cases it will be found necessary to alter and re-alter the grades and size of pipes before obtaining for each branch the best depth and velocity.

The depth of storm sewers is usually fixed by grade alone, but should never be less than two feet and better three or four feet. The depth of house and combined sewers is usually determined by local conditions; where there are no cellars and very little frost they may be as shallow as four feet, otherwise six feet and even up to fourteen or sixteen feet the latter should not be exceeded since the cost increases very rapidly for a depth greater than sixteen feet although some sewers have been laid in tunnels at a depth of fifty feet or more.

The grade and size are interdependent and are also governed by the amount of flow. The velocity should be about three to four feet per second for house sewage and four to five feet per second for storm water, while a maximum of ten or twelve feet per second should never be exceeded. The grade should change so as to increase the velocity near the outlet, since a decrease would cause deposits.

In determining the size of pipes with a given flow per capita per diem and tributary population per hundred feet of sewer for a separate system the accompaning Sewer Design Diagram, based upon Kutter's and Weisbach's formulae for flow, is very easily understood and gives very good practical results.

Kutter's Formula: $V = c\sqrt{RS}$

V = velocity per second; R = Hydraulic radius;

S = slope;

$$c = \text{a constant} = \frac{41.6 + \frac{.00281}{S} + \frac{1.811}{n}}{1 + \left(41.6 + \frac{.00281}{S}\right)\frac{n}{\sqrt{R}}}$$

The values of n:

Well planed timber.	.009
Neat cement, very smooth iron pipe.	.010
Unplaned timber and ordinary iron pipe.	.012
Smooth brick work.	.013
Rubble or granite block.	.017
Channels in earth; rivers.	.025
Streams with detritus.	.030

Weisbach's Formula: $V = \left\{2gh \div (1.505 + c + l \div d)\right\}^{\frac{1}{2}}$

V. = velocity of flow;

$c. = 0.01439 + 0.016921 \div \sqrt{V}$

l. = length and d. = diameter in the same terms as are V and h.

To illustrate the use of the diagram suppose we have a flow of eighty gallons per capita per diem and a tributary population of eighty persons to each one hundred feet of sewer, with a length of pipe of five thousand feet .

Beginning at the left at 5000 we follow the heavy diagonal until we come directly under 80 then on a horizontal to the right we find four thousand as the total tributary population, thence on a diagonal up and to the right until we come under eighty gallons per capita per diem, then by interpolating a horizontal we find 320000 gallons as the total flow per diem.

Now the size of the pipe is dependent upon the grade and is obtained by following a horizontal from 320000 to the right until a point directly under the fall per hundred is reached the last size just passed over will be the size of pipe to use. For instance let us assume a one per cent grade, then on a horizontal to the right of 320000 we find under 1.0 that an eight inch pipe according to Weisbach or between an eight and a ten inch according to Kutter will do. From the velocity curves we also see that the flow in these pipes is about four feet per second. Of course the diagram can be used in reverse order according to the data at hand and the quantities to be determined.

Flushing and Ventilation.

Despite all the care in modern sewer design to guard against deposits of silt etc., there still remains the trouble due to dead ends, small velocities etc. There are two ways of removing these obstructions either by dragging them out by means of hoes and scrapers or by means of flushing. The latter is effected by the use of flush tanks which are located at man holes or dead ends, or may be located any where near the section to be flushed. The main object being to suddenly turn loose into the obstructed section a large quantity of water at a high velocity, so as to wash out all deposits. The main and only value lying in the high velocity since no matter how great the amount, if it is not let in suddenly the effect is of no value.

There are many contrivances for flushing, such as automatic flush tanks which discharge from a siphon action and reservoirs which are filled and then discharged at the time of greatest need, while others are dependent upon the rain fall. The flow of rain water is diverted into the sewer pipe so as to flush it out.

Most likely the first mentioned is the best . certainly not the last mentioned. since in periods of greatest deposits we have the smallest rain fall .

Sewers are ventilated generally by means of man-holes, lamp-holes and pipesfrom the house traps. In extreme cases currents of air are driven through the sewers by means of fans. or large stacks are built along the line to act as chimneys in drawing off the gases. These man holes (which are nothing more than holes some two feet in diameter atthe top then growing larger being about four feet in diameter at the bottom. large enough for a man to enter and to work from in dragging deposits from the sewers). are usually covered with perforated tops to admit of the free passage of the gases and to allow their dilution by the surrounding atmosphere.

The house trap pipes are usually run from the trap out through the roof thus carrying the gases above any point at which they might be objectionable.

Lamp holes are from eight to twelve inches in diameter and are used to lower a light into so as to light up the sewer making the location of deposits or obstructions more easily determined from the man holes. Their part in ventilation is of course slight since their covering is not usually intended to allow the free passage of gases.

Disposal of Sewage.

In the water carried system almost every description of refuse is found , such as house slops , manufactoring waste waters and acids, drainage from stables. waste paper. rags etc. This is called house sewage. but in case the combined system is used beside the rain water are found vegetable refuse, sand, gravel, and other heavy matter which finds admission through the street inlets. The common impression that human excreta alone is dangerous is erroneous since kitchen wastes are now considered fully as detrimental.

Owing to the great difference existing as regards the character of the sewage of different communities, the question of proper disposal is a complex one. The difficulty of disposal is increased by the dilute condition of the sewage, since on an average about only one part in a thousand is organic matter.

The sewage of several Western cities in the arid region is disposed of for irrigation purposes at a considerable profit; but the method of collecting this large amount of sewage for what little fertilizing properties it posseses has not proven very succesful.

The primary aim in disposing of sewage is to get rid of it in such a way and at such a place as not to create a nuisance. The simplest and cheapest solution of the problem is to discharge the sewage directly into some flowing stream or large body of water ; but the effects of sewage pollution of streams in creating a nuisance are well illustrated by the great epidemic of typhoid fever which visited several cities on the Passaic river in the winter of 1898 - 1899. This method of disposal is forbidden by law in several states and the laws are likely to become more rigid in other states as the population becomes more dense.

Where conditions are favorable sewage may be disposed of by running it out upon large sand beds. This is a very satisfactory method in that oxidation and seepage take place very rapidly .

In the disposal of sewage in the separate system the system of Septic Tanks and Filters is extensivly used wherever local conditions do not allow of the dispossal through natural channels, The accompanying blue print of the system at BluefieldW. Va. explains the action and uses of such a system .

The sewage first flows from the large fifteen inch main into a man hole. there it divides, flowing by two eight inch pipes to the two grit chambers ; the object of this division is that the grit chambers may be cleaned out by closing one of the eight inch pipes at a time. Upon flowing into these grit chambers the sewage flows in so low on the side , (as shown in section on A B) that an opportunity is given for all of the heavier matter to deposit in these chambers.

From here the sewage, robbed of its heavier matter, flows over a weir (shown in section on AB) into the septic tank . In this tank the action of the first set of bacteria , the anaerobic , takes place. These bacteria thrive best in water in contrast with the aerobic which are found in the filters and mustbe kept practically all of the time under water. In the septic tank besides the action of these bacteria the process of oxidation is also continuing and some very slight deposits os silt take place .

From this tank the liquid is carried by means of a fifteen inch pipe into a weir chamber and thence into the dosing chamber, or effluent distributing chamber.

Running from the dosing chamber to and across the various filters (which are as their name signifies mere beds containing come good filtering substance such as coke breeze , gravel etc.) are troughs or as on the blue-print, effluent distributing channels.

In the filters we find the aerobic bacteria or those which live part of the time under water and part of the time in the air. The filters are filled by means of the troughs leading from the dosing chamber; and this flow is so regulated that among the four filters one is standing full , one is filling . one is emptying, and one is standing empty all the time. The gearing is arranged to act automatically and the process continues.b

Beneath the weir and dosing chambers are outlet pipes which allow the scouring out of these chambers. Similar arrangement is made for the septic tank. From the filters the liquid flows off to any natural outlet.

The advantages of this system as regards the prime aim of sewage disposal is certainally very evident. for the system so purifies the flow as to render it harmless, a condition which frequently is attained by the other systems of disposal, but only too frequently fails to occur, the result then being a serious detriment to the life and happiness of the inhabitants of the city in which it is used.