Water and Wastewater Engineering
Dr. B. S. Murty
Department of Civil Engineering
Indian Institute of Technology, Madras

Sanitary Sewerage Systems
Lecture # 38

In the last lecture we discussed about water distribution networks. In this lecture we will discuss about sanitary sewerage systems. First of all what is a sewer. A sewer is a pipe or conduit that carries wastewater. A sanitary sewer is the one carries sanitary wastewater.
What is sanitary wastewater?
This is the wastewater coming from residences, institutions, commercial establishments and industries that is what we call sanitary wastewater.

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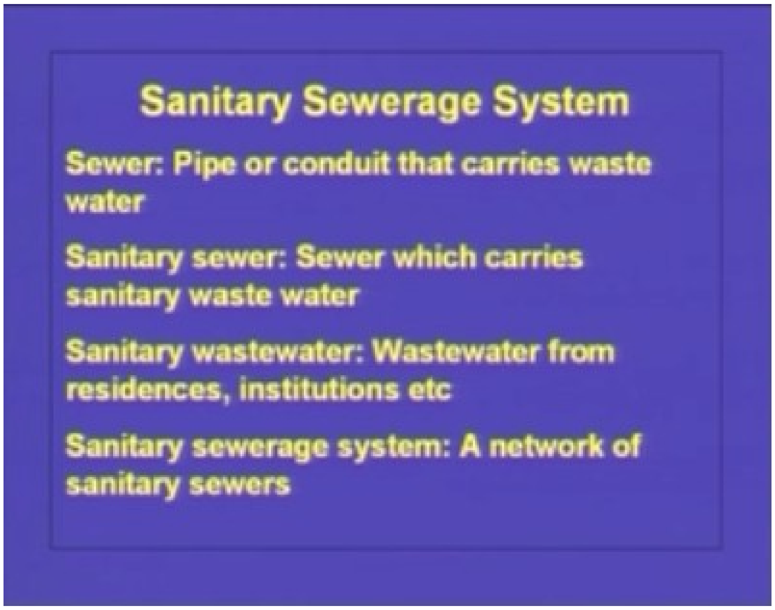

What is a sanitary sewerage system?
This is nothing but a network of sanitary sewers.
What are the important considerations that we have to remember while designing a sanitary sewerage system?
First of all, a sanitary sewerage system transports wastewater from one location to another by gravity, this is a very important point to note. That is it is transporting wastewater from one location to another by gravity, we want to transport this water by gravity because it gives low maintenance cost, the operating cost also will be low because we will not be having much of pumping and it also requires limited skilled personnel to implement these projects or construct these projects or maintain these projects so that is one important thing.

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The other one is while designing we design the system such that the sewers can resist erosion and corrosion.
Where is the erosion coming from?
Erosion comes because this sewage which is being carried in a sanitary sewer may have lot of suspended matter and other material which can abrade against the sewer walls and then can erode. So we have to design the system such that it can resist this erosion. The other important point in the design of sanitary sewer system is the corrosion. Corrosion occurs because of release of hydrogen sulphide gas. The wastewater which is being carried in a sanitary sewerage system contains lot of sulphates and because of that hydrogen gas can get produced and that can lead to corrosion. So the system should be designed such that it can resist this corrosion.

The other important consideration in the design of sanitary sewer system is it should withstand backfill, impact and live loads. The sewers are made underground, there is a lot of cover above this and the backfill and they are also laid under the roads so there will be traffic load that is coming from these loads which gets transferred to these sewers so they should withstand that backfill, impact and live loads.

The other important consideration in the design are they should have adequate flow velocity. The velocity in sewers should not be below a minimum value because if the velocity is not very high then anaerobic conditions can set in or septic conditions can set in and that can lead to more corrosion of the pipelines. Not only that but if the velocity is not very high then the suspended matter can get settle down to the bottom of the sewers and that can lead to decrease in the capacity of the pipeline, also it can lead to enhanced corrosion. So the velocity in sewers should be more than a minimum value this is very very important in the design of sanitary sewers.

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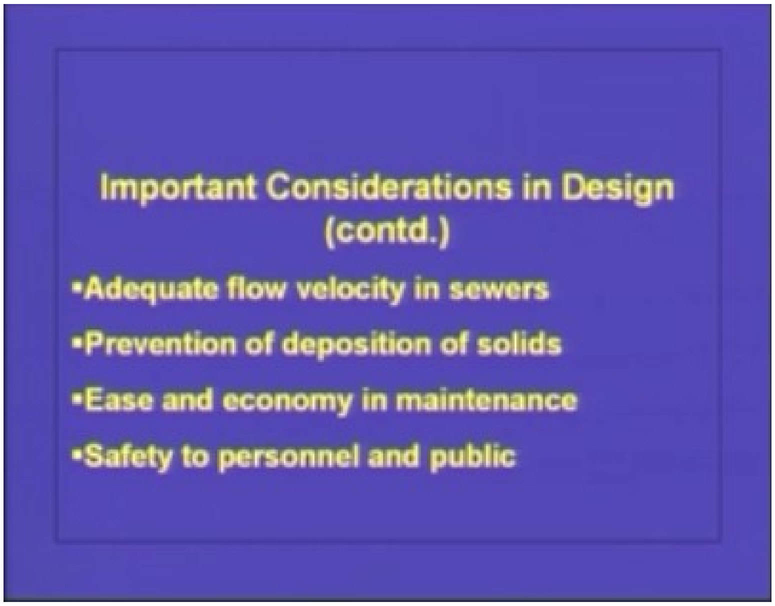

Again the important points in the design of sanitary sewers are ease and economy in maintenance. That is it requires constant maintenance otherwise the system will not perform to what we want. Hence the maintenance factor should be considered at the design stage itself. The maintenance aspects should be considered while designing the sanitary sewer system. Of course the economy is always important in design of any system so whatever is the sanitary sewerage system that we are designing it should have a minimum capital cost plus minimum operating and maintenance cost.

Safety to personnel and public is also very important while designing a sanitary sewer system. Because people will be getting into the sewer system through manholes for the maintenance and thy should be taught properly about the dangers of health risks and things like that before they get into the sewer system and that should be considered while designing a proper sewer system.

What are the decisions to be taken while designing a sewer system?
First of all we have to decide upon the location of the sewers. The wastewater is generated in the houses, in the commercial establishments, in the institutions and industries and from that it has to be taken to the treatment plant before it is released into the receiving water body or lake or river or things like that. So we have to see how we transport this water through the sewers so the location of the sewers is the first decisions we have to take while designing a sanitary sewerage system.

The next important thing is the size of these sewer lines. What should be the diameter of each of these sewers? What should be the diameter of the lateral, what should be the diameter of the branch, what should be the diameter of the interceptor or the trunk main and the other important thing is at what slope the sewer should be laid because the slope affects the velocity. If the slope or the sewer is not very high then the velocity will be very low and that can lead to deposition of the solids and consequent corrosion problems etc so the slope should be high. At the same time if the slope is very high then the sewer will be buried very deep into the ground and that can lead to extra cost in drenching etc. so the slope and depth of burial are interrelated factors in the decisions to be taken while designing the sewer system.

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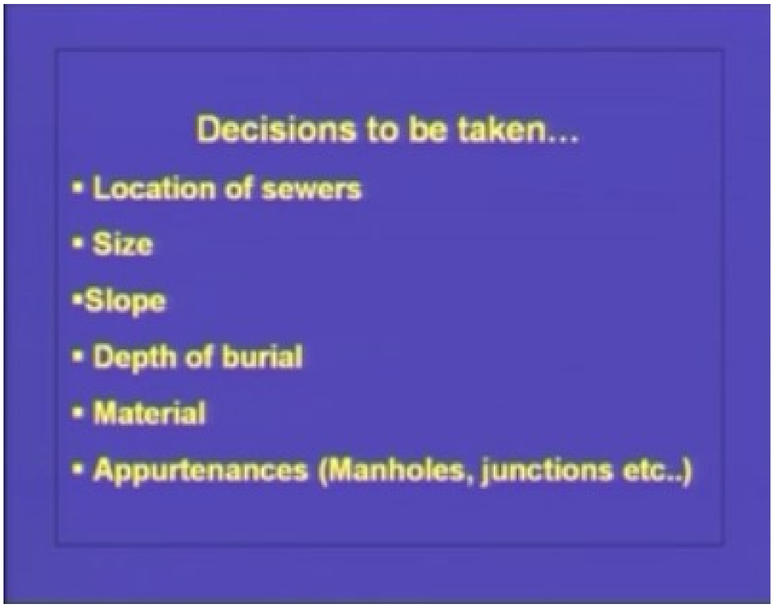

The other important point in the design of sewer systems is what material we should use for the sewers. The materials could be brick, concrete or plastic or steel and so on. So which material we should use for this sewer system is of main concern to us. The other important points in the design of sewer systems are appurtenances, where we should locate manholes, where we should locate junctions, the flow measuring devices etc so for that also we have to take the decision.

Before we go to the design of a sewer system we will discuss the main difference between sewerage system and water distribution system. In a water distribution system water can flow either by gravity or by pressure. In fact in a water distribution system even if pumps are not there the pipes will be flowing full under pressure whereas in a sewerage system the water can be carried through the sewer lines, whether they are covered or uncovered the flow conditions we have are free surface flow conditions. That means a sewer system even if it is covered it should not be operated such that there is surcharge that is the wastewater is being carried under pressurized conditions. So, flow is by gravity in a sewerage system as opposed to the flow in a water distribution network and that is why they are designed as open channels but with covers.

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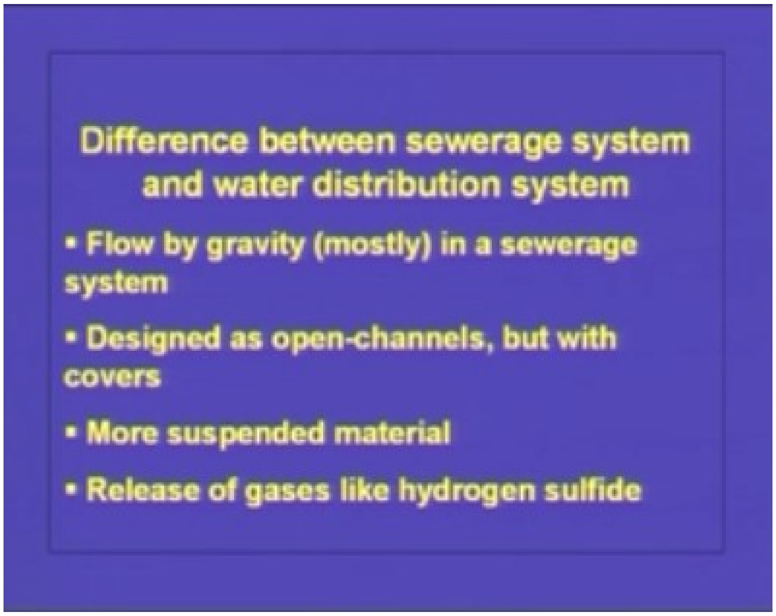

There is more suspended matter in a sewerage pipeline as compared to a water distribution pipeline so that also should be taken into consideration while designing. In a water distribution network or water distribution pipeline there is little scope for the release of gases like hydrogen sulphide which lead to corrosion whereas in a sewer line this corrosion is a very very important factor.

What are the design criteria?
We have to worry about this while designing a sewerage system. The design period is the first thing because we will not design a sewerage system for the present conditions or for the present needs. Because once we put in the system we expect it to operate in a proper manner for the next twenty years or thirty years or ten years so the design period is an important consideration.

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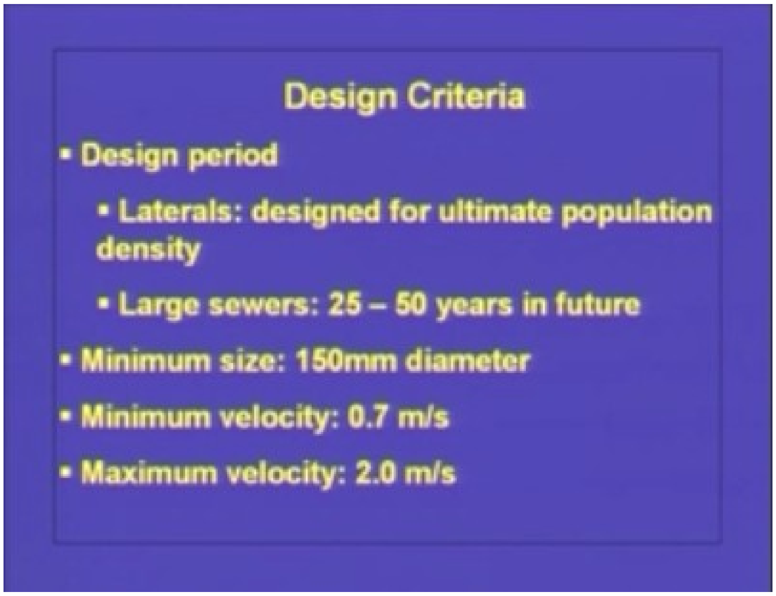

Typically laterals are designed for ultimate population density in a particular area whereas a large sewer is designed for 25 - 50 in future. The minimum size is another important criteria. We should not use any sewer line which has a diameter less than 150mm because this may lead to the problems in the maintenance. So the minimum size for a sewer line is 150mm. As I already talked about, why we should maintain a minimum velocity in a sewer line?

The minimum velocity should be more than the point seven meters per second. Under extraordinary circumstances we may allow point six meters per second sewer line.

Maximum velocity: This consideration comes from the requirement that there should not be any erosion so the maximum velocity cannot exceed more than 2 m per second at any point in the system. The minimum depth a sewer line should be buried in the ground. It should be buried in such a way that it can receive wastewater from the basements of the buildings. If the basements of the buildings are below the elevation of the sewer line then the wastewater from the buildings cannot enter into the system by gravity so there should be sufficient depth such that the wastewater from the basements can enter into the sewer system.

It should be more than 1 meter below ground, it should be more than 0.9 meters below the basement floor, the sewer line should not be above the water line, this is another important consideration.

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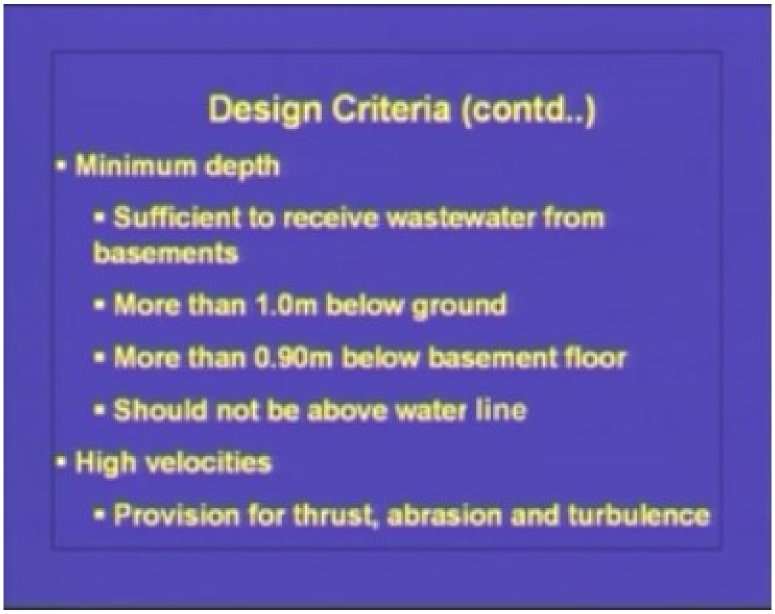

If the sewer line is above the water line and the joints in the sewer system and the water distribution network are not water type then wastewater from the sewer line can enter into the water distribution network and can spread diseases so the sewer line should always be above the water line.

If we are permitting high velocities in a sewer line then we should make provision for thrust, abrasion and turbulence. The high velocities can cause turbulence. As you know the Reynolds number of the flow if it is more than 2000 turbulence sets in. If there is turbulence then it will be easier for gases to escape from the solution so turbulence should be avoided as much as possible.

The manholes are a very important part of the sewerage system. The spacing for manholes depends upon what kind of methodology we are using for maintenance. In India the spacing is 30 m in urban areas. If we are following mechanized methods of cleaning these sewerage systems or sewers then we can go for longer lengths or longer spacing between the manholes.

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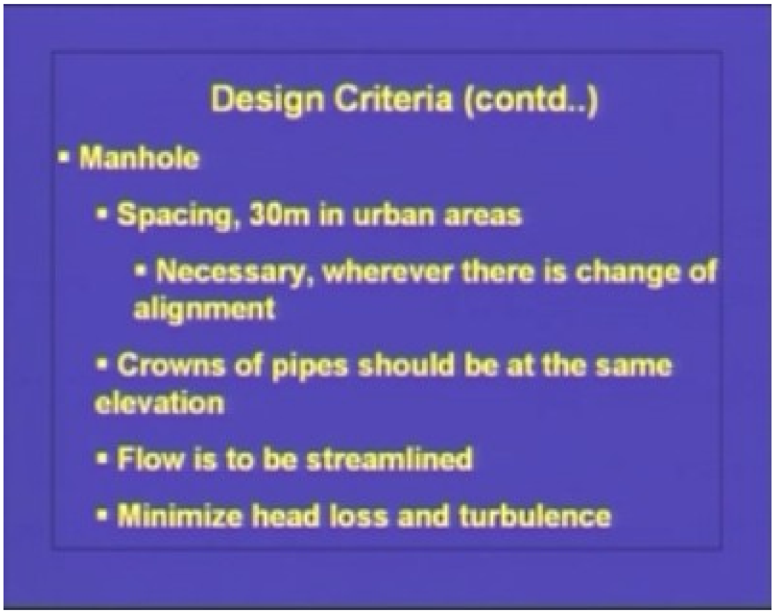

Again, manholes are necessary wherever there is a change of alignment. The change of alignment is the change of direction in the horizontal plane or the change in the slope so the manholes should be provided whenever there is a change of alignment. Manholes are also provided at all the junctions wherever the laterals are meeting the mains or where the branches are meeting the mains.

At a manhole the crowns of pipes could be more than two or more than or equal to two or three pipes will be meeting at a manhole so the crowns of all these pipes should be at the same elevation at a manhole. At a manhole flow is to be streamlined. The streamlining is necessary to reduce the head loss at a man hole and also to reduce the turbulence level. As I mentioned earlier if there is too much of turbulence then the release of gases is facilitated and that can lead to corrosion.

Before we go to the design of a sewer we will discuss how we can analyze the flow in a sewer. Here you can see the picture of a sewer and as I mentioned earlier the sewer should be designed such that the water is carried under free surface conditions. That means sewer will not be operating under full conditions or pressurized conditions. In such a situation we can use open channel flow equations for describing the flow in a sewer.

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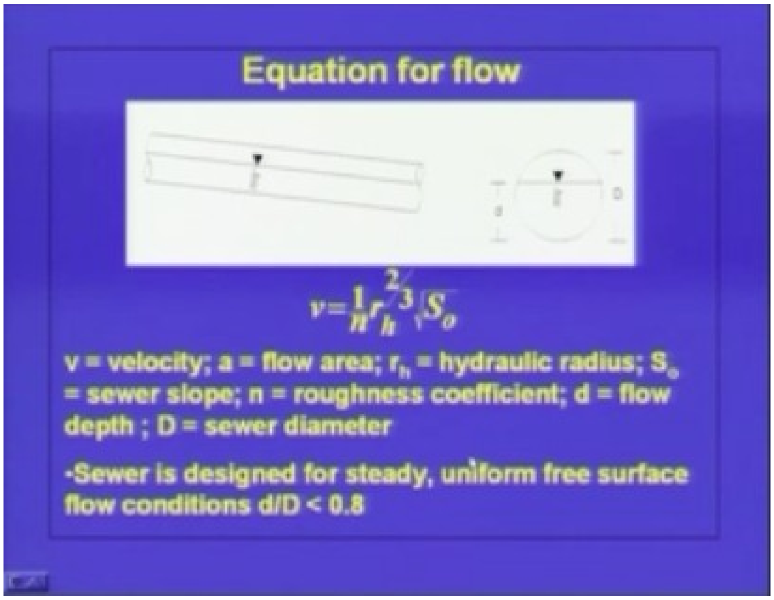

The open channel flow equation that we can use for designing the sewer is the classical Manning's equation. This Manning's equation is valid for uniform and steady flow conditions. So our design of a sewer system is always based on steady, uniform, free surface flow conditions such that D the actual flow depth divided by the diameter of the sewer should always be less than 0.8. Here the Manning's equation is velocity is equal to 1 over n multiplied by rh to the power two thirds under root S_0. If I put it in terms of the flow rate it will be Q which is equal to discharge is equal to 1 over na where a is the area of the cross section the flow area multiplied by rh to the power two thirds under root S_0, rh is the hydraulic radius and S_0 is the slope of the sewer, rh hydraulic radius is given as a that is flow area divided by p where p is the wetted perimeter. This is the equation we use for analyzing the flow in a sewer.

While designing the sewer we can see that if I have less slope that is S_0 is very less then the velocity will also be less and that can lead to deposition of the solids. If I have S_0 a very high value the velocity will be very high. If the velocity is very high the abrasion can take place. Not only that if S_0 is very high then the depth of sewer will be increasing in the downstream direction that is why we have to choose this slope of this sewer in a proper manner.

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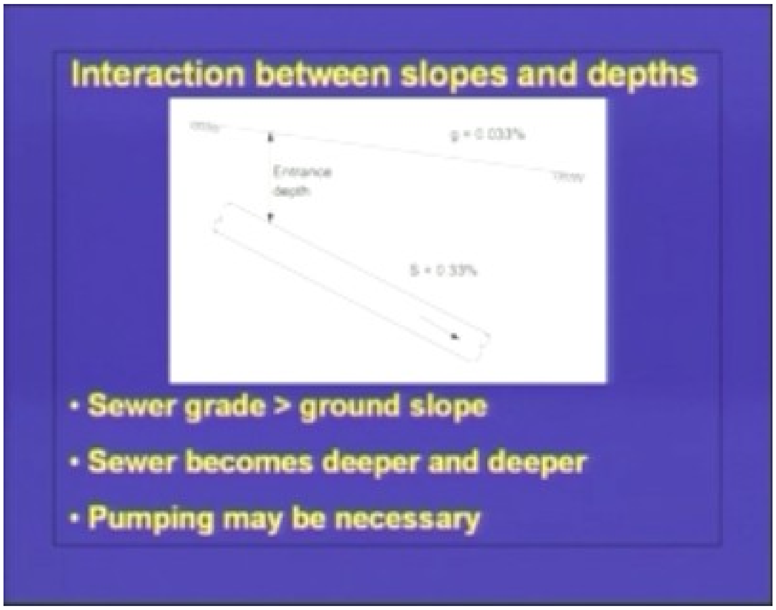

Interactions between slopes and depths:
Imagine there is a situation where your sewer line is buried underground that is the most common situation. The ground slope in this particular case is 0.033% whereas the minimum slope required for the sewer to have a minimum velocity of either 0.6 m per second or let's say 0.7 m per second is equal to 0.33%. The sewer grade is greater than the ground slope. If I have to maintain a minimum depth of one meter at the entrance to the sewer that is the entrance depth let's say if I have to maintain 1 m there and if the sewer grade is greater than the ground slope in the downstream direction then the sewer will be buried very deeper into the ground that can increase your trenching cost and the construction cost for the manholes and the capital cost for the manholes and even the maintenance costs will be increased.

Therefore to economize on that side we need to pull up the sewer close to the ground after sometime, this can be done by having a pumping. So a small pumping station may be required or a small pump may be put in the manhole and can lift this wastewater to another sewer which is not buried so deep.

Consider another situation where your ground is very steeply sloping. Let's say ground slope is 1% whereas the minimum slope required for the sewer to carry the water at minimum velocity is 0.7%. Even if I want to carry water at a higher slope let us say if I take slope of the sewer greater than point seven percent but it is less than the ground slope what happens.

In the downstream direction the sewer will be coming closer and closer to the ground surface that is not allowed. We need to maintain a minimum depth of burial of say one meter. In such a situation what can we do? We have to have a fall or a drop a sewer and then at the manhole the outgoing sewer can be put at a lower elevation than the incoming sewer. So, that interaction between slopes and depths is very important to maintain the required velocity within the limits that is between the minimum velocity requirement and the maximum velocity requirement and the necessary for pumping or the necessary for providing drops and the overall economy and ease of maintenance.

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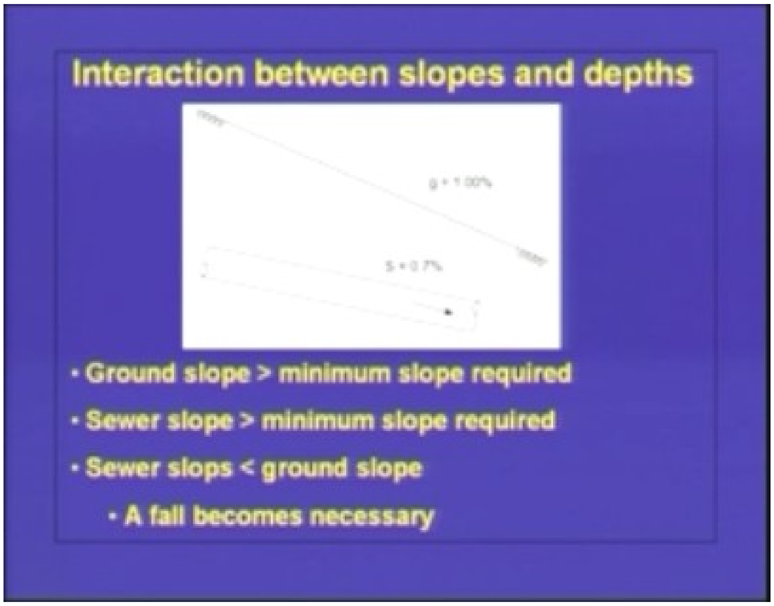

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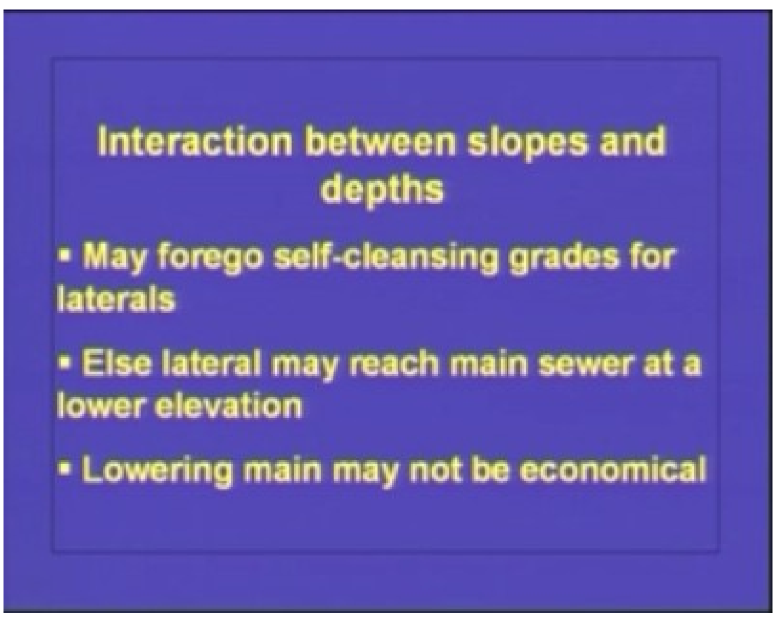

Sometimes we have to forego the self-cleansing velocities in the lateral sewers that is if the lateral sewer is laid at a steeper slope it may reach the main sewer at a lower elevation. So, to lift the water from lateral sewer to the main sewer we may require some pumping. We may not want that due to maintenance problems so in such a case what we do is we put a lateral sewer at a flatter slope such that it meets the main sewer at the right elevation. If that slope is less than the slope that is required for maintaining minimum velocities then lateral sewers can get clocked more frequently. So we should go for more frequent maintenance cleaning or these lateral sewers in such a case.

If we don't want to lower the lateral sewer but we want to lower the main sewer then that may also lead to more uneconomical situation. Before we go to the design what is the information that is required to start the design. First of all we need to have a detailed plan and a profile of the streets this will tell us how to locate our sanitary sewers.

Cellar level elevations of buildings are also important information. This will tell us at what depth we should lay our sewer lines. the locations and elevations of existing drains is very important because if you are going for capacity enhancement then we should know how to lay the newer pipes in relation to the once which are already existing.

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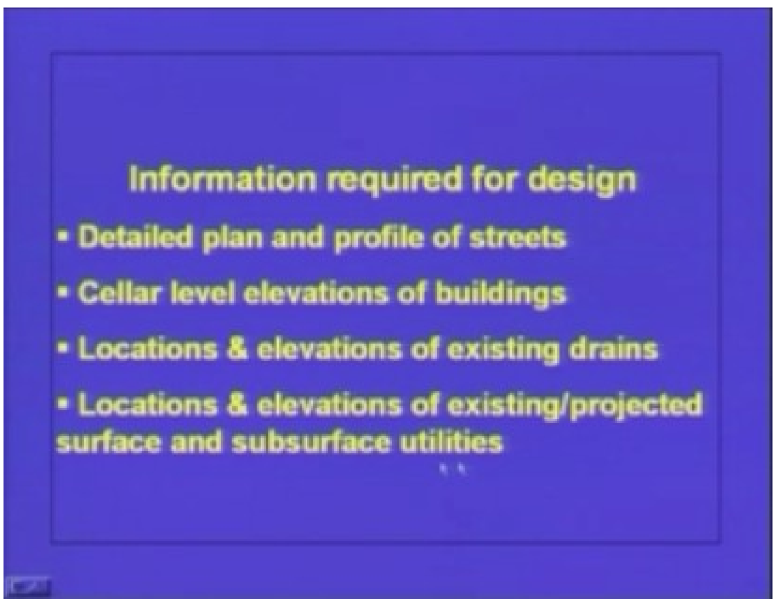

The locations and elevations of existing/projected surface and subsurface utilities as I have already mentioned the sewer line should always be below water distribution lines so we should know the locations of water distribution lines before we lay the sewer lines that information is very important.

Information required for design:
What other information is required?

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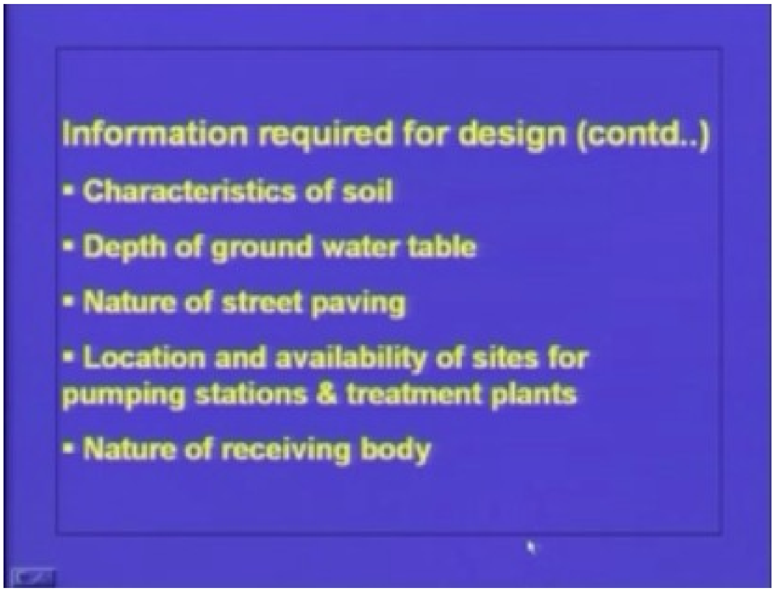

The characteristics of soil is very important they should be designed to take the overburden load and the traffic load because the sewers are laid buried under the ground so in that sense characteristics of the soil is very very important. How the loads are transmitted from the road surface to the sewer line depends upon characteristics of the soil.

Depth of ground water soil is also very important. If the sewer is laid deep into the ground water then some amount of ground water can always leak into the sewer line. So the capacity of the sewer line should be such that it is not only carrying the wastewater from the buildings but it is also carrying the infiltrated water from the ground water so that is an important information.

Nature of street paving is also an important information because that tells us how the load transfer is taking place.

The location and availability of sites for pumping stations and treatment plants is another important information because the layout of the sewer line depends upon where we are locating the treatment plant, where the place is available to locate the treatment plant and where the pumping has to be carried out that will decide how we are configuring our network.

The nature of receiving body is also an important consideration or the information that is required for the design of sewer systems because if it is a lake or if it is a river or it is a pond or what we are doing with this treated wastewater has an important bearing on the design of sewer systems, this we can see in little bit more detail later on.

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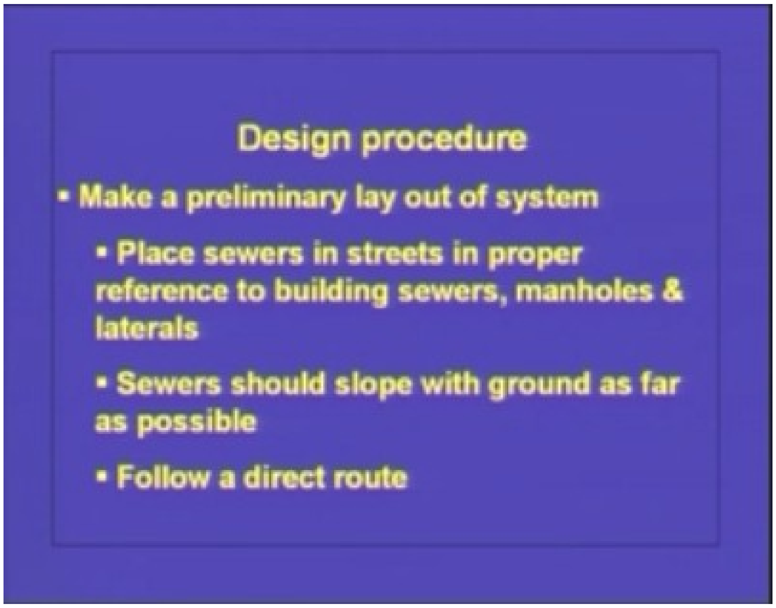

What is the design procedure?

First of all make a preliminary layout of system. Place sewers in streets in proper reference to building sewers, manholes and laterals. For this we have the maps we can also use geographic information systems for this particular step in the design. One important point to remember while doing this exercise is sewers should slope with ground as far as possible. If it is more than the ground slope then the depth of burial will be higher, if it is less than the ground slope then sewer may come very close to the ground, this we have seen already.

Another important point is to follow a direct route. We should not lay sewers on a curved path. The sewers should be straight from one point to another point that will facilitate easy maintenance.

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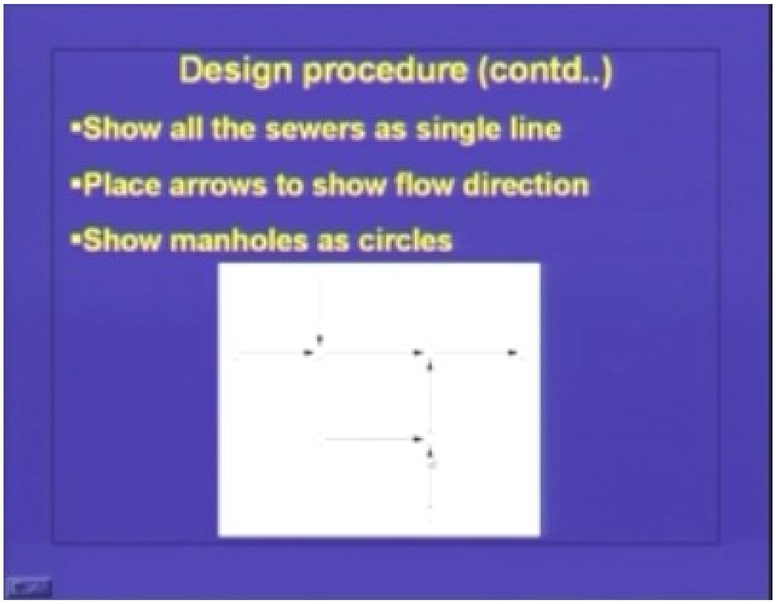

Show all the sewers as a single line. Look at the figure. This is one sewer and this is another sewer, this is another sewer so show all the sewers as single lines. We place the arrows to show the flow direction. This is a lateral which is carrying water from this manhole to this manhole (Refer Slide Time: 25:43) this is another lateral which is carrying water to this manhole; the water is being carried from here to here so we place arrows to show flow direction. We show manholes as circles on this figure. This will facilitate the computations in a step by step manner. The next step is preparation of alternate layouts.

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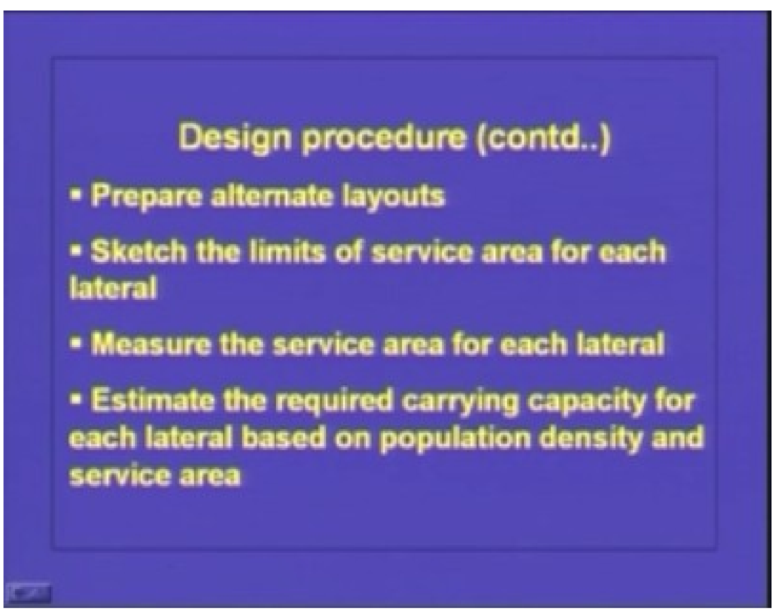

There could be several ways of carrying the wastewater from its place or origin to the treatment plant. We should prepare alternate layouts to see which one gives us the overall economy and which meets all the constraints. Then sketch the limits of service area for each lateral. For example, if we have this lateral here, the service area for this lateral could be this one, for this lateral the service area would be like this, the service area for this lateral is like this (Refer Slide Time: 26:48) so we have to sketch the limits of service area for each lateral this gives us what should be the size of that sewer because we can find out what is the amount of wastewater generated in that locality and this particular lateral should carry.

The next step is measure the service area for each lateral. Estimate the required carrying capacity for each lateral based on population density and service area. If you know the population density and if you know the service area then we know what the population is. We also know how much of drinking water we are supplying to this population. The per capita consumption of drinking water is known. We assume that about 80% of this per capita consumption of drinking water appears as sewage. That way we can estimate what is the amount of wastewater that this particular lateral has to carry.

Next one is estimate the required carrying capacity for each branch and main line based on proposed layout.

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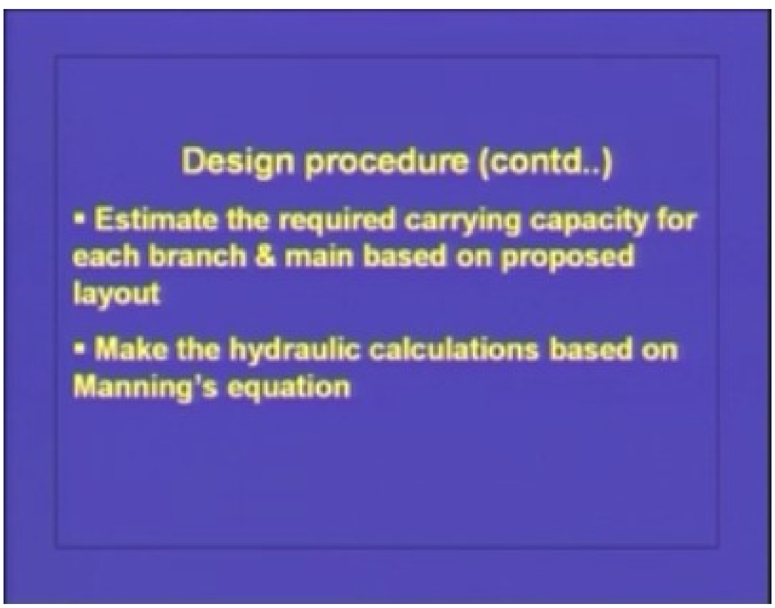

For example, if we consider this particular sewer line, this particular sewer line should carry all the wastewater that is coming from here that is coming from this lateral, that is coming from this lateral and that is coming from this lateral (Refer Slide Time: 28:28) combined the discharge from 1 2 3 4 these four laterals is appearing in this particular line so it should be designed for that whereas this particular line is designed only for the wastewater coming from this lateral and this lateral. So, depending upon the configuration and how connectivity is occurring in the network we can find out what should be the carrying capacity of each line in the system.

The next important step is we have to make hydraulic calculations based on Manning's equation. Look at this equation (Refer Slide Time: 29:10) Q is equal to one over n a rh to the power of two third under root S_0. In this the decision variables are the slope of the sewer line and the depth of flow or based on the depth of flow what should be the diameter of the sewer line. What we know in this equation is Q that is the flow rate or design carrying capacity for the sewer line. There is only one equation here but we need to find out two parameters the slope of the sewer and the depth of the flow or the diameter of the sewer line so we have to choose one to start with.

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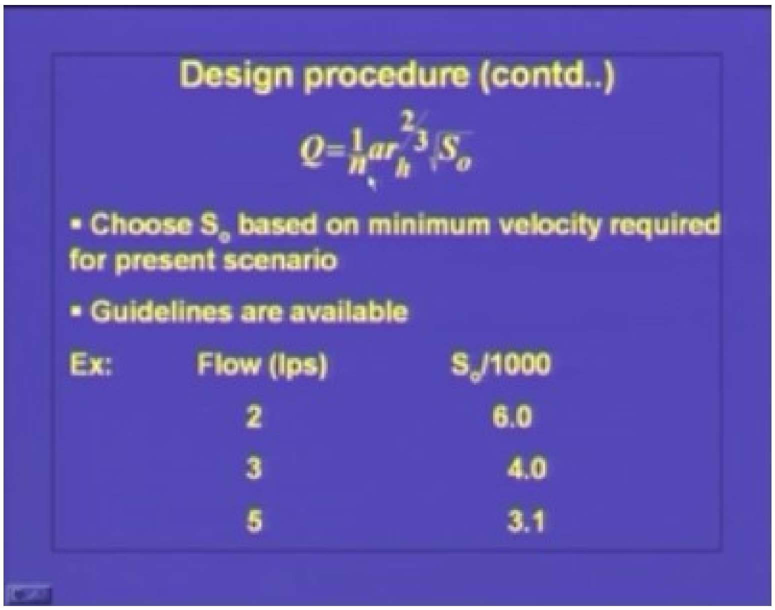

We choose the slope of the sewer line S_0 based on minimum velocity required for present scenario. Why are we considering the present scenario? If we consider the future scenario and if we are operating now the actual amount of wastewater that is flowing through the system is less than what the sewer system is designed for so definitely the velocity will be low for the present operating conditions or the immediate operating conditions so that velocity should be more than the minimum value that is the reason we choose S_0 based on minimum velocity required for the present scenario.

There are certain guidelines available for choosing this S_0 value depending upon what is the flow rate in the sewer line. For example if the flow rate is 2 liters per second then S_0 divided by 1000 should be 6. If it is 3 liters per second it should be four and if it is five it should be 3.1. But please remember this is only a guideline. We should choose this slope based on this guideline based on what would be the actual velocity for the present flow rate that may come immediately after the insulation of the system and the ground slope.

After determining S_0 or after choosing S_0 value we have to choose the diameter for the sewer line. We choose a diameter D. As I mentioned while choosing this diameter we also should remember that a minimum diameter value of 150mm has to be ensured.

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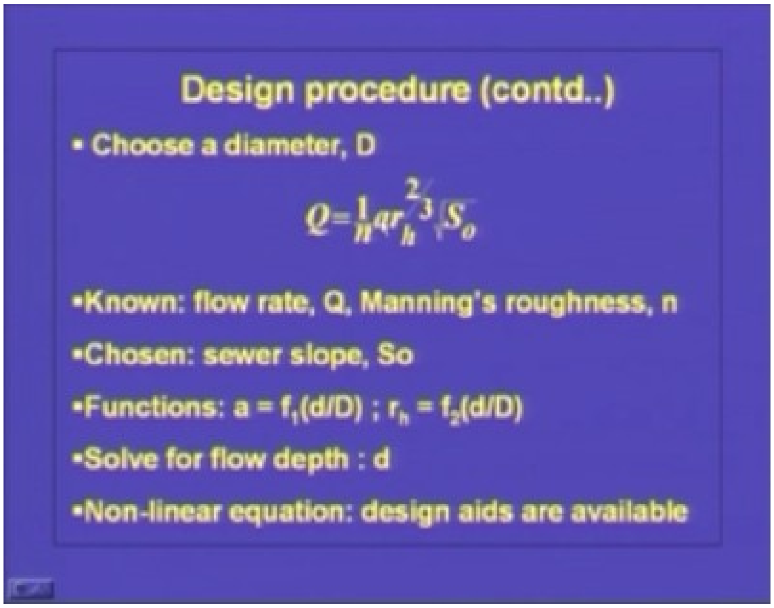

After choosing the diameter D the actual flow depth may not be equal to D in fact it should not be equal to the diameter of the sewer line. So in this equation we know the value of the flow rate Q, we know the value of S_0, we have chosen a particular diameter for the sewer line D, area of the flow will be a function of the actual flow depth divided by the diameter of the sewer line. Similarly, the wetted perimeter will also be a function of the actual flow depth and the diameter D of the sewer and n the Manning's roughness coefficient in a sewer line is a function of depth of the flow, it is not a constant. So depending upon d by D we have to choose the n value.

If we put these functional relationships in this equation then we have one equation in one unknown. The unknown is the lower case d value or the depth of the flow so we can solve for this depth of the flow. As you can see here this equation is a non linear equation in one unknown d and that we can solve for using any numerical method like Newton-Raphson method or Picard iteration method. There are also design aids available in standard textbooks and standard manuals. So we can use those design aids to solve for this equation and to obtain the value of d which is the flow depth.

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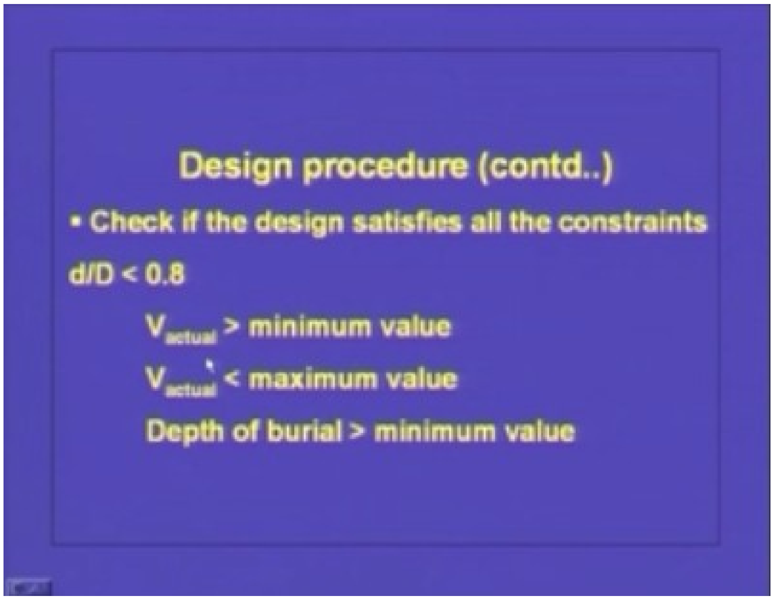

After determining the flow depth in each of the sewer lines we have to check if the design satisfies all the constraints. What are the constraints?
Actual flow depth divided by the chosen diameter should be less than 0.8. We always need to have clear space between the water surface and the crown of the sewer line. That is the only way we can ensure free surface flow conditions. Then we check for the actual velocity. Once we determine the flow depth if we know what is the Q value then Q divided by the flow area will give you the velocity. that V actual should be greater than a minimum value, that V actual should be less than a maximum value then for the chosen slope and the known ground slope we draw the profile of the sewer line between the two manholes and see what is the depth of burial for the sewer line at any point. This depth of burial should be greater than a minimum value.

Next, for a given layout as I have mentioned earlier several alternative designs are possible depending upon what value of S_0 we have chosen. And for each of these layouts we work out the hydraulics of the flow, we check for the constraints and if the constraints are satisfied then we work out the cost.

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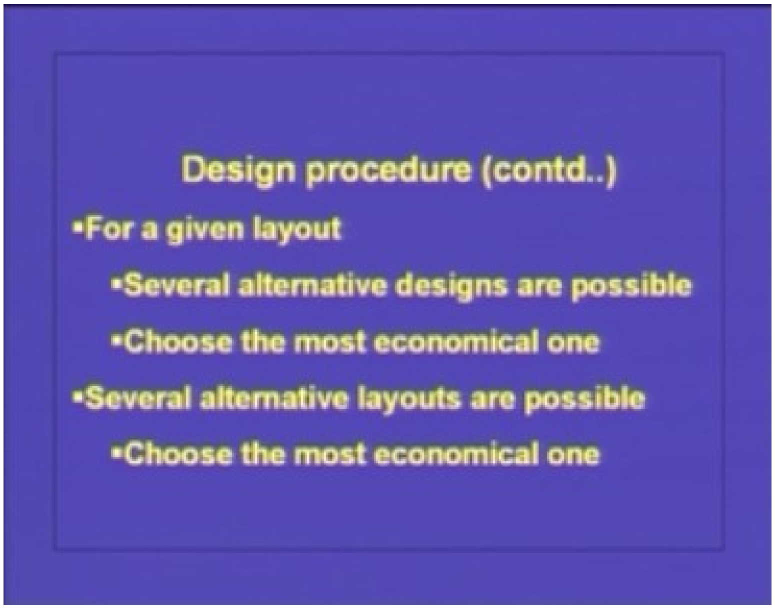

The cost is based on the diameter of the sewer line, the depth of the trenching and what could be the operating costs if some pumps are provided and what could be the maintenance costs depending upon the depth of burial and so on. We work out the total cost the capital cost plus the operating cost plus the maintenance cost. We choose that alternative which gives the least cost or the most economical one.

As mentioned earlier several alternative layouts are possible. For each of these layouts we come up with what is the most economical diameters and what is the most economical slopes. So, for each layout we have the most economical solution then we scan through this most economical solutions for each layout and come up with the layout we want to adopt finally and that could give you global minimal cost in terms of laying of the system. This is in a nutshell, the complete design procedure for a sewerage system.

The sewerage systems are different from water distribution system in one aspect the corrosion. Corrosion is an important factor in the design of a sewerage system. We should understand what is causing this corrosion and what affects this corrosion and how we prevent this corrosion. As you know wastewater contains sulfates, these sulfates are usually reduced by sulfate reducing bacteria under anaerobic conditions to sulfides. Sulfate reducing bacteria are found in all the wastewaters and sulfides can get produced because of this sulfate reducing bacteria. The sulfide combines with hydrogen or H_2 to give hydrogen sulfide or H_2S.

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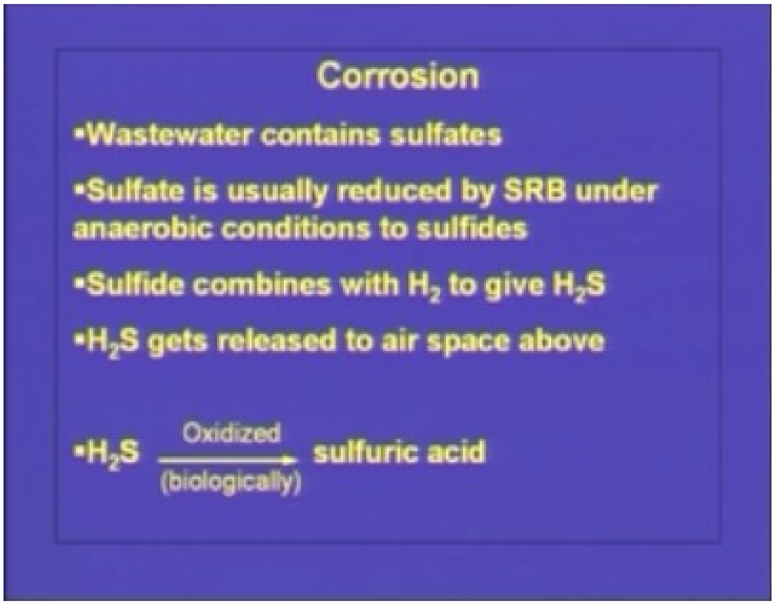

The H_2S gas can get released to air space above and once it gets released to the air space above it can get oxidized biologically to sulfuric acid and this sulfuric acid is the one which is primarily responsible for the corrosion of sewer lines. What are the factors which affect this corrosion?
Dissolved oxygen is an important parameter. If dissolved oxygen is very high then the anaerobic conditions are not predominant or aerobic conditions will be predominant and the sulfate reducing bacteria will not be very active.

Temperature: If the temperature is high you know the chemical reactions can go in an easier manner so the temperature is an important factor which affects this corrosion.

Concentration of organic matter: if organic matter is not present then the sulfate reducing bacteria will not be active and there is no biodegradation that is taking place. So the concentration or organic matter if it is very high then the corrosion is more likely to happen.

Concentration of metals: this is another important factor. Any metal can combine with hydrogen sulfide and can precipitate. So, if metals are present then the corrosion activity will be less. As you know pH is always an important factor in any chemical reaction so the sulfate reducing bacteria survive within a particular range of pH. If the pH is above or below particular range then they will not be active.

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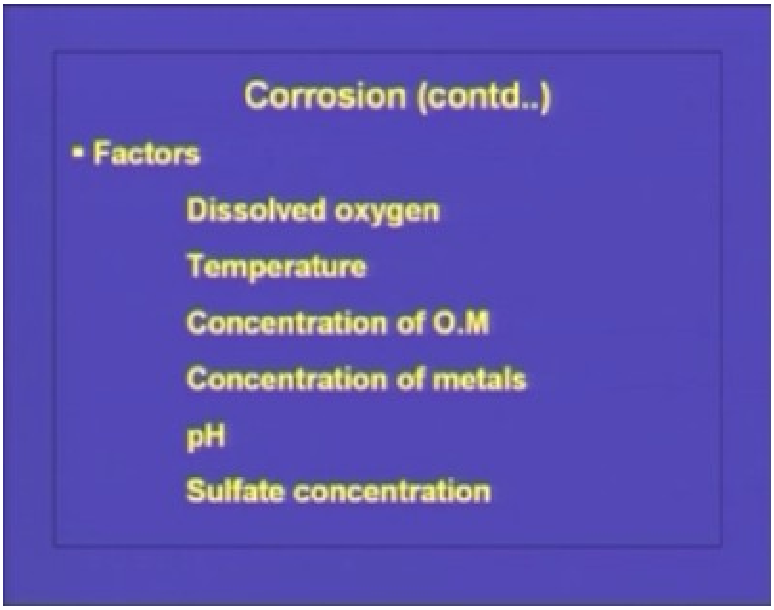

Of course sulfate concentration itself is an important parameter. If sulfates are not present then corrosion will be very less. How do we control this corrosion?
We can control corrosion by creating aerobic conditions or going away from anaerobic conditions that we can do by adding oxygen or air or hydrogen peroxide. We can reduce anaerobic growth of microbes using chlorine. If we add chlorine to wastewater that will kill the anaerobic bacteria or we can change the pH by adding sodium hydroxide NaOH.

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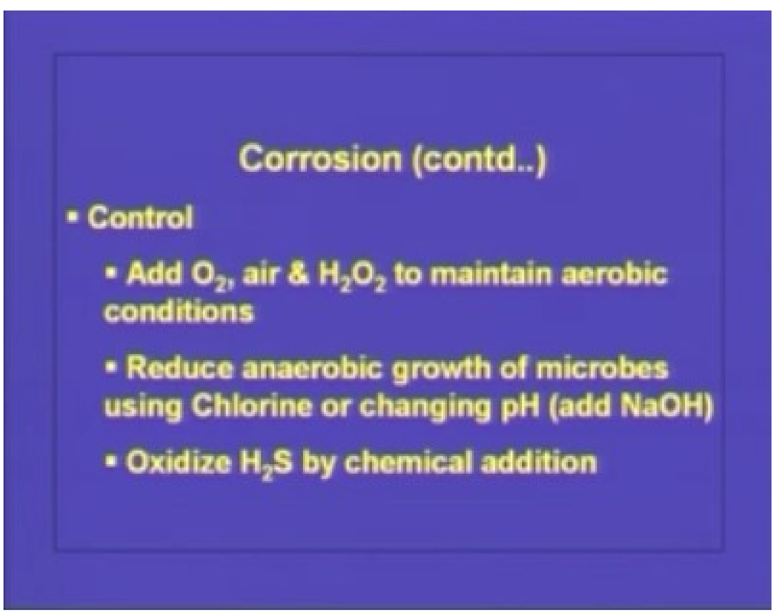

If we add NaOH it increases the pH to a very high value under which conditions this SRB cannot survive. We can also oxidize this H_2S, instead of forming sulfuric acid I can oxidize this H_2S by chemical addition.

The next important thing in the design of sewerage system is the layout. There are different layouts which are possible. For example, we are showing a perpendicular pattern here.

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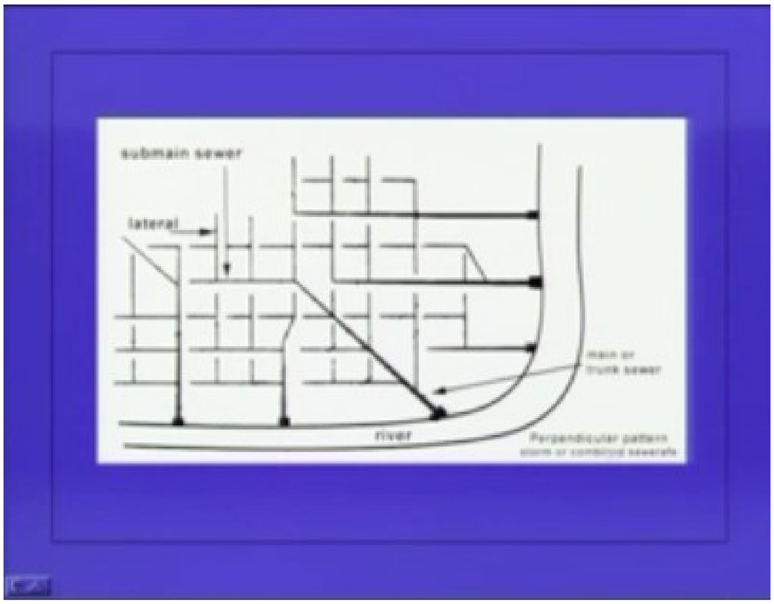

In this perpendicular pattern the storm water is combined with the sanitary sewage and it is disposed of to a river at the closest point so this gives a perpendicular pattern. For example, here this is the lateral (Refer Slide Time: 41:20) this lateral is carrying the wastewater as well as the storm water into this submain sewer. The submain sewer will carry this combined wastewater and storm water to a main or trunk sewer and this main or trunk sewer will dispose off the wastewater into the river at this location. From this area this is the lateral and this is another lateral, this is another lateral and this is a submain and this also discharges wastewater at this location. This is what we call a perpendicular pattern.

The problem with the perpendicular pattern is the wastewater is discharged at several locations in the river and we should see what would be the effect of the disposal of this wastewater in this river because we are not treating this wastewater before releasing it to the river in this particular pattern. Therefore we go for another system where we intercept the wastewater before it is discharged into the river.

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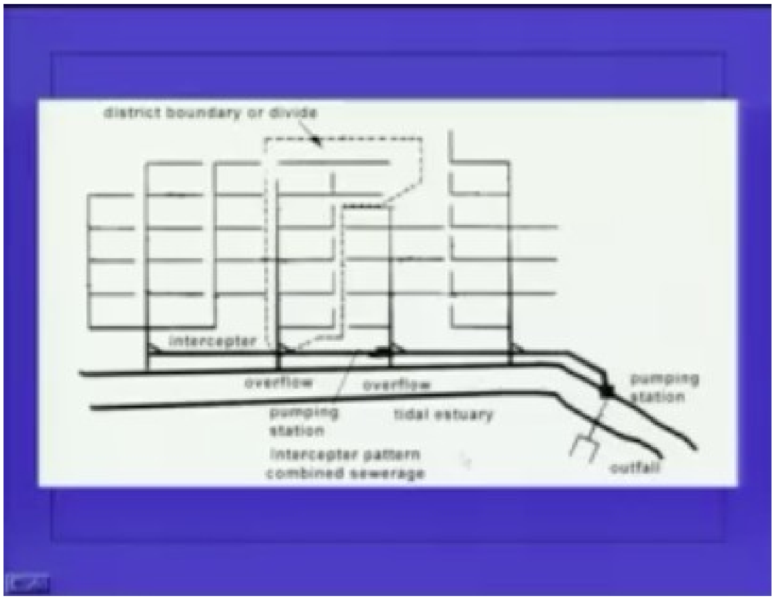

Here in the interceptor design the wastewater from several locations and submains is collected in a main pipeline called an interceptor and this interceptor carries the wastewater to one single pumping station and treatment station and after it gets treated it gets discharged into the river or lake. Before it goes to the pumping station or the treatment station some amount of wastewater can also get released into the river or lake that is what we call as overflow.

Why do we need this overflow?
This is a combined system which carries the storm water during the rainy season as well as the wastewater from the domestic areas. During non rainy season the carrying capacity required for this interceptor is very small whereas during the rainy season the carrying capacity for this interceptor should be very high. If we are going to design this interceptor for the maximum possible range in that area then the size of this interceptor will be very very high as well as the size of the pumping station as well as the size of the treatment plant will be very high so we do not design this treatment plant pumping station and this part of the interceptor for the maximum possible range or for maximum possible storm discharge.

We design for some averaging conditions. But during heavy rainfall we need to divert the water without the treatment into the estuary or the river and that is why we have these overflow paths in this interceptor pattern. The problem with the interceptor pattern is the main interceptor line which is near the water front. The soil conditions generally there are not very conducive to the structural strength of this interceptor. So what we do is again if we have only one interceptor like this the size of the interceptor will be very high, the maintenance will not be very easy. So in the next pattern which is called the zone pattern we intercept at several levels. we have a high level interceptor here, we have an intermediate level interceptor here (Refer Slide Time: 45:05) and we have a low level interceptor here, these are the contour lines, this is the high ground, this is the intermediate ground and this is the low level ground.

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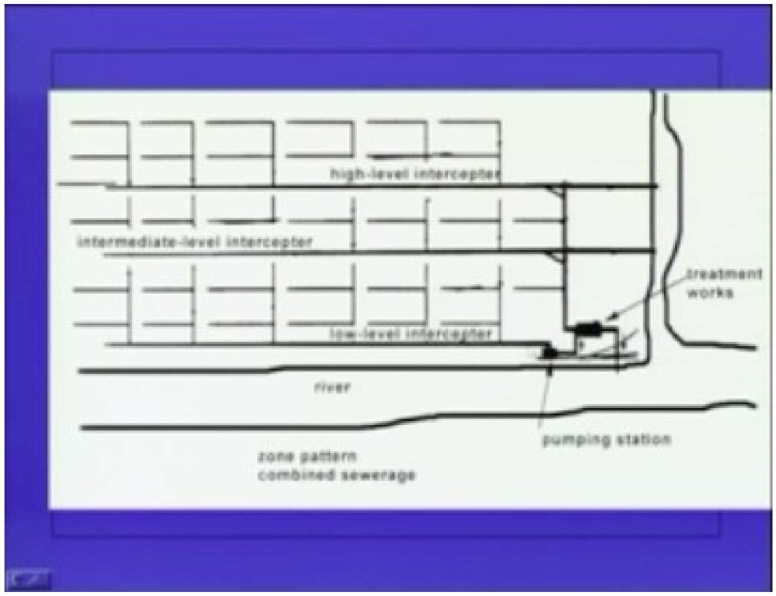

Therefore, from the low level areas the water is collected in the low level interceptor and from high grounds water is collected in the high level interceptor. Now all these interceptors, this interceptor has an overflow provision at this location, this intermediate level interceptor has an overflow provision at this location and the low level interceptor has an overflow at this location (Refer Slide Time: 45:50) and from all these interceptors water is taken to the treatment works and after it is treated it is dumped into the river. The low level interceptor will need to have a pumping station because it is at a low level and the treatment plant could be at a higher ground so there may be a requirement of a pumping station here. This is what we call the zone pattern which we adopt for a combined sewerage system. A combined sewerage system is the one which carries both the sanitary sewage as well as the storm water. Another pattern is what is known as fan pattern.

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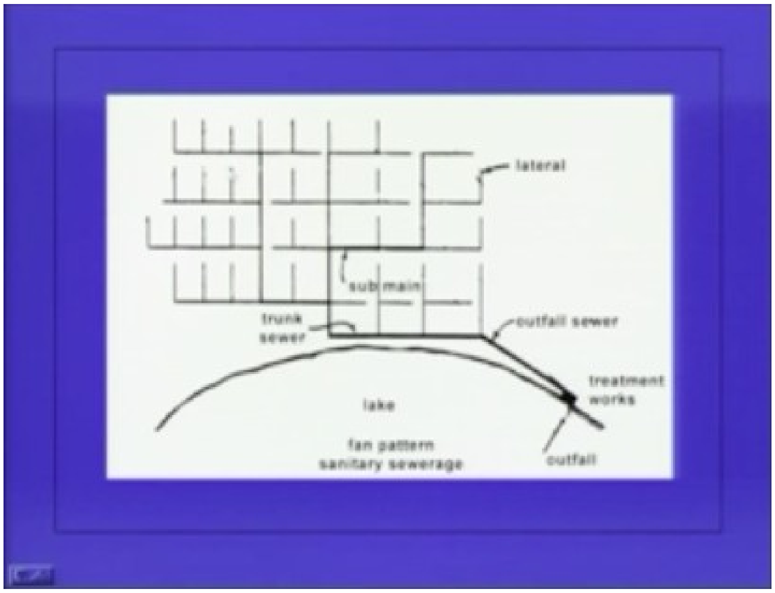

In the fan pattern we collect the sanitary sewage. The fan pattern is typically adopted for sanitary sewerage systems. In this fan pattern sewage from all the outskirts of the city are collected and taken towards the water front. For example, the sewage from here this is the lateral it is coming and then joining the submain and from the submain it is going to the trunk sewer. So, from all the outskirts of the city or from all the locations of the city the sewage is carried to one single treatment works here like a fan and then it is treated and through the outfall it is discharged into the lake. This is called the outfall sewer because it is carrying water from the trunk sewer to the outfall.

The problem with this hand pattern is typically if we have a water front they also develop much more than the other parts of the city so this is already crowded, already developed and as the city is expanding outwards we may lay more and more lateral sewers. This lateral sewers design is not a problem but all these lateral sewers now they will be contributing to the outfall sewer. The outfall sewer should be able to take this extra amount of wastewater that is coming in but this area is already developed. Removing this outfall sewer or changing it to a larger size or laying a parallel outfall sewer is going to be a problem in this hand pattern so we go in for another pattern in such situations. This is called the radial pattern.

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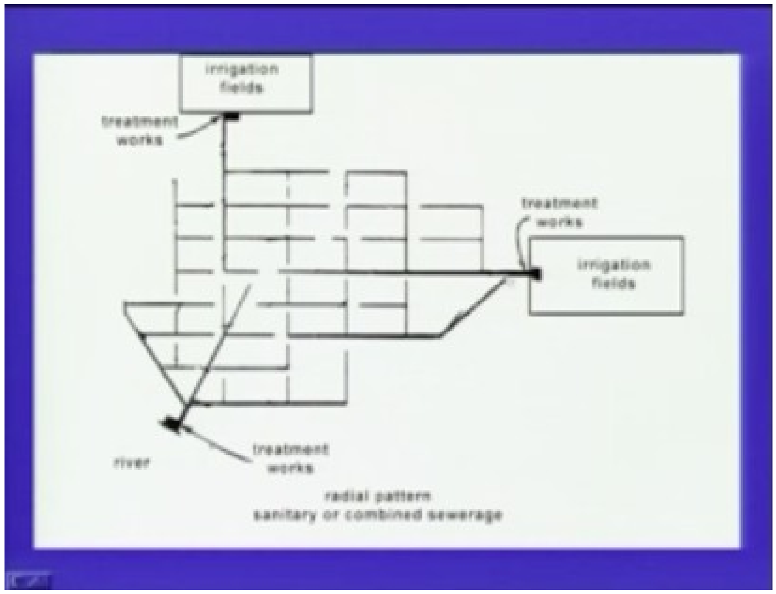

In the radial pattern the wastewater from the middle of the town is carried towards the outskirts. For example, this is one main (Refer Slide Time: 48:30) and this is carrying water from this whole area into this particular discharge point whereas the sanitary sewage from this area is being carried to this main line and this treatment works here and from this area it is carried outwards to this discharge point.

The problem with this radial pattern is we need to have several treatment facilities. We need to have a treatment facility here, we also need to have a treatment facility here, we need to have a treatment facility here as well as we need to have a proper discharging situation as where are we going to discharge this. Here I have a river so I can discharge the treated water, here I don't have a water body so I can take this treated water and apply to irrigation fields but then I have to see to what level I should treat this water but that may create some problem or it may increase the cost of the system.

The last thing I would like to discuss in this lecture is the sewer materials. The factors which affect the selection of the materials are;
The material should have resistance to acids gases and solvents
It should resist erosion/scour. We have already seen where this erosion is coming from because of the grid, it should have enough strength because scours are buried underground they have to take the load of overfill or backfill and the traffic load they should have enough strength. The cost of the scour line should be a minimal, we should have ease in the assembly of several scour lines and appurtenances and we should have ease in handling.

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Availability of appurtenances and fittings is another important factor. Whatever is the material of the scour line the appurtenances and fittings should also be made of similar material or the same material so they should be available. The flow characteristics also affect the selection of the material. If the material is very rough then the carrying capacity will be low for that kind of a scour made of that material so it should be smooth enough to carry the flow very easily.

What are the different materials we have?
For example, brick is a very common material for scour lines. The problems with the brick scour lines are high cost; also it requires large space for construction and the progress of work if we are using brick as a sewer material it is generally slow.

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One important consideration is we should have a minimum of 12.5 mm thick cement plaster cover when we are going for brick as a sewer material because if you don't have this sewer plaster cover then the sewer line could be leaking profusely.

Concrete is another common material for sewer lines because we can get reasonable strength with concrete by properly having a mix and reinforcement. It facilitates the construction of a wide range of sewer lines. The construction can be very rapid. However, the concrete lines are susceptible to corrosion if the sewage contains acid material.

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If the septic conditions are present at low flow velocities it can corrode the concrete. To get over this problem we can use high alumina cement. Vitrified clay or stone is another material which is normally used for construction of sewers. They are typically available from 80 to 1000 mm sizes. Standard fittings are available. They can resist corrosion from most acids; they can resist erosion due to grit. However, the vitrified clay or stone ware sewers require special bedding or concrete cradling to increase their strength. The other problem we have with this kind of a material is they are difficult to handle. While they are being constructed many of these sewers can break very easily because they are brittle material.

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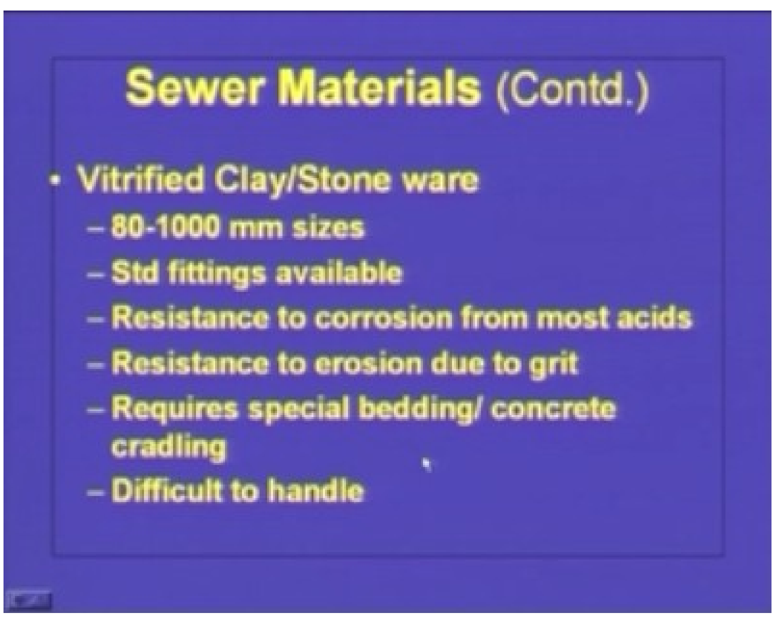

Asbestos cement is another material which we can use for sewers. They are non corrosive, they are very smooth and give good flow characteristics, they are light in weight we can easily machine and we can easily handle this. However, problems with asbestos cement are it is highly carcinogenic. As you already know in most of the developed countries this asbestos is banned.

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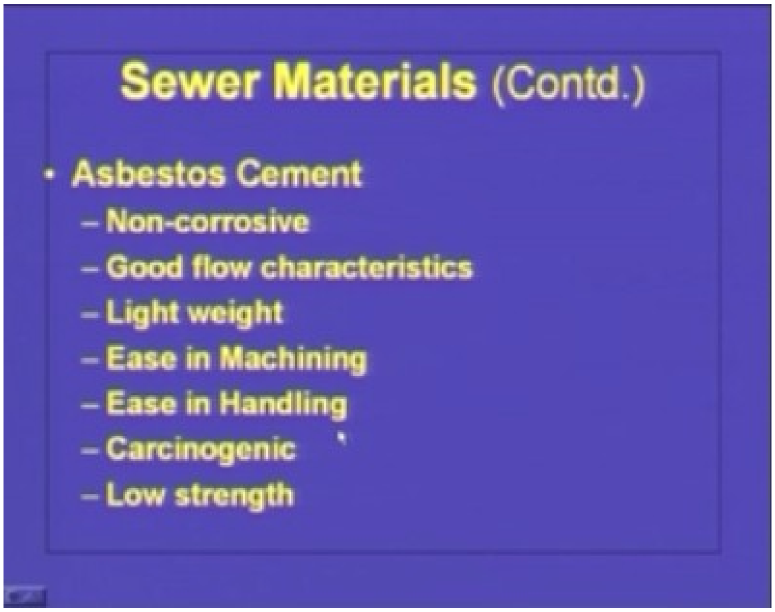

Another problem with this asbestos cement pipe is its low strength. Just like vitrified clay and stone wares this asbestos cement scour lines also require the special bedding to increase the strength. We can also use iron and steel as sewer material. In fact iron and steel is the most common material for sewer lines when they are designed as pressure sewers for sewers above ground, within sewage treatment plants and where absolute water tight joints are required or where long laying lengths are required but they are susceptible to corrosion. We can also use plastic pipes, glass fiber reinforced plastic pipes and fiber glass reinforced pipes for sewers.

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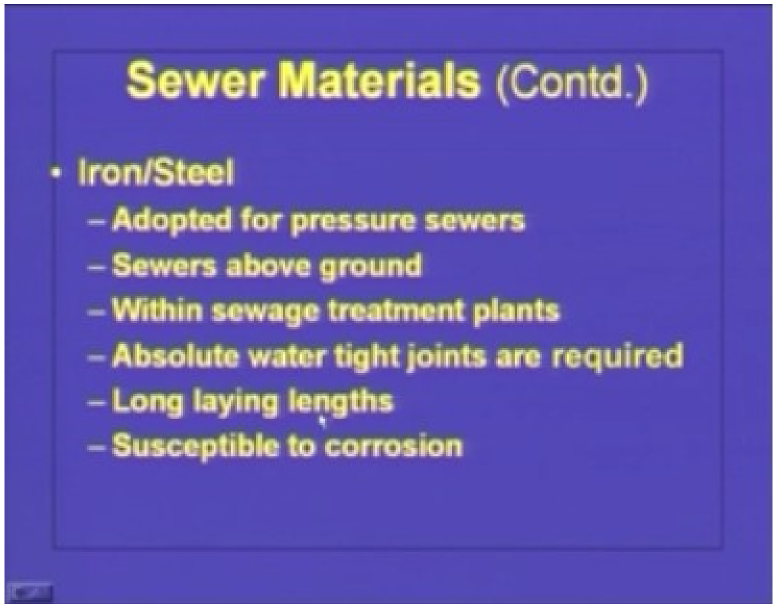

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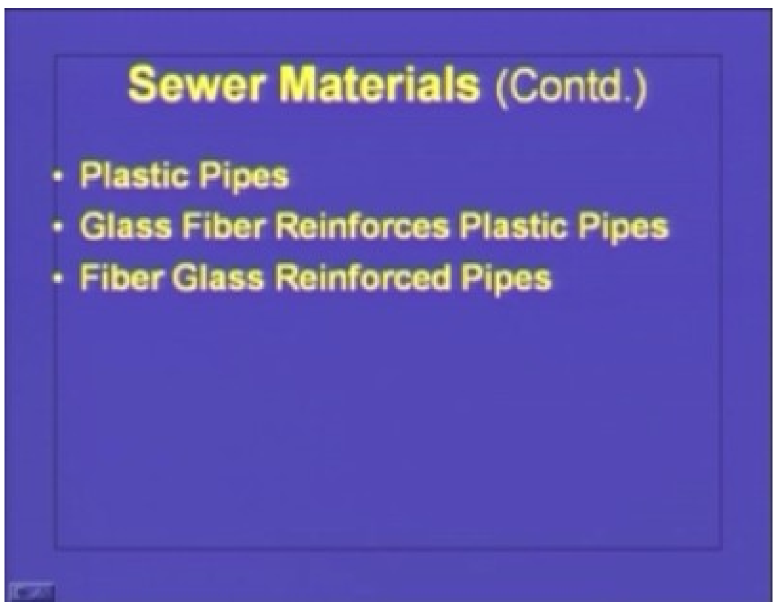

To summarize in this lecture we have seen what are the main considerations in the design of sanitary sewerage system. We looked at how the design is carried out, what are the design steps, what is the equation used for determining the flow characteristics. We also looked at the different patterns you can adopt for laying the sewer lines, how it is important to prevent or control the corrosion and what are the materials that can be used for sewer lines.