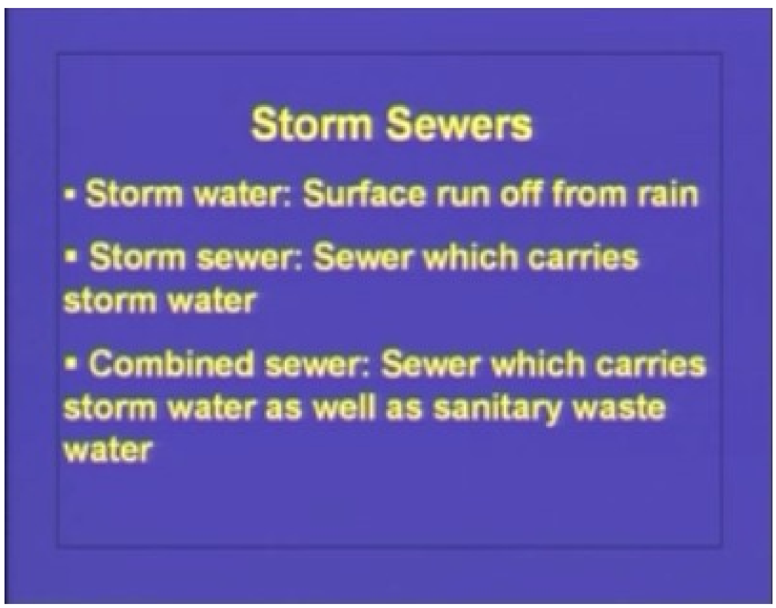
Water and Wastewater Engineering
Dr. B. S. Murty
Department of Civil Engineering
Indian Institute of Technology, Madras

Storm water Sewerage Systems
Lecture # 39

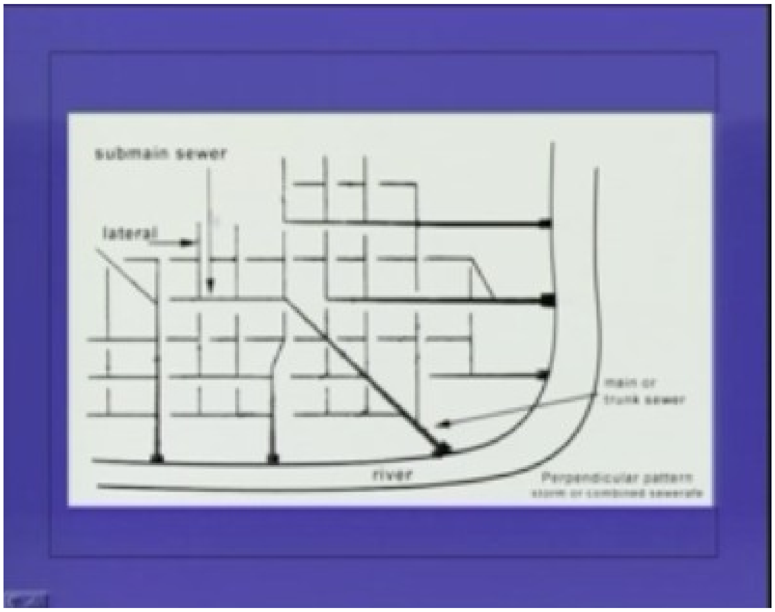
In the previous lecture we have looked at the design of sanitary sewerage systems. In this lecture we will discuss the design of storm water sewerage systems. What is storm water? The storm water is the surface run off from the rain and a storm sewer is a sewer which carries the storm water.

(Refer Slide Time: 01:40)



In the earlier days people used to design a combined sewerage system or a combined sewer is a sewer which carries storm water as well as sanitary wastewater. The problems with the design of combined sewerage systems we will discuss later. First we will concentrate on the design of storm water sewerage systems. In this figure we will see the layout of a storm water sewerage system which can also be used for combined sewerage system.

(Refer Slide Time: 02:10)

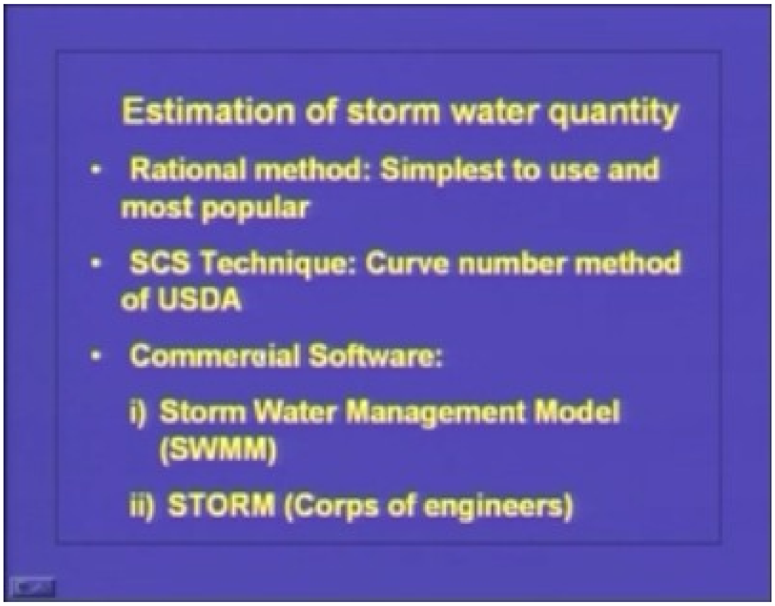


Here this is a lateral and then all the laterals join to form a submain sewer and the submain sewers join to form main or trunk sewer. The excess rain water from the drainage area which I am showing here gets collected into the laterals first. Similarly the excess rain water from this drainage area is collected into this lateral first and all the laterals join to make a submain sewer submain sewers join to make the main trunk or sewer system.

So in the design of storm sewerage like this the first step is to estimate the amount of storm water quantity. What are the steps involved in the estimation of storm water quantity. There are several methods which are available. First is rational method which is the simplest to use and it is the most popular method. Many designs even now in our country are being done by this rational method.

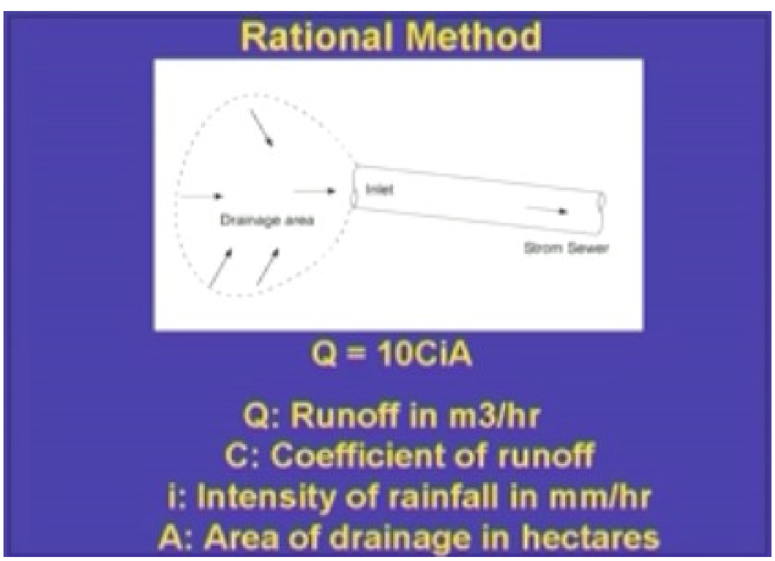
Other methods are also available like SCS technique. SCS or Soil Conservation Society of United States department of agriculture has come up with a method called curve number method for estimating the storm water quantity. There is also commercial software available which estimate this quantity in a more refined manner.

(Refer Slide Time: 03:45)



For example storm water management model or SWMM is one such software. US code of engineers also have developed one software for this purpose this is called the STORM. In this lecture we will concentrate only on the estimation of storm water quantity using rational method. For example, see this particular figure here I have a storm sewer and this is the inlet for the storm sewer and this water is getting carried in this direction. All this area is marked by this dash line is called the drainage area the rain falling in this particular area the excess of this rain travels in this direction and enters the storm sewer at this inlet point.

(Refer Slide Time: 04:50)



We are interested in knowing how much of the discharge is going to come into the storm sewer or for what discharge the storm sewer should be designed. That discharge is given as Q which is runoff in meter cube per hour. That runoff is equal to ten multiplied by C multiplied by i multiplied by A. C is what we call coefficient of runoff, i is intensity of rainfall in mm per hour and A is the area of drainage in hectares. This is the drainage area that is contributing the flow to the storm sewer so this area we should know that is what we call the area of drainage and i is the intensity of rainfall that we can get from the rainfall measurements in that particular area. C is the coefficient of runoff. Not all the rain that falls in this particular area will contribute to the flow into the sewer because some of the rain water would have been stored in the depression storage in drainage area or lot or rain water would have percolated into the ground so not all the rain that is falling here contribute to the flow in this particular storm sewer.

We will look at how to estimate this coefficient of runoff and the intensity of rainfall in a more detailed manner in the next few minutes.

(Refer Slide Time: 06:15)

Design Peak Flow:
We need to know what data is required. First of all consider a storm sewerage system like this. I have a lateral here, I have another lateral here, I have another lateral here and this is the drainage area for the lateral and this is the inlet (Refer Slide Time: 6:12). Similarly this is the drainage area for the lateral and this is the inlet, this is the drainage area for this lateral and this is the inlet. This lateral and this lateral are forming to this particular sewer. So the amount of discharge that is coming here is the combined discharge from these two laterals. Not only that there will be a time lag effect. The peak load that is occurring here will occur at a little time earlier compared to the peak load in this. That time lag one has to consider while estimating the design peak load for this sewer here. Similarly the time lag that occurs for the peak load from this point to this point here has

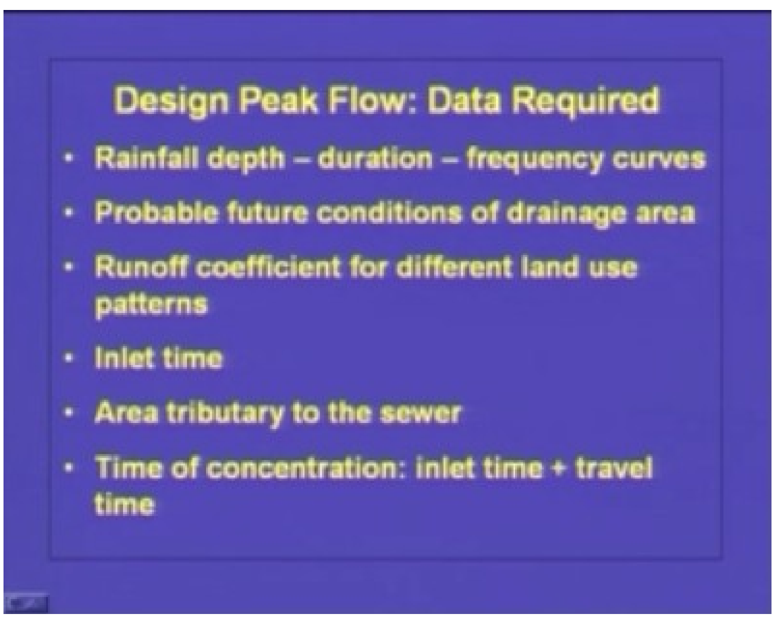
to be considered while designing the storm sewer in this region.

Design Peak Flow:
The data required are the rainfall depth duration frequency curves. One can get this by collecting the rainfall information and conducting the hydrological analysis.
Then we need to know about the probable future conditions of drainage area.
For example, this is the drainage area currently which is a grassland. Maybe in future urbanization will be taking place so all these areas get paved. Once the area gets paved then the amount of rainfall coming here and the amount of percolation that is going to be affected certainly depends upon what kind of pavement I have. So if it is completely concreted then one can say that almost hundred percent of the rain will appear in the storm sewer here. So we have to see what is the future scenario regarding the development of the drainage area and that we have to factor it into our design.

So the probable future conditions of drainage area are an important information. This is very difficult to quantify but one has to think about it while doing the design.

Then we have the runoff coefficient for different land use patterns. Again if the land use patterns if you have parks then the amount of rain that comes into the storm sewer is going to be different compared to if that area is full of houses and apartments and so on and so forth. So depending upon what is the land use in the drainage area the runoff coefficient gets affected. We will see this in more detail.

(Refer Slide Time: 08:50)



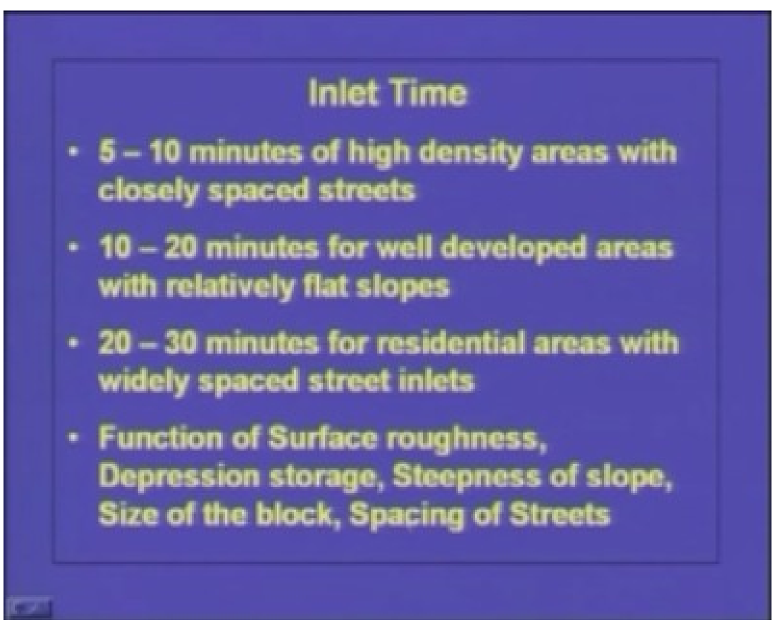
The other important information that is required for estimating the design peak load is the inlet time. Inlet time is the time taken for the water to move from the farthest point in the drainage area to the first point of the inlet sewer. So, if I have the rain falling in this particular drainage area I will see what is the time taken for the water particle to travel from this point to this point. That is what we call the inlet time.

Area tributary to the sewer is another information that is required for estimating the design discharge. I have already talked about what is the area tributary to the sewer. This is this is the area tributary to this particular sewer here, this is the area tributary to the sewer here and this is the area tributary to the sewer here (Refer Slide Time: 9:47). So what is the area of this drainage basin contributing to the flow here should be known.

Time of concentration is another important parameter to be considered in the design. The time of concentration is defined as inlet time plus travel time. For example consider the network here. For the water particle to move from here to here takes some time and that time is what we call inlet time. Then the water particle has to start from this point and then move all the way down the sewerage system.

If I am considering this part of the sewerage system I am interested in the design for this particular sewer then I have to see what is the total time taken for the water particle to move from the farthest point in the drainage area that is inlet time plus this is the farthest lateral corresponding to this particular sewer here (Refer Slide Time: 10:50). So what is the time taken for the water particle to travel in the sewerage system itself should be added to the inlet time that is the travel time plus the inlet time is what we call the time of concentration. The time of concentration here truly indicates the picture of rain falling on the entire drainage area and all that rain is contributing to the flow here. That is the time of concentration and that is an important parameter in the design of sewerage system.

(Refer Slide Time: 11:45)



The inlet time is a function of surface roughness, depression storage, steepness of slope, size of the block and spacing of streets. For example, if the surface is very rough then the velocity will be small or the water will be moving slower and your inlet time will be higher. Similarly if you have depression storage in the initial stages of the rain most of the rain water will get stored in those depressions so it will take time for the rain water from the farthest end to go and then reach the inlet point of the sewer. So, depression storage is another important factor which affects the inlet time.

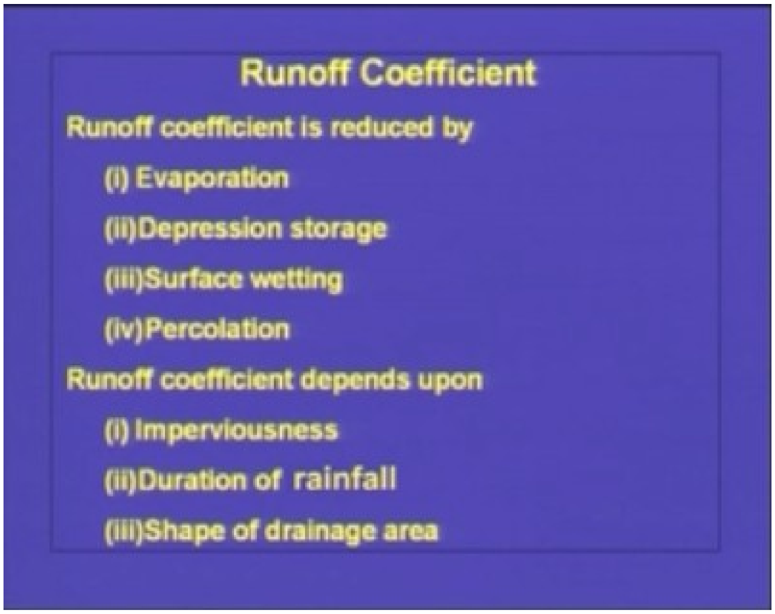
Similarly, the steepness of slope, if the slope is very steep then the velocity for the flow over the surface, the overland flow velocity will be faster and then inlet time will be shorter. Similarly the size of the block, if the farthest point is very very far away from the inlet point of the sewer then obviously the inlet time will be longer, you will have larger inlet times.

Spacing of streets: the spacing of streets is affecting your inlet time because your sewers are normally placed below the streets. Hence, if you have more number of streets then you are going to have more number of laterals. That means the farthest point from the drainage basing to inlet point will not be as longer if the laterals are not many. So here inlet time will be short if the spacing of streets is denser.

Typically inlet time can be estimated using certain guidelines which are given here. Hence, 5 to 10 minutes is the inlet time for high density areas with closely spaced streets. Then 10 to 20 minutes is for well developed areas with relatively flat slopes. As you can see when we have flat slopes then inlet time increases because for the flat slopes the velocities will be slower. Similarly 20 to 30 minutes is for residential areas with widely spaced street inlets so the inlet time will be more because the number of street inlets is less so they are widely spaced.

The runoff coefficient is basically equal to the percentage of rainfall that is going to come into the sewer. The runoff coefficient is reduced by the evaporation loss, the depression storage, surface wetting and percolation.

(Refer Slide Time: 14:25)



Evaporation: Imagine the rain falling in the month of June just after the summer season. Now the temperatures are going to be high. So, as the rain is falling much of this rain or a part of the rain itself is going to get evaporated or it falls on very hot surfaces and it gets evaporated. So evaporation as the rain is falling is an important factor in the decision for the runoff coefficient.

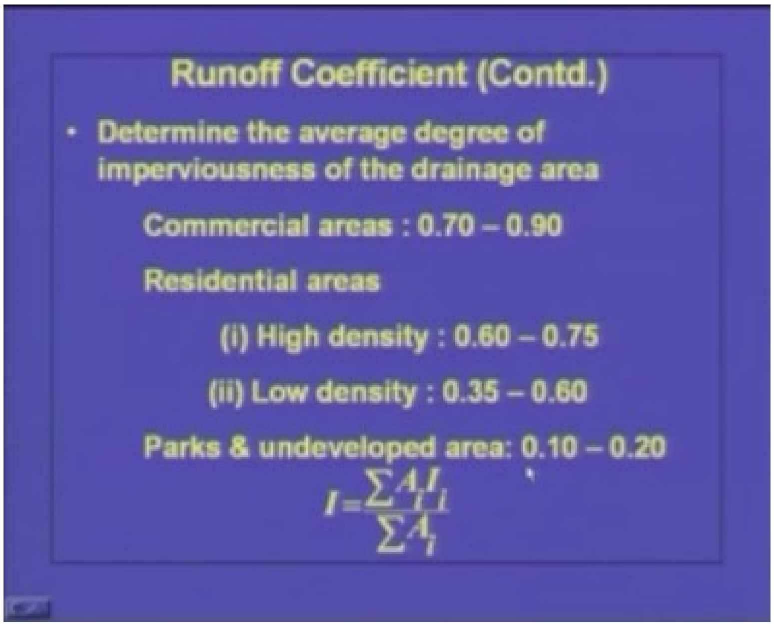
Similarly if the ground is uneven a lot of pot holes are there, lot of depressions are there in the surface then the initial part of the rain is going to get stored in these depressions. So that way the depression storage is also an important factor in terms of how much of rain will come into the storm sewer.

Surface Wetting: If a rain has already occurred sometime before and the ground is completely wet if this is followed by a subsequent rain then because the ground is already wet the amount of percolation that takes place into the ground gets reduced because the ground is already saturated. Naturally the amount of overflow that is occurring will be higher so more amount of water will come into the storm sewer so your runoff coefficient in such a case will be higher. Percolation and surface wetting are kind of interrelated to each other.

The runoff coefficient depends upon imperviousness, duration of rainfall and shape of drainage area. For example, if the surface is highly impervious then the runoff coefficient will be very high, if the duration of rainfall is very long then again the runoff coefficient will be higher because in the initial stages of rain more of the rainfall gets percolated into the ground and as the ground is getting saturated and if the rainfall is still occurring naturally the amount of rainfall that appears as overland flow will be more so duration of rainfall has an effect on the runoff coefficient. This we will see in the next few minutes.

First of all for estimating the runoff coefficient we need to determine the average degree of imperviousness of the drainage area. The whole drainage area can be divided into several regions of homogeneity or local homogeneity and imperviousness factor is assigned to each of these areas. For example, if we have commercial areas then the imperviousness factor is 0.7 – 0.9. For residential areas where we have high density population then the imperviousness factor 0.6 to 0.75, for low density residential areas it is 0.35 to 0.60.

(Refer Slide Time: 17:50)

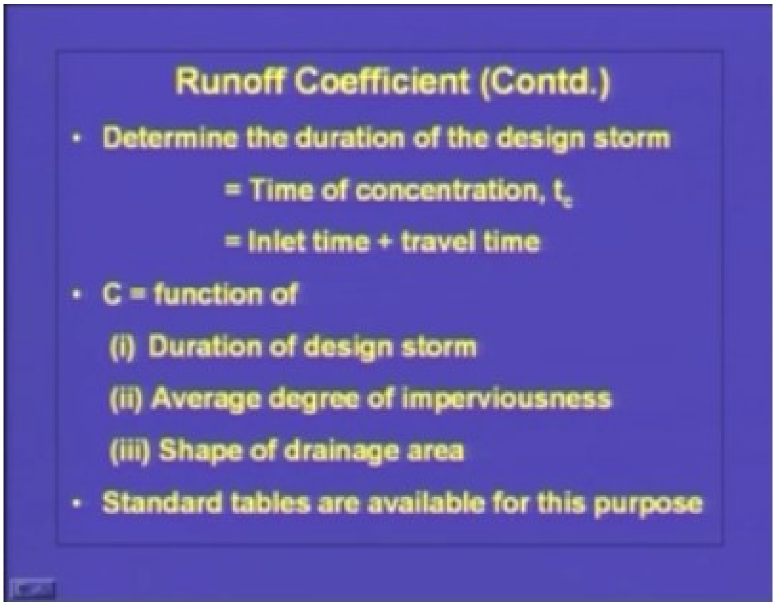


For parks and undeveloped areas the concrete pavement is not going to be there, it is mostly grassland so the percolation will be very high or the infiltration will be very high in such cases the amount of overland flow will be low that is why we have imperviousness factor here as 0.1 to 0.2.

The average imperviousness factor for the whole area is made up as sigma A_i I_i divided by sigma A_i where I is a sub part of the drainage area i which has an imperviousness factor of I_I and the area of that sub part is A_i so we basically multiply A_i with I_i and then take the summation divided by the total drainage area which will give us an average imperviousness factor.

Next we need to determine the duration of the design storm. Typically what we do for the design is the duration of the storm is taken as more than or equal to time of concentration t_c. We discussed this earlier as how to estimate the time of concentration. The time of concentration is inlet time plus travel time. Now this C that is your runoff coefficient is a function of duration of design storm which we already have and we have taken as more than or equal to the time of concentration and average degree of imperviousness. It also depends upon shape of drainage area, a fan shape, rectangular shape or circular shape.

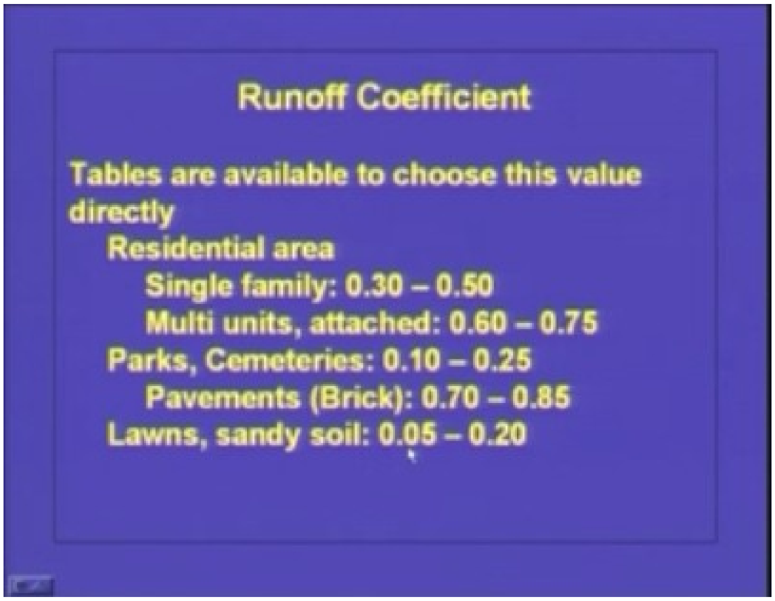
(Refer Slide Time: 19:40)



The standard tables are available for picking up the value of C based on these three factors. We can also pick the value of runoff coefficient from tables directly instead of worrying about what is the imperviousness factor, what is the duration of the storm etc, this also we have done many times if you want to make quick calculations or if you don't have much information available to us.

For example, residential areas where single family units are there the runoff coefficient is 0.3 – 0.5. If you have multi units with attached in residential areas then it is 0.6 – 0.75. For parks and cemeteries the runoff coefficient is 0.1 – 0.25. For pavements which are made of brick they are 0.7 – 0.85, for lawns and sandy soils the percolation or the infiltration loss will be lot more so the runoff coefficient will be very low which is from 0.05 – 0.2.

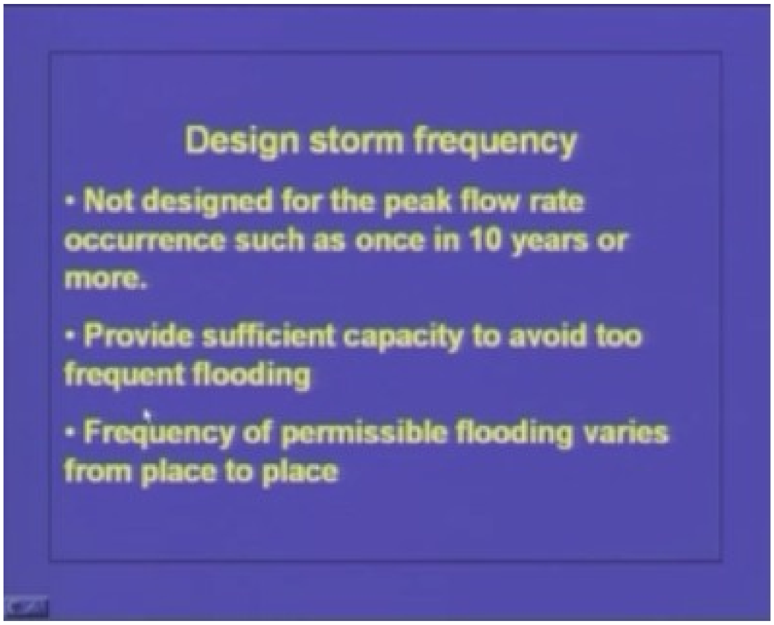
(Refer Slide Time: 20:35)



The next important step in the estimation of design Q is the estimation of design storm frequency. Typically the storm sewers are not designed for the peak flow rate occurrence such as once in ten years or more, such a design would result in over design because the storms are occurring only once in ten years. Not only that but if we want to treat this water or if you want to pump this water then those pumping stations and treatment stations will be designed for very high value of Q and that will result in high cost. So we do not design the storm sewer systems for peak flow rates of occurrence such as once in ten years or more.

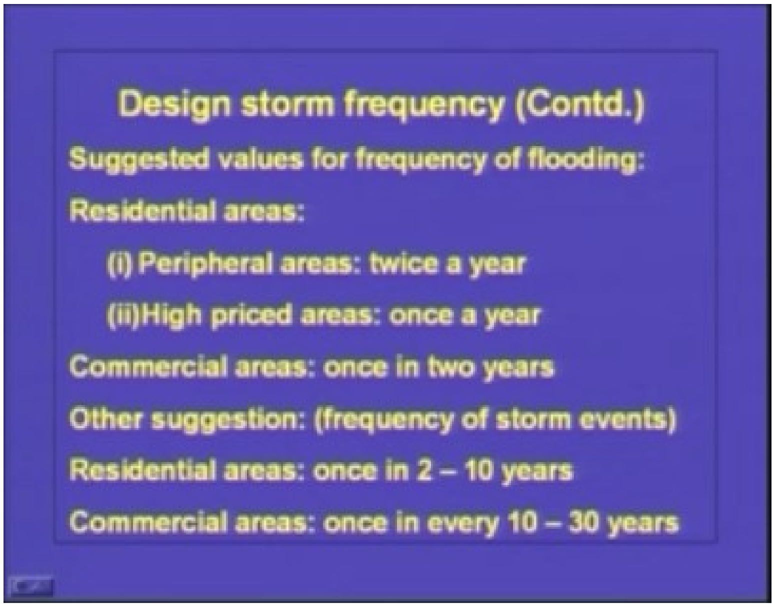
But at the same time we have to provide sufficient capacity to avoid too frequent flooding. If our system is not designed adequately to carry the water that is coming from more frequently occurring storms and if the sizes of storm sewers are chosen to be very small then the frequency of flooding will increase. So the design of these storm sewerage systems should typically depend upon what kind of storm frequency we take for the design.

(Refer Slide Time: 22:30)



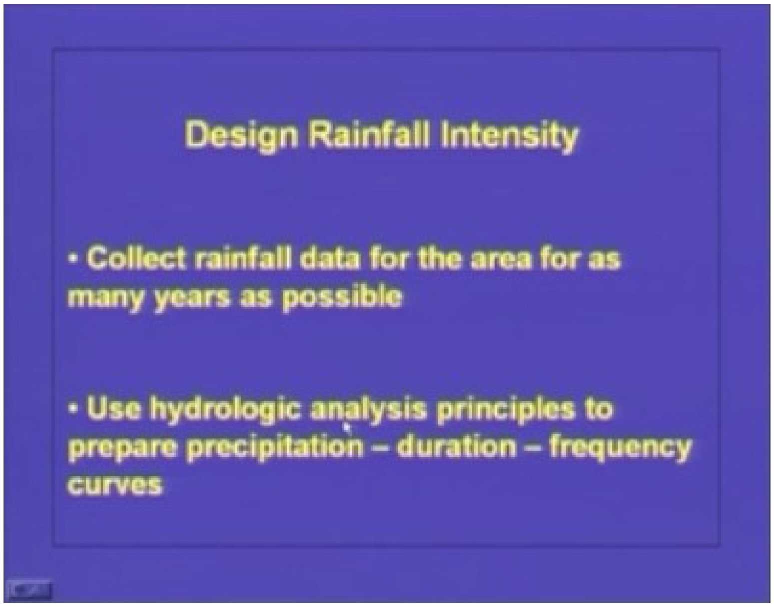
Frequency of permissible flooding varies from place to place depending upon the importance of the activity in that area. Typically the suggested values for frequency of flooding in residential areas or peripheral areas are twice a year. That means in the residential areas which are kind of suburbs we would allow flooding twice a year, we would design our storm sewerage systems in such a way that we won't say that it has failed the flooding is only twice a year. Whereas in high priced areas out storm sewerage system should be designed in such a manner that the flooding should not be more than once a year. Whereas in commercial areas where flooding can affect the activity or will result in loss of income we would not allow flooding more than once in two years. Instead of going for frequency of flooding as a parameter in the design we can also go for frequency of storm events as a parameter in the design. This is in an easier manner in which we can do the design.

(Refer Slide Time: 23:45)



There are guidelines available for frequency of storm events or the design storm which should be considered in the design of storm sewerage system. For residential areas we consider the design rainfall such that the probability of occurrence of this design rainfall is once in 2 – 10 years. So we can choose anywhere between two to ten years as a recurrence interval for our design storm whereas in commercial areas we take the design storm recurrence interval as once in every 10 – 30 years. That means the probability of occurrence of that rainfall is once in 10 – 30 years that kind of a storm will have very high magnitude, very high rainfall depth or rainfall intensity. So, if we design for that storm which is going to occur once in ten to thirty years then we will have adequate capacity in the storm sewerage system.

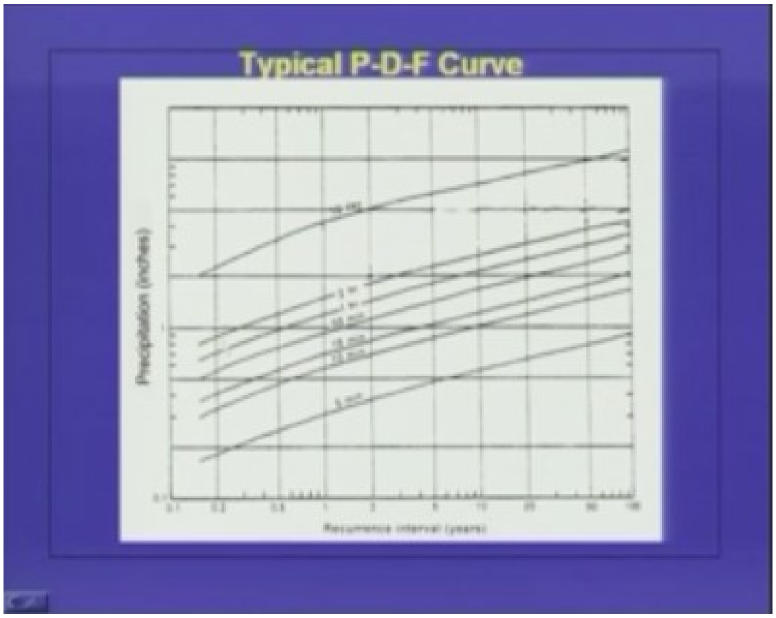
(Refer Slide Time: 25:25)



Design Rainfall Intensity:
How do we estimate the design rainfall intensity?
First we have to collect rainfall data for the area for as many years as possible.
Particularly for urban areas this rainfall data is typically available for the previous thirty to fifty years, we construct rainfall data for that area then we use hydrologic analysis principles to prepare precipitation duration frequency curves.

What are these precipitation duration frequency curves and how do they look?
Here I give a typical precipitation duration frequency curve. Here in the x axis you have recurrence interval. The recurrence interval is the inverse of the frequency or when we say the storm probability is once in ten years that means the recurrence interval is ten years or if the storm is occurring once in thirty years that means the recurrence interval is thirty years.

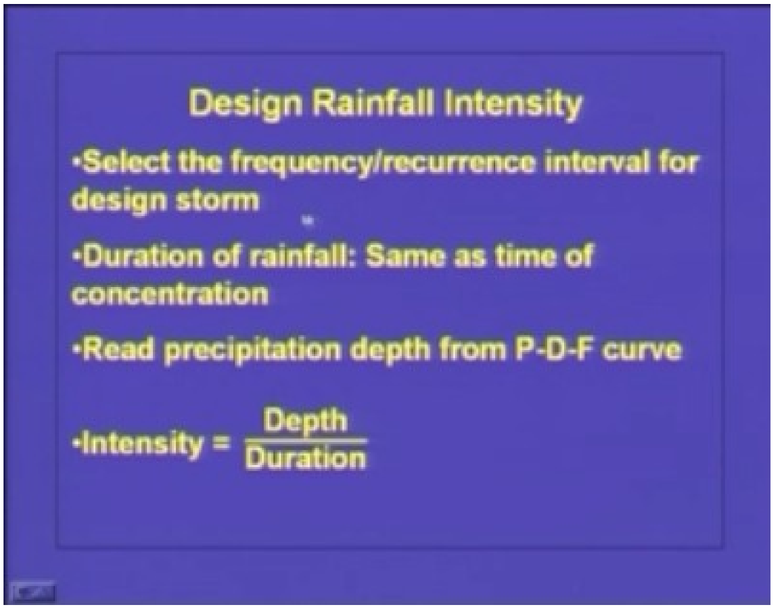
(Refer Slide Time: 26:20)



On the y axis you have the precipitation. Here in this particular figure the units are used as inches but in India we use the units in mm so we have the precipitation depth on the y axis and these curves are the precipitation duration frequency curve. the five minutes that is shown on this curve indicates that the probability of occurrence, let's say I take this point here (Refer Slide Time: 26:35) which says that the probability of occurrence of this storm is once a year and the storm duration is five minutes and corresponding to that we get a precipitation in inches about 0.225. So this figure can be used to estimate the intensity of the storm. How do we do that?

We first select the frequency or the recurrence interval for design storm. As I mentioned we can take this recurrence interval anywhere between 2 – 10 years for residential areas or ten to thirty years for commercial areas so you choose the frequency of the recurrence interval first. Next we estimate the duration of rainfall. The duration of rainfall we take in our design calculations is same as time of concentration.

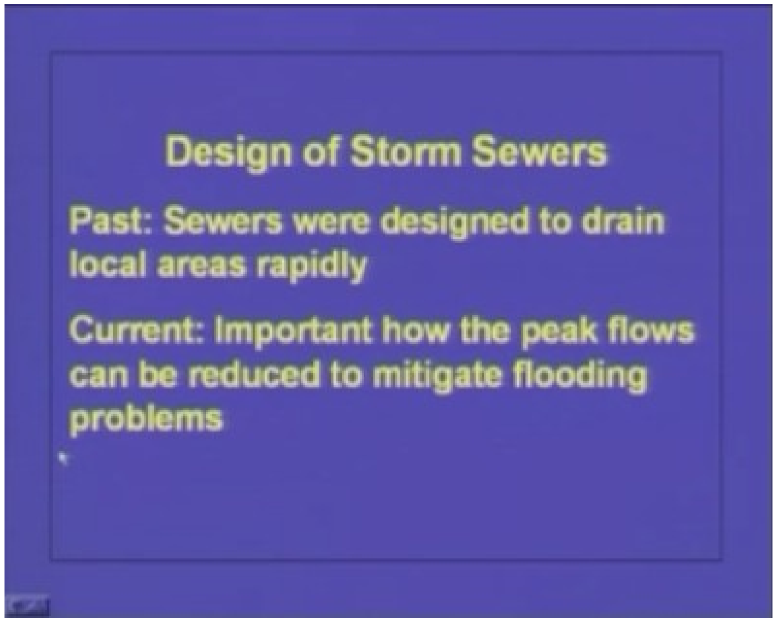
(Refer Slide Time: 27:40)



We have seen how to estimate the time of concentration which is equal to the inlet time plus the travel time in the system. Then we go to this figure. We know the recurrence interval let us say two years and let's say our time of concentration is one hour then the duration of rainfall is taken as one hour so two and I go here to one hour and from that I read off the value for the precipitation depth or the precipitation which is almost equal to 1.4 inches.

Once I have the precipitation I also know the duration of the storm which is one hour so the intensity would come out to be 1.5 inches per hour. This is the I value I would use in my rational method. As I mentioned in intensity is equal to depth that I read from the figure divided by the duration. Next we see what goes in the design of storm sewers, what is the underlying concept for the design of storm sewers.

(Refer Slide Time: 29:40)

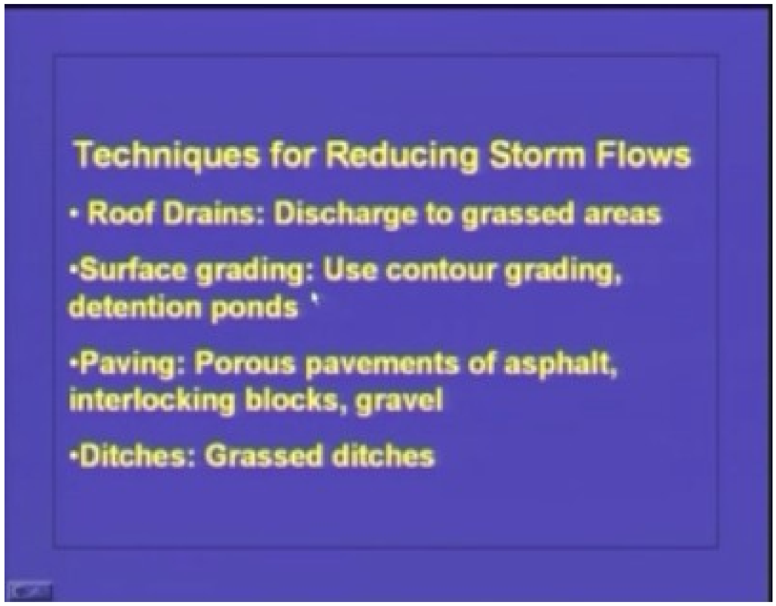


In the past sewers were designed to drain local areas rapidly. Now that kind of a concept is not used in design these days. Currently it is important in our design to consider how the peak flows can be reduced to mitigate flooding problems. So an overall picture has to be taken into consideration. That means we need to design our system in such a way that the peak flow rate is somehow reduced so that there is not much of stress on the receiving water bodies or the downstream flooding is reduced. If the peak flow discharge is reduced through our design then the downstream areas will not get flooded more frequently as well as my receiving water body will be able to carry this amount of water without any flooding.

Techniques for reducing storm flows:
What are the different techniques for reducing the storm flows?
First we consider the roof drains. The water from the roof drains don’t take it and then leave it on the paved surfaces. Because if you leave it on the paved surfaces then it will go into the storm sewerage system very quickly and the time of concentration will be very low or all the areas will be contributing simultaneously to the flow in the storm sewers and the peak flow will be very high so we want to slow it down. How do we do that? We take the rain water from the roof drains and first discharge it to the grassed areas. So it will flow over the grassed areas before it goes into the storm sewers.

Surface Grading: We use contour grading so that the slope is not very high and the water finds its way to the storm sewers in a more natural manner. We can also slow down the movement of water to the storm sewerage system from the adjoining areas by having detention ponds. Each detention pond is like a mini flood control reservoir. Water first comes into the detention pond it gets detained there it sits there for some time before it goes into the storm sewerage system. So this also is used for reducing storm flows.

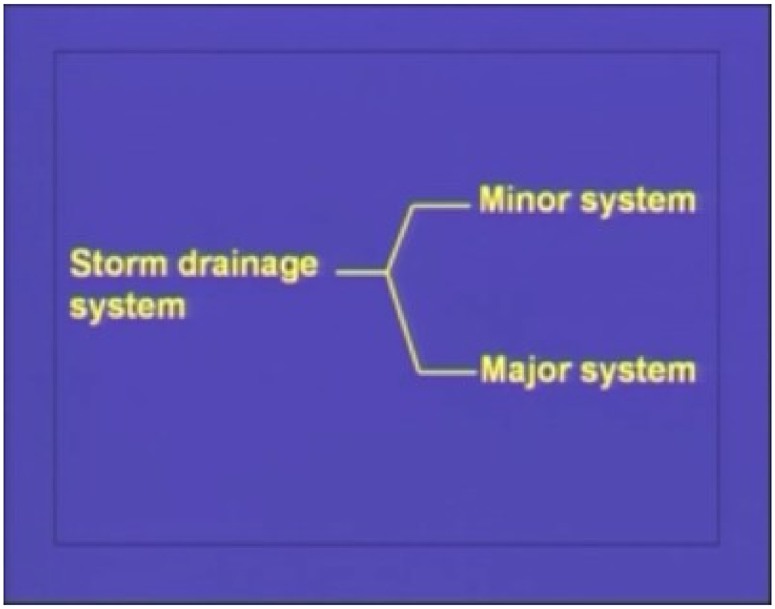
(Refer Slide Time: 30:50)



Paving: choosing of the paving material is very important in reducing the storm flows. When we are allowing the development to take place we make sure that pavements are made of porous materials like asphalt or interlocking blocks or gravel. If you have a porous material like gravel and when the rain falls on that, as it flows there is lot of infiltration that is going to take place and the amount of water that gets into the storm sewers is going to be less because more of water would have gone into the ground to reach the ground water table.

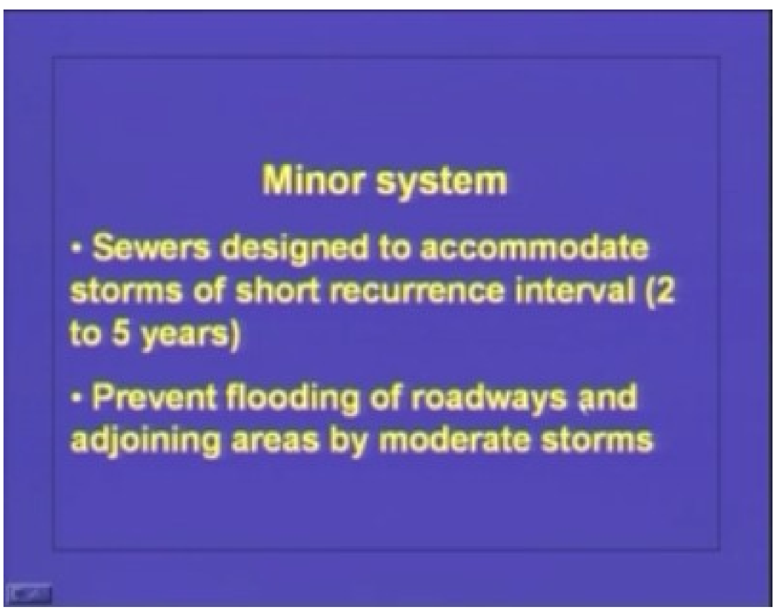
The other important consideration is the design of ditches. If you use grassed ditches as compared to the concrete ditches or other paved ditches then certainly the roughness will be very high for the grassed ditches and that is going to slow down the movement of water. Similarly through the grassed ditches there will be more percolation so that also will reduce the amount of storm flow. Therefore, if we follow these guidelines and then do the development of that area then the capacity for which the storm sewerage system should be designed will be low. That means the value of Q will be low and the storm sewerage system can adequately drain off the area in a proper manner.

(Refer Slide Time: 33:00)



The storm drainage system is made up of two components. In fact there is a minor system and there is a major system.
What is a minor system?
Sewers designed to accommodate storms of short recurrence interval of 2 – 5 years is called a minor system.

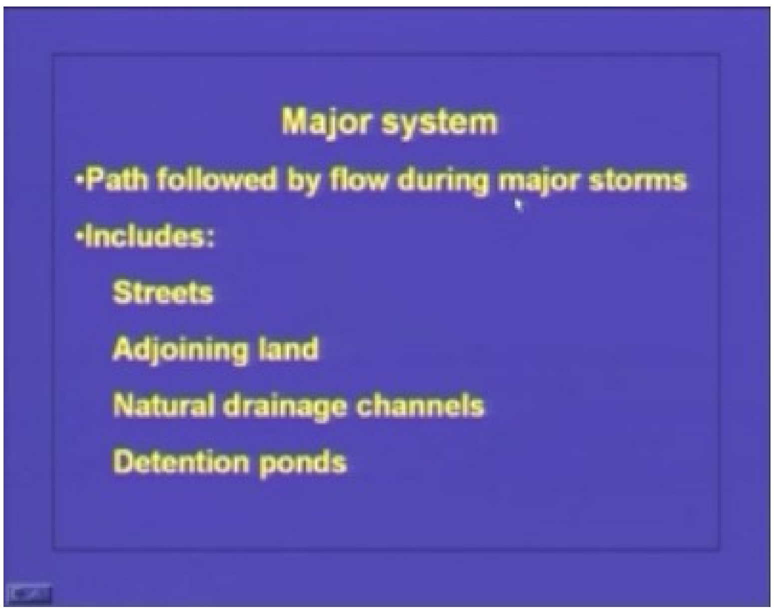
(Refer Slide Time: 33:20)



The purpose of the minor system is to prevent flooding of roadways and adjoining areas by moderate storms. That is once in w years or once in 3 years kind of a storm is occurring in that area and the minor system should be designed in such a way that for that kind of a storm should prevent flooding of roadways and adjoining areas. The major system is defined as the path followed by flow during major storms. Here the major storms are the storms which are not considered in the design of minor system.

Let us say I have considered three years as the recurrence interval for the design storm in the design of minor system. So any storm which has a recurrence interval for more than 3 years or any storm which has a probability of occurrence of once in 10 years is called a major storm. Certainly the minor system will not be able to carry all the storm water which is coming when a major storm occurs so the water is going to flood the adjoining areas and water is going to flow in the streets and adjoining lands. So the major system includes the streets, adjoining lands and natural drainage channels.

(Refer Slide Time: 35:00)

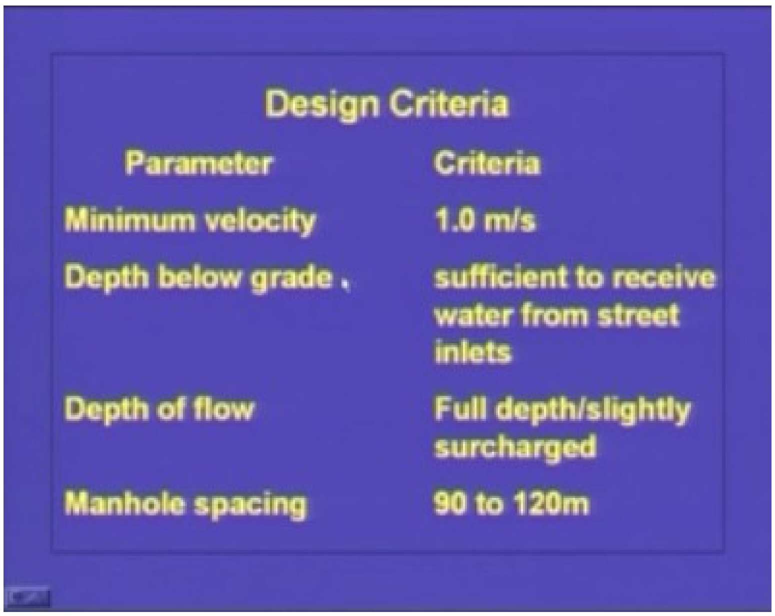


When we are doing the development we may not spoil the natural drainage system but we may leave it there in its place. So in such cases these natural drainage channels also can be used for draining of the areas when a major storm occurs. Similarly when a major storm occurs to reduce the peak flow we can use the detention ponds. That way major system includes the proper design of streets for the drainage, the landscaping of the adjoining land, how we retain the natural drainage channels and how many detention ponds and what is the size of the ponds we are going to put so all these things in an integrated manner should be considered in the design of major system.

I want to mention one thing here. For the design of major system the estimation of the peak flow rates we should not consider or we should not use the rational method. The rational method is based on the concept of steady uniform flow but in actuality the flow in a sewerage system or the storm sewerage system is always an unsteady non uniform flow. Although we are making this assumption the errors introduced as far as the design is concerned is not very much when we are designing a minor system. But the errors introduced if you use a rational method for estimating peak flows for the design of a major system will be very very high so the major system have to be designed using what we call model based techniques. The model based techniques for the design of major systems consider the complete unsteady non uniform flow situation.

What is the design criteria when we are designing a storm sewerage system?
Here I have given parameters and correspondingly the criteria.

(Refer Slide Time: 37:30)



The minimum velocity in a storm sewerage system should be one meter per second. This is to ensure self cleansing.

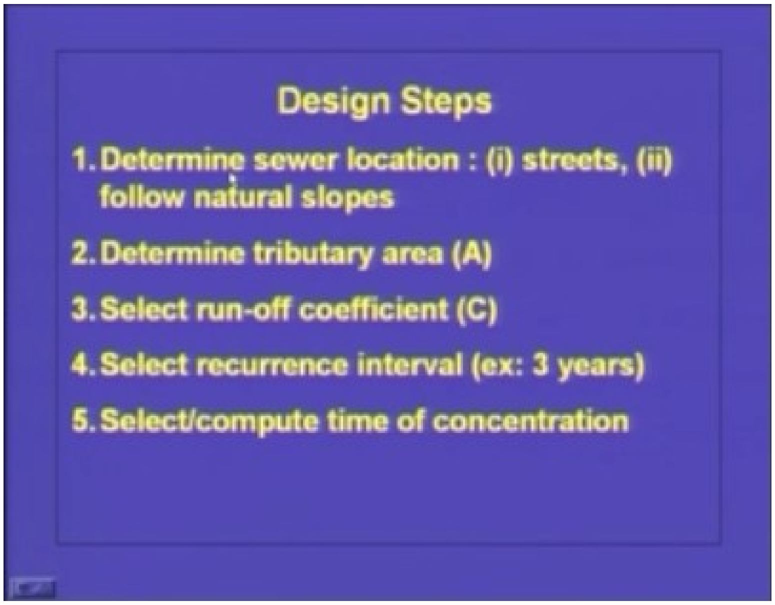
Depth below grade: as opposed to or as compared to sanitary sewerage system the depth below the grade for a storm sewerage system should be just sufficient to receive water from street inlets. We have street inlets from which water gets carried to the storm sewerage system. So the storm sewerage should be just below the ground such that it receives water from the street inlets without any problem. If we have any more depth than this then the construction cost or the laying cost will be very high whereas in sanitary sewerage systems the depth below the grade is much larger. The sanitary sewers are buried much deeper into the ground so that they can get water even from the basements of the buildings.

Depth of flow: Here in a storm sewerage system we allow full depth of flow and in fact sometimes we design slight surcharging, slight surcharging means the storm sewer will be completely full of water and will be flowing under pressure, so slight surcharging is also allowed many times in the design of storm sewerage system so that the size of the sewer can be smaller and then we get a better economy.
This is not done while designing a sanitary sewer. While designing a sanitary sewer we

have to design in such a way that there is some amount of space between the water surface and the top of the sewer. This is to accommodate the gases that are being released from a sanitary sewer. That kind of a problem doesn't arise in the design of storm sewers so we allow full depths to occur and sometimes even in the slightly surcharged conditions.

The other important criteria for the design is the manhole spacing. Here it is given as 90 – 120 m. If we have the mechanized cleaning of the storm sewers or if the better maintenance facility is available for the manholes then we can go for 90 – 120 m spacing of the manholes otherwise the manhole spacing should be much shorter than this. Probably we go for about 30 m for the manhole spacing if the sewers are cleaned manually.

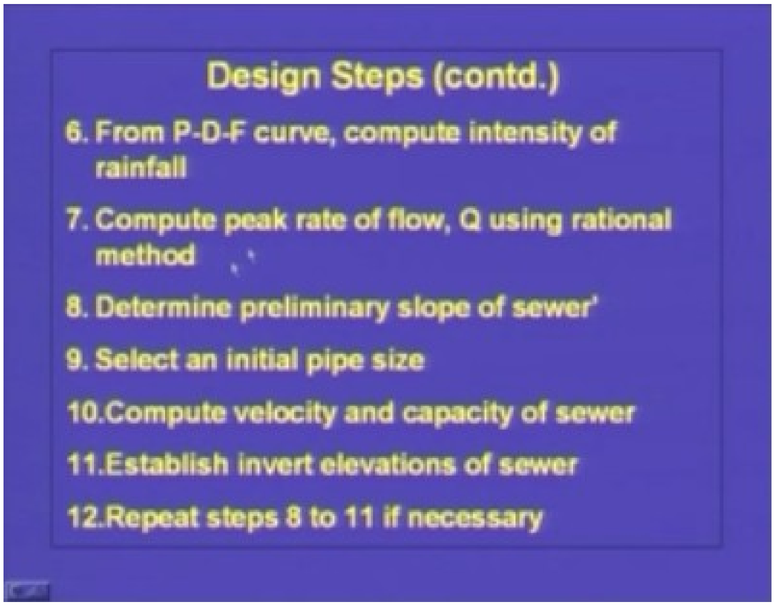
(Refer Slide Time: 39:45)



What are the design steps?
The design steps include the determination of sewer location. Sewers are typically located underneath the streets or underneath the pavements and they follow the natural slopes. So if we have a map like this (Refer Slide Time: 39:56) then from the local map the road map following the streets we can come up with a layout for the sewers. This is the first step. Next we compute the peak rate of flow Q using rational method. This we have discussed in detail earlier.

(Refer Slide Time: 40:10)

(Refer Slide Time: ...)

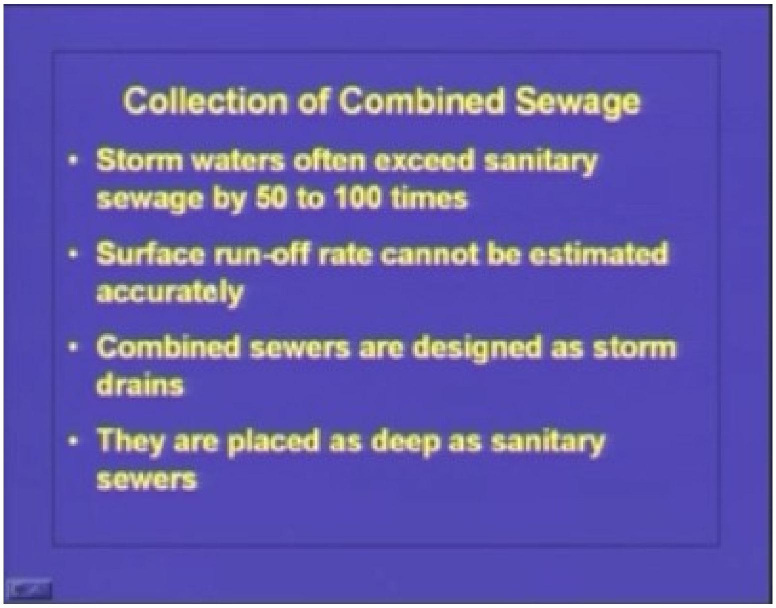


After computing the Q for each location in the storm sewerage system we have to determine the preliminary slope of the sewer. Typically the slope of the sewer is taken as the ground slope to start with, to start the design calculations then we select an initial pipe size. Earlier experience in the design will help in the selection of the initial pipe size. After selecting the size we know the diameter of the sewer the storm sewer, we know the slope, we know the discharge so what we do is from the slope and the size of the sewer we assume that this sewer is going to flow full but under free surface conditions.

We use Manning's equation to determine the capacity of sewer. We have looked at the Manning's equation in the previous lecture on design of sanitary sewerage systems. So using the Manning's equation we estimate the capacity of sewer and we also get the velocity and this capacity of the sewer should be greater than whatever is the design peak rate of flow.

For the actual rate of flow we can also estimate what is the velocity that is going to come in. After this step establish inverse elevations of the sewer because we know what is the slope of the sewer and we have the guidelines on what should be the depth of burial, we can get invert elevations for each of the sewers. After this we repeat steps 8 to 11 if necessary. That means if the capacity of the sewer is less than what is the design peak rate of flow or if the velocity in the sewer is less than what is the minimum velocity that is required or if the slope that is provided is excessive or very flat then we repeat the steps 8 to 11 so that our design comes out properly and economically.

(Refer Slide Time: 43:25)



Now we talk about collection of combined sewage.

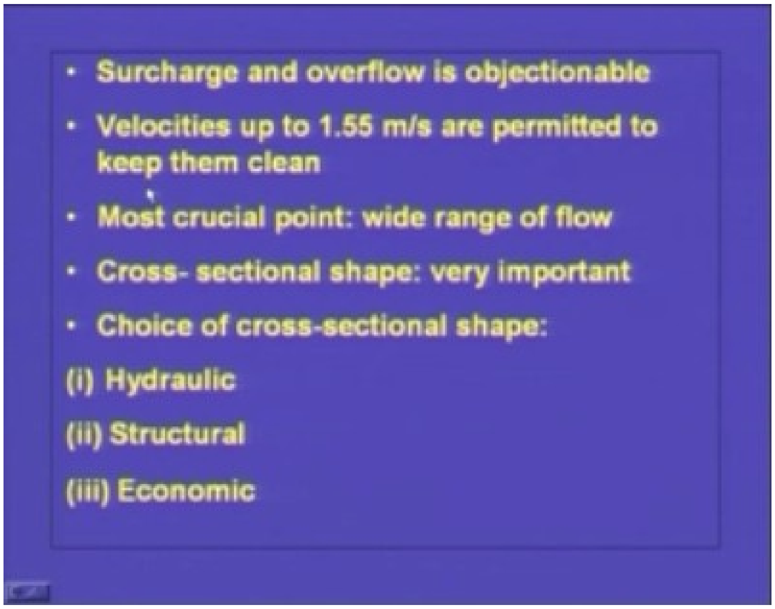
The storm water in a combined sewerage system often exceeds sanitary sewage by fifty to hundred times. This is an important consideration in the design of a combined sewerage system. Not only that it is obvious that surface run-off rate cannot be estimated very accurately whether for storm sewerage system or combined sewerage system as compared to the estimation of sanitary sewage for the design of a sanitary sewage system. That can be done more precisely as compared to the estimation of surface run-off rate.

We also design combined sewers as storm drains because the combined sewers have to carry the storm water as well as sanitary sewage. And as I mentioned the sanitary sewage or the storm water is fifty to hundred times the sanitary sewage
so we design the combined sewers as storm drains.

However, because they are also carrying the sanitary sewage they should be able to collect this sanitary sewage from the buildings so they should be buried much deeper compared to the storm drains so they are placed as deep as sanitary sewers that is an important point.

In a storm sewer or a storm drain we allow surcharge and overflow that will not give rise to any safety problems whereas in a combined sewerage system because they are carrying the sanitary sewage the surcharge is not allowed. Also the overflow is objectionable. A storm sewer which is designed for a written period or a storm of one in 10 years but if a storm of one in 20 years occurs then we will be allowing some amount of overflow. However, when we design a combined sewerage system we cannot go with that kind of a philosophy because under no circumstance the overflow is allowed if it is carrying a sanitary sewage because that is going to give rise to the health problems or the health risk will be very high. Also the velocities up to 1.55 m per second should be allowed in these combined sewers so that they are kept clean.

(Refer Slide Time: 45:35)



The other most crucial point in the design of combined sewers is the wide range of flow. During the rainy season the flow that is to be carried by the rains will be much higher compared to the non rainy season, this has to be kept in mind. Because of this point because of the wide variation in the range of flow we need to have self cleansing velocities even when the flow is not very high that is even when the storm is not occurring and only sanitary sewage is being carried so even then we need to have a minimum velocity or minimum self cleansing velocity. Because of this requirement the cross sectional shape that we choose is going to be very important.

The choice of cross sectional shape depends upon hydraulic parameters, the structural strength that particular shape can have and economic considerations. For example, we take this egg shape or the oval shape; it is made of two circles here like a large circle here and a smaller circle here. this is meant for carrying the flows when there is no rain (Refer Slide Time: 47:00) so it is meant for carrying sanitary sewage whereas the flow would be occurring in this portion when it is carrying both sanitary sewage and the storm sewage so the quantity of the storm sewage is normally very high so we need to have higher capacity that is why we have chosen a shape like this.

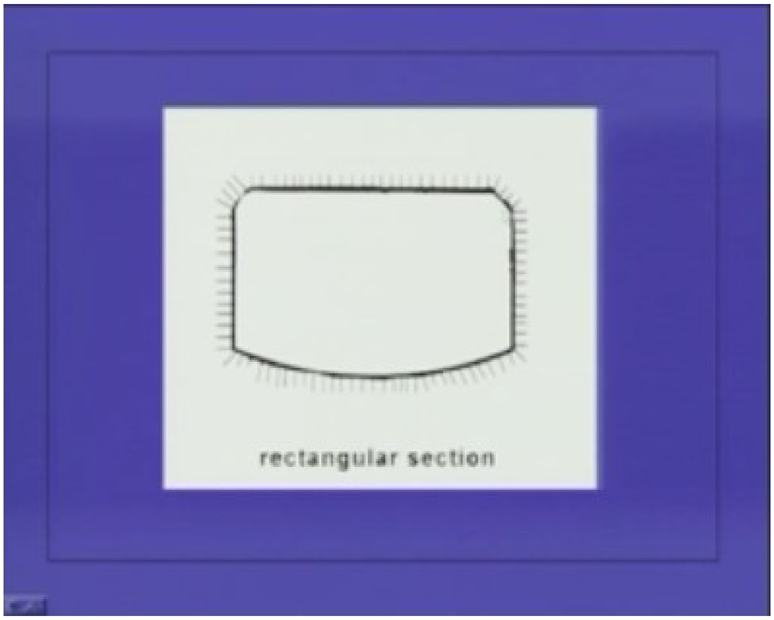
(Refer Slide Time: 47:10)

When it is carrying only the sanitary sewage then the width is less here and the velocity will be very high. In fact this particular shape if you look at the hydraulic radius for this shape is more or less equal whatever is the depth of flow. If the hydraulic radius is same and the same slope is there for whatever is the depth the velocities will be more or less same. So whatever be the depth of the self cleansing velocities are maintained in this shape. But the problem with the shape is the structural strength. It is not very good as far as the load carrying capacity is concerned.

(Refer Slide Time: 48:40)

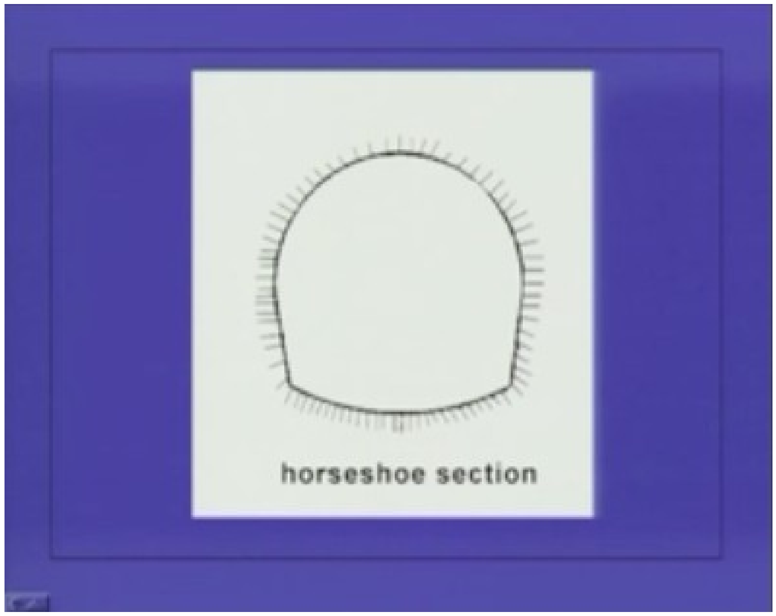
This is a semicircular section with a cunette. This is what we call a cunette. It is obvious that when only sanitary sewage is being carried then the depths of flow will be very less and the width here is less so naturally the velocities will be very high and we will be able to maintain the self cleansing velocity even when only sanitary sewage is being carried. Whereas when the combined sewage is being carried we need to have more capacity and we have a larger width here or a semicircular shape here.

(Refer Slide Time: 49:25)



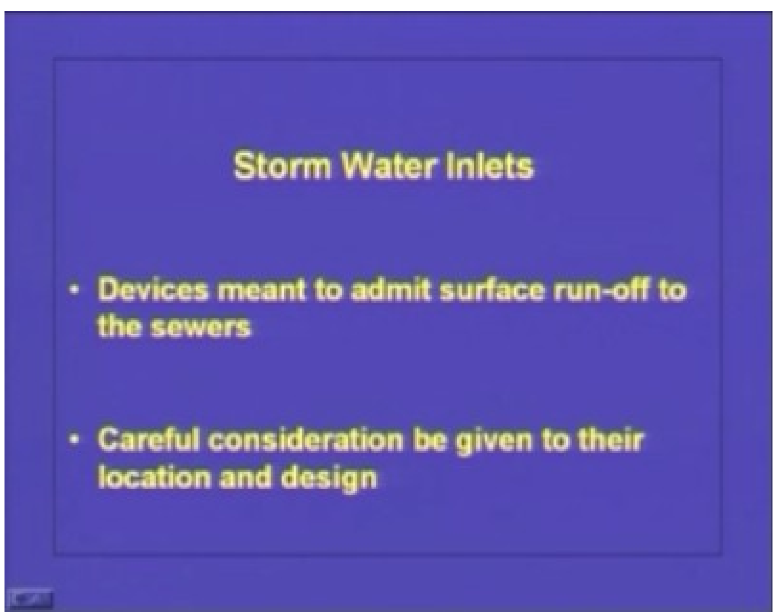
A rectangular section is sometimes adopted this is because for economic reasons. The trenching cost will be much less here in a rectangular section. Not only that but I need to provide head room when I am carrying the combined sewage. Above the water surface level and the crown of this thing the head room that needs to be provided will not be very high because I have enough width here. Of course as I said the main consideration in choosing a rectangular section is the economy.

(Refer Slide Time: 49:35)



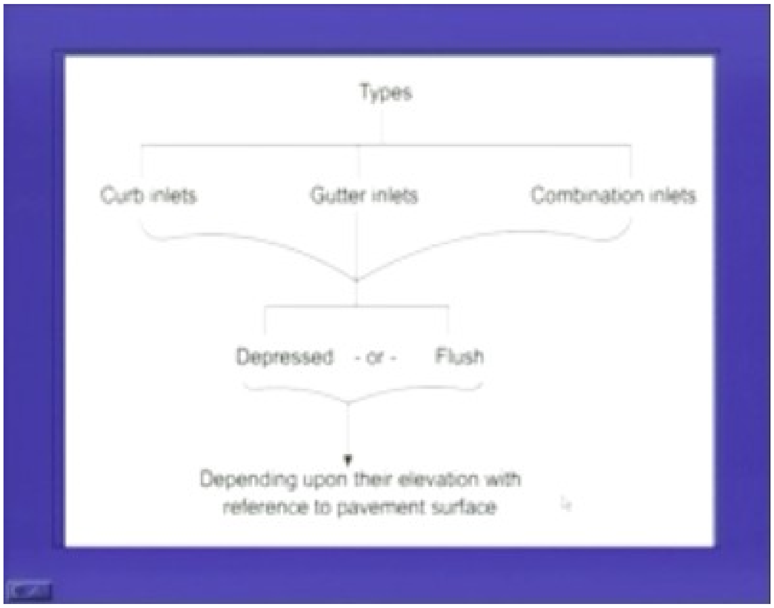
Many times horse shoe sections are adopted for designing storm sewerage systems. A horse section has very good structural strength. Of course because the width is very high even when the depth of the flow is small this may not be as good for carrying a combined sewage. The next important aspect in the design of a storm sewerage system is the storm water inlets. The storm water inlets are the devices meant to admit surface run-off to the sewers. We have to give careful consideration to their design, to the placement of these storm water inlets.

(Refer Slide Time: 50:00)



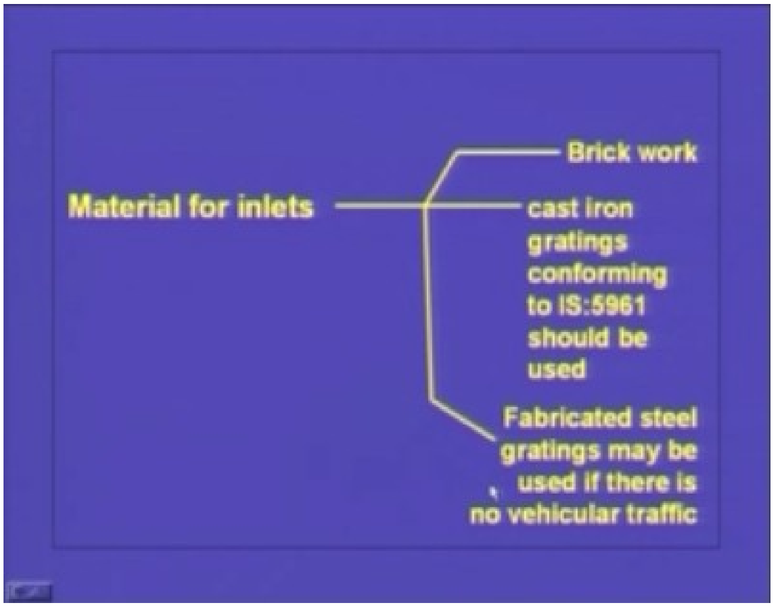
However good our design of storm drains is and because these inlets are the entry points for the storm water into the drainage system if they are not designed properly then the flooding is going to occur. So a careful consideration should be given to their location and design. There are different types of these storm water inlets. For example, curb inlets, gutter inlets and combination inlets. All there of them can be either depressed or flushed.

(Refer Slide Time: 50:45)



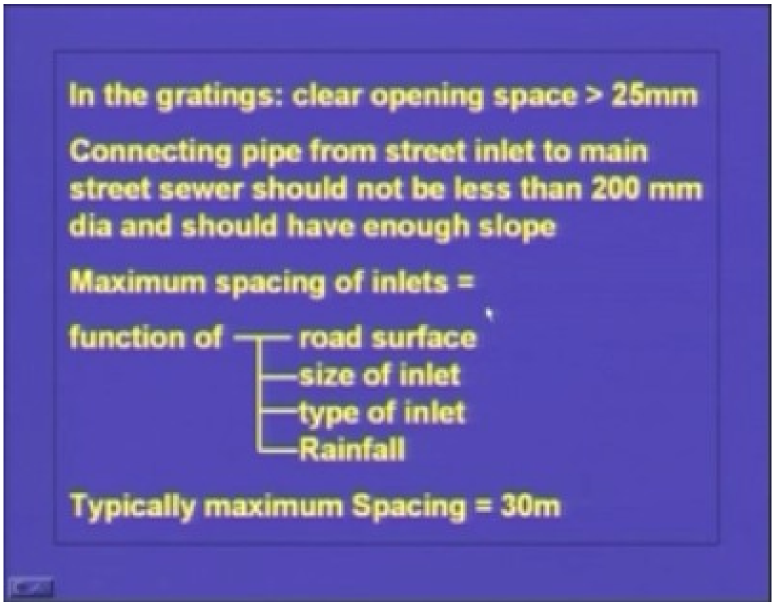
Now, depending upon their elevation with respect to or with reference to the pavement surface the materials for inlets should be used as for the construction of these inlets. Sometimes we also use cast iron gratings conforming to IS: 5961 for the construction of inlets or fabricated steel gratings may also be used if there is no vehicular traffic.

(Refer Slide Time: 51:10)



In the gratings the clear opening space should be more than 25 mm and the connecting pipe from the street inlet to the main street sewer should not be less than 200 mm diameter and it should have enough slopes. If it is less than this then it will be getting choked more frequently. The maximum spacing of inlets is a function of the road surface, the size of the inlet, the type of the inlet and the rainfall. If the rainfall magnitude is very high then certainly you have to place these inlets at more frequent intervals. But of course if the size of the inlet is very large then we may not have to place them at closer intervals. All these are interrelated factors based on which the spacing of inlets is chosen. Typically maximum spacing is 30 m.

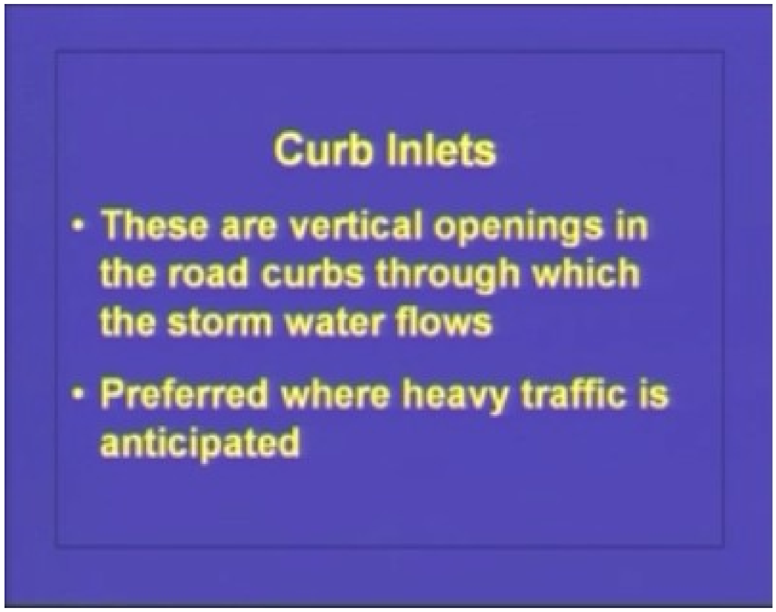
(Refer Slide Time: 52:15)



The street inlets are so placed and designed such that they can remove the flow in gutters with a minimum cost with minimum interference to the vehicular traffic as well as pedestrian traffic, they should not come in the way of the movement of people and the vehicles so the interference to the pedestrian and vehicular traffic is a important consideration in choosing what type of inlet that we want to have.

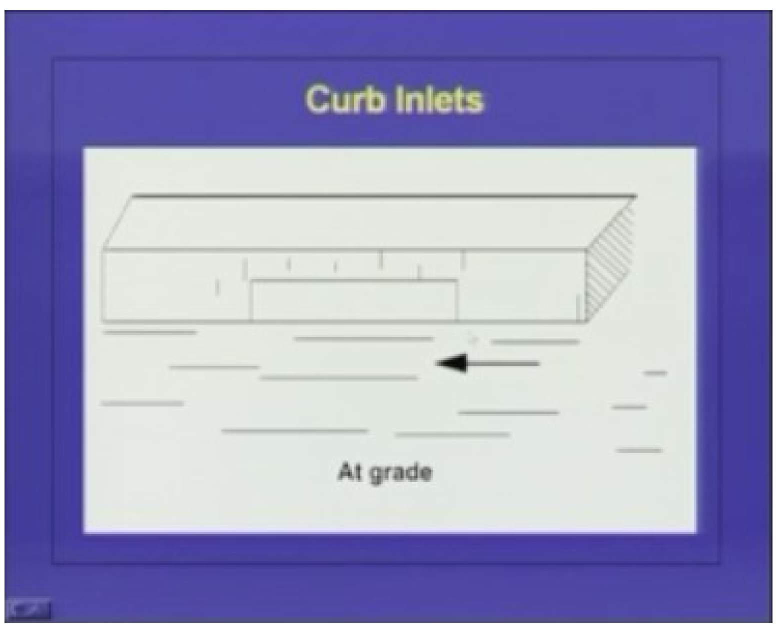
(Refer Slide Time: 53:00)

Certain inlets have better hydraulic capacity but they are costly. Certain other types will interfere traffic and we cannot choose them if the traffic is very high.
(Refer Slide Time: 53:25)



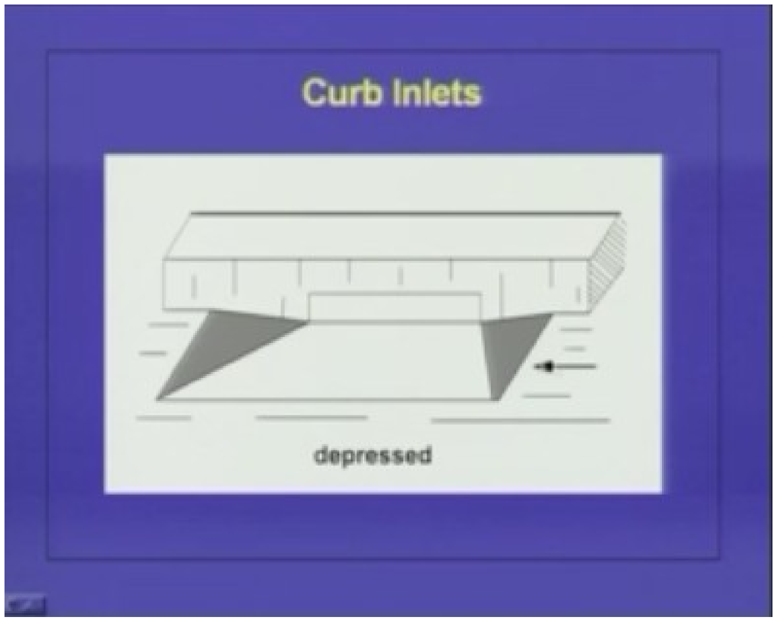
Curb inlets are vertical openings in the roads through which the storm water flows. These curb inlets are the ones which are preferred if the heavy vehicular traffic is anticipated. Look at this figure, these are the curb inlets.

(Refer Slide Time: 54:00)



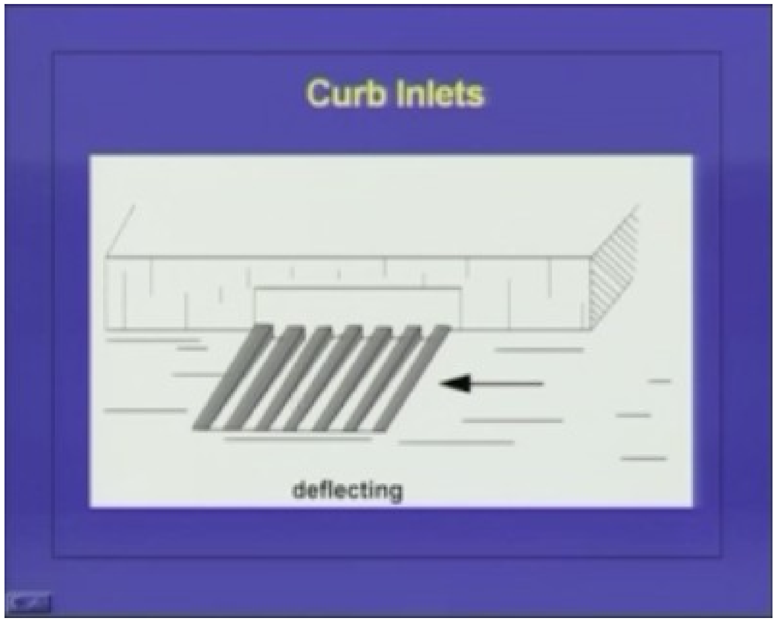
This is my road and between the road and the pavement is what we call the gutter that is slightly depressed from the elevation then we have this pavement. This is the curb (Refer Slide Time: 53:45). We make an opening in this curb so the rain water which is getting collected in the gutter will go through this curb into the storm water drain which is placed underneath this. This is what we call At grade curb inlet. We can also have a curb inlet which is not At grade. Look at this figure.

(Refer Slide Time: 54:30)



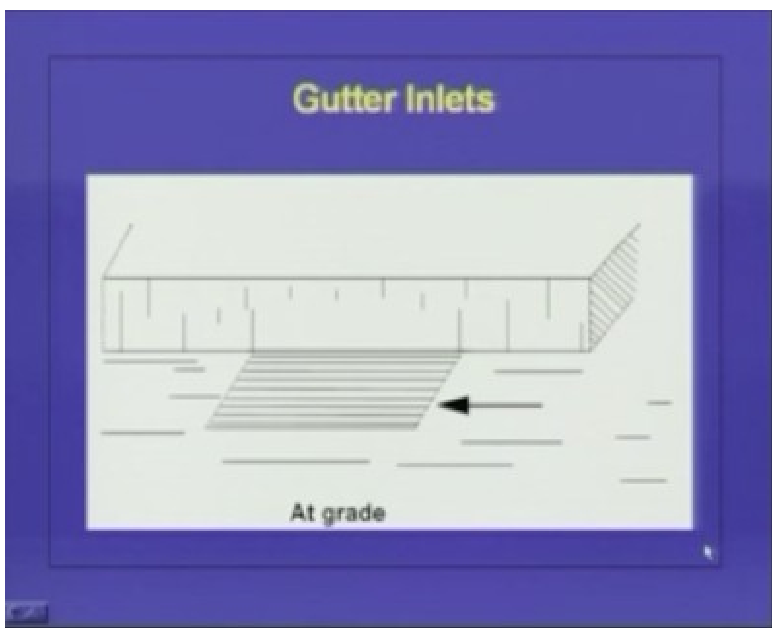
The curb inlet is depressed compared to what is the average elevation of this gutter so this is called a depressed. This kind of a depression allow better flow into the curb and the capacity of the curb inlet take the water and the rate of flow will be higher so that’s where we get this depressed. But if you have depressions like this then this may interfere with vehicular traffic. We may also have deflecting structures like this in the curb inlets which will guide the flow into the curbs so the capacity of the curb inlets get increased if you have a deflecting type of a curb inlet.

(Refer Slide Time: 54:47)



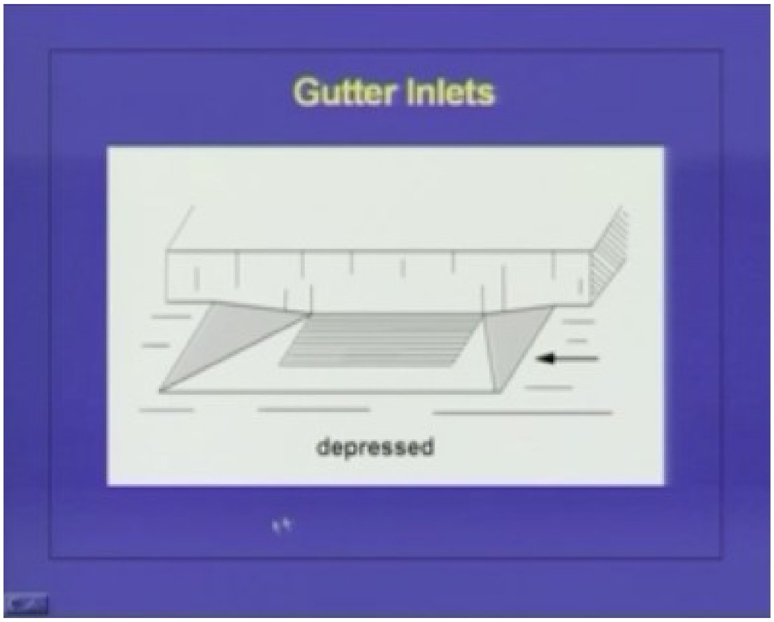
A gutter inlet is the one which is placed in the gutter itself, it is flushed with the gutter. These are the gratings or the bars (Refer Slide Time: 55:05) and this is the spacing I was talking earlier and the material that is going for the construction of these gutter inlets.

(Refer Slide Time: 55:10)

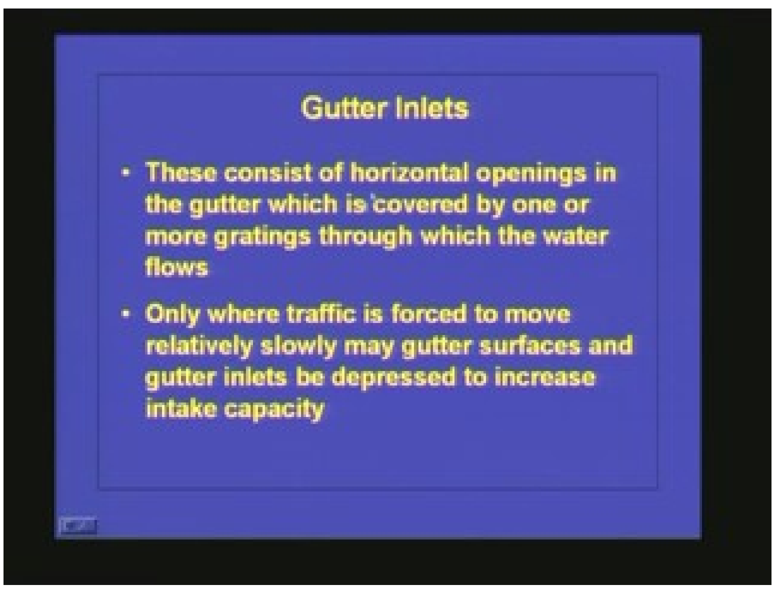


This is At grade gutter inlet, this is a depressed gutter inlet. It is the same gutter inlet but it is where we place this gutter inlet we put it slightly below the actual gutter elevation at that location.

(Refer Slide Time: 55:18)

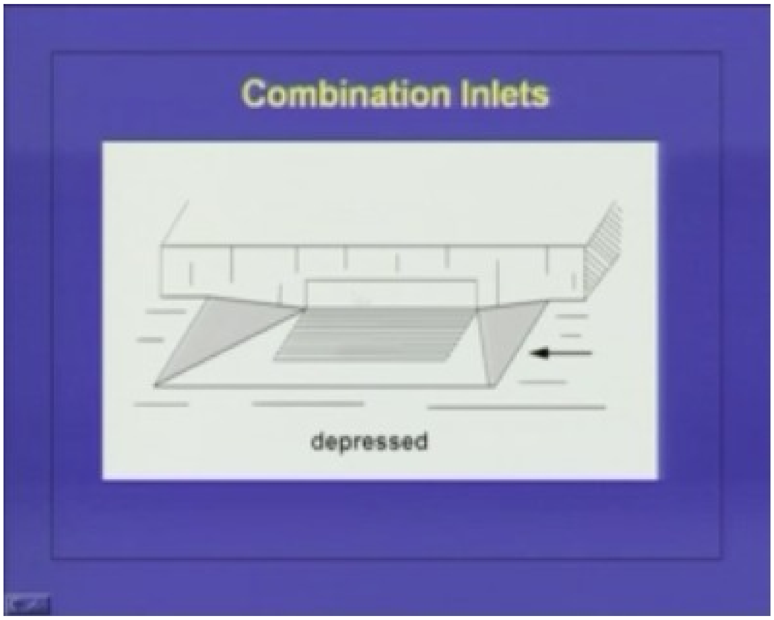


(Refer Slide Time: 55:30)

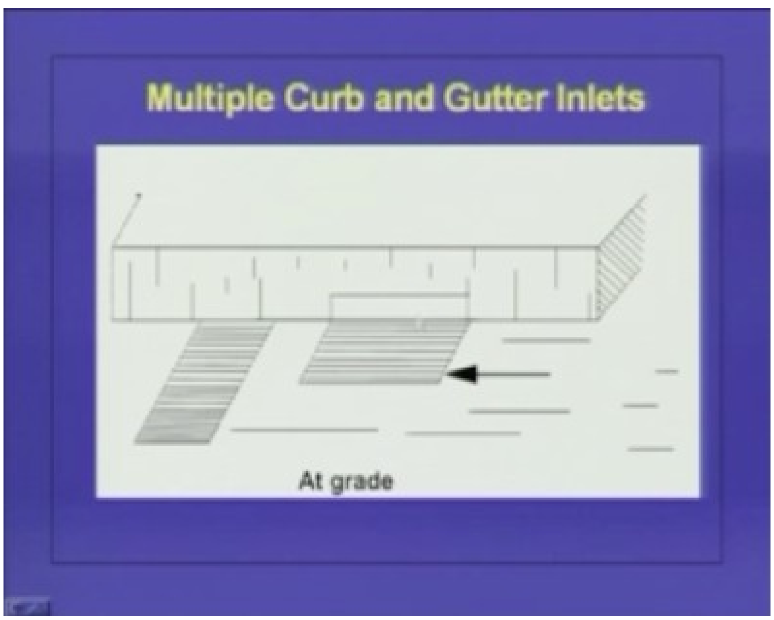


The gutter inlets consist of horizontal openings in the gutter which is covered by one or more gratings through which the water flows. These are used only where traffic is forced to move relatively slowly. We may also have combination inlets. This is a curb inlet which is being used along with a gutter inlet and it is depressed.

(Refer Slide Time: 56:00)



(Refer Slide Time: 56:15)

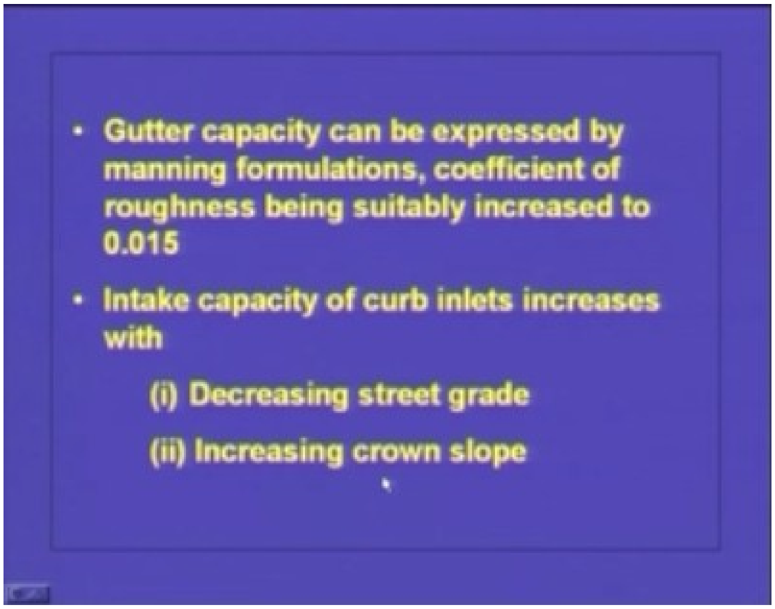


We can also use multiple curb and gutter inlets. This is At grade and this is a gutter inlet, this is also a gutter inlet placed somewhere in the downstream of this and these are curb inlets (Refer Slide Time: 56:13), and this is At grade.

The gutter capacity can be expressed by Manning's formulations. The amount of water that is flowing in the gutter can be estimated using the Manning's equation and the Manning's roughness coefficient we normally take is 0.015.

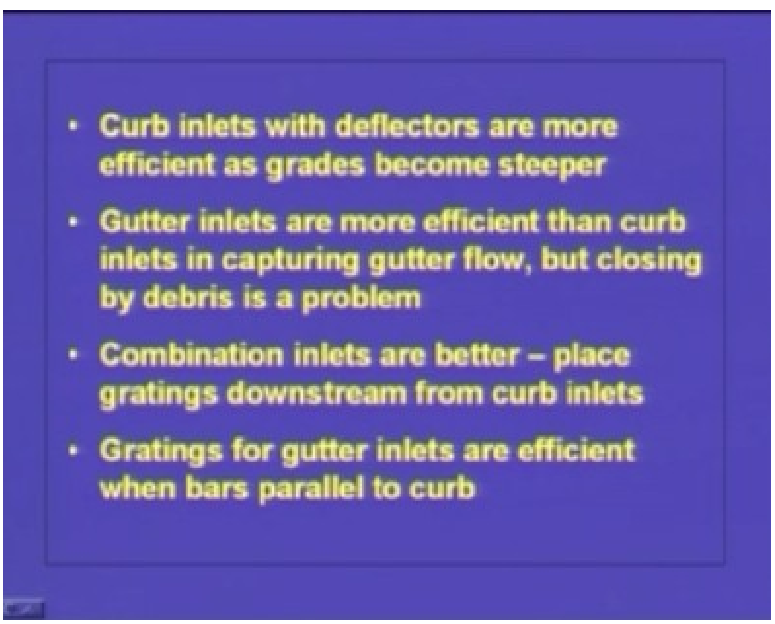
The intake capacity of curb inlets increases with decreasing the street grade or increasing the crown slope.

(Refer Slide Time: 56:50)



Curb inlets with deflectors are more efficient as grades become steeper. Gutter inlets are also more efficient than curb inlets but as it is obvious these inlets get close much more frequently that is a problem. Combination inlets are better. In combination inlets we place the gratings downstream from curb inlets.

(Refer Slide Time: 57:20)



Gratings for gutter inlets are efficient when bars are parallel to the curb. But sometimes we need crossed bars for strength purpose. These crossed bars should be placed below these parallel bars.

In this lecture we have seen the design of the storm drains or the design of storm sewerage system. We have discussed how to estimate what is the design flow rate. We also looked at what are the different steps we should follow for the design of these storm sewerage systems. We looked at the rational equation for estimation of Q. We also discussed the problems that are faced while designing a combined sewerage system. We looked at the different shapes that can be adopted while designing the storm drains and we looked at what are the different inlets or the different types of inlets we should provide or we can provide while designing these storm sewerage systems.

In the next class we will look at the design of pumping systems. The pumping is to be carried out many times in sanitary sewerage systems as well as storm drainage systems.