Water Supply Engineering
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Lecture-32
Rapid Sand Filter: Filter Media and Components

Welcome back friends, so continuing our discussion from the previous class when we are discussing about the filtration process and we did talk about the slow sand filters. So, in this particular class we will be talking about the rapid sand filters and more so ever the focus will be on the filter media and different components of a rapid sand filter.

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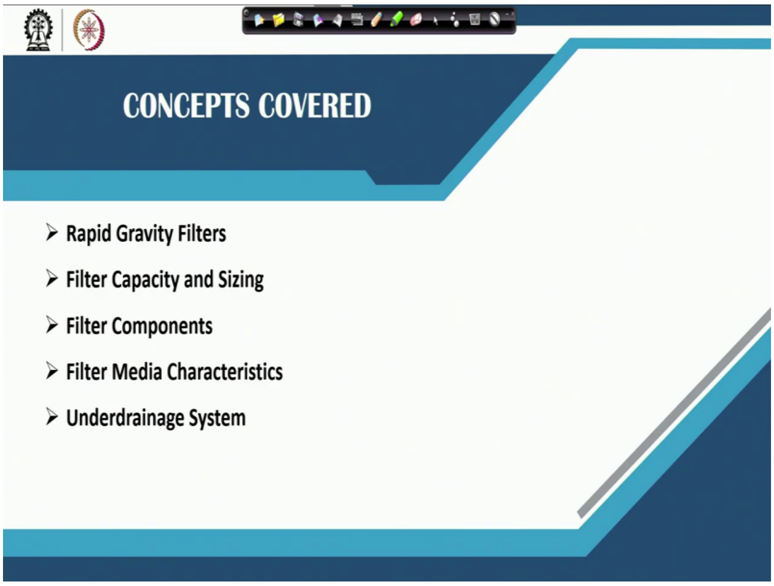

So, what we will be covering will be covering the basics of rapid gravity filter will be covering the filter capacity and sizing of the rapid gravity filters. What are the various filter components, what are the filter media materials and their characteristics, the under drainage system in the rapid sand filters. So, this is what will be talking in this particular class.

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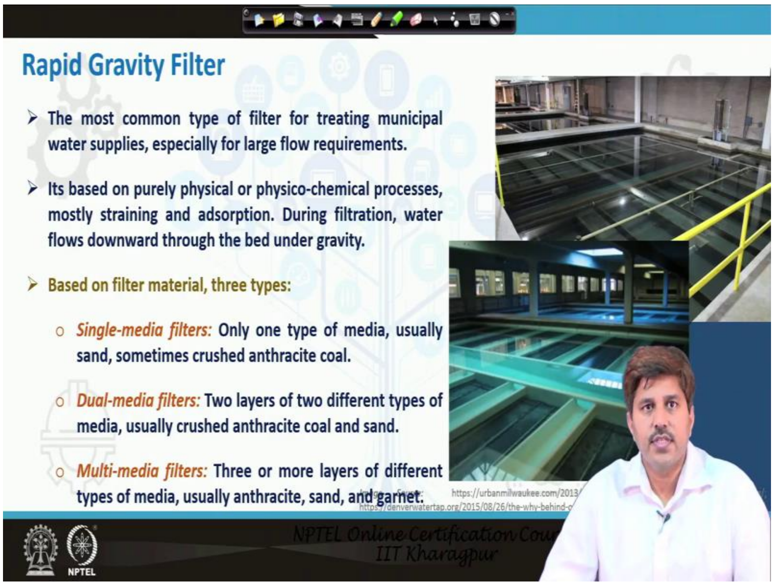

Now rapid gravity filters are the most common type of filter for treating municipal water supplies. Municipal water supply is generally target big flows and as just we discussed that the slow sand filters would not be appropriate because that will require huge amount of area so that goes off then what we are left with the pressure filter or rapid gravity filter. Pressure filters are quite costly and have other operational difficulties what we will be discussing in the next class.

That way the rapid gravity filters or rapid sand filters becomes the most preferred choice for the treatment of the large water supplies or municipal water supplies. The objective with which we go for a filtration unit we already have discussed that we want to remove the micro floc's. We want to remove the very fine sediment particles which has come off the clarification unit. So, that is what we target here as well.

Now it is based on the purely the rapid gravity filters our general based on the purely physical or physical chemical processes. Mostly straining and adsorption we do not get a biological activity in rapid gravity filters as we get in a slow sand filters because in order to develop a biologically active layer and act that act upon that layer needs larger time of operation whereas rapid gravity filters has much higher flow rate and it is usually back washed within a like one to two days period.

And that is why we do not get the development of any biologically active layer and as a result we do not get much of the biological activity. So, the major removal happens through these training and adsorption process. Now based on the filter material there are 3 types of rapid gravity filters the single media filtered dual media filter and multi media filter. So, of course single media will have only one type of media which could be mostly sand at times the crust anthracite coal is used. Dual media filters generally have both of these sand as well as anthracite and multi media filters will have sand anthracite and usually have granite as well.

There are other additional layers like activated charcoal and those kind of materials may also be included.

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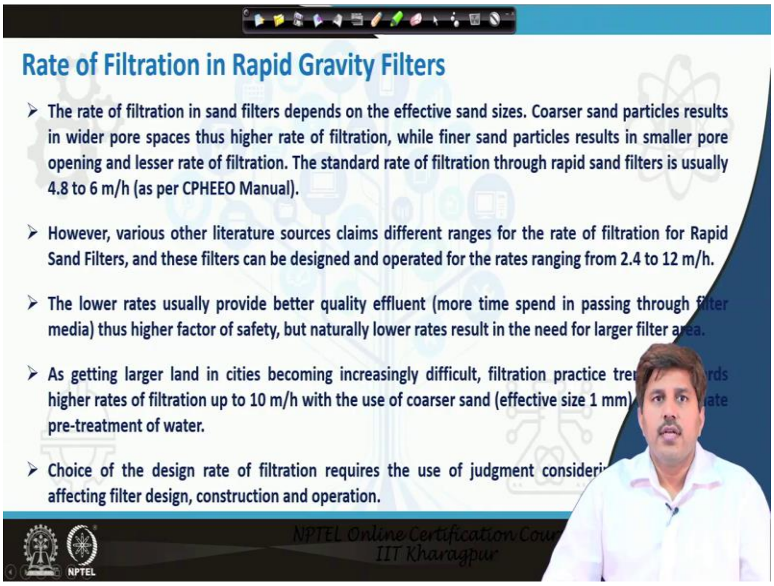

The rate of filtration through the rapid gravity filters is generally depends on the like size of the grains, size of the sand particles coarser sand particles will result in the wider pore spaces. If we are using the bigger size sand particles so the pore spaces will be bigger and as a result will get higher flow. If we are using relatively finer sand particles so then pores will be smaller and will be operating at lesser later filtration.

Now the standard rate of filtration through rapid sand filters is used when 4.6 to 8 meter per hour. So, even as we see even if you are operating at around 5 which is say close to 4.8 the lower range we are still getting 50 times higher rate as opposed to the slow sand filters. Now there are various literature's claims different ranges this is the range referred as CPHO manual but there are various other manuals or reports or studies.

So if we see the; if you try to thoroughly review the literature we get these range of flow for rapid gravity filters range from 2.4 to 12 meter per hour. So, it can go as high as 12 and people do operate it at a lesser flow rates also as low as 2 meter per hour. The lower rates usually will provide the better affluent quality why so because lower rate means we are working with a smaller sand particles and it is actually spending more time in passing through the filter media and the sand sizes are also smaller.

So that way like the pore spaces are smaller retention is going to be better so efficiency would be better. Whereas the higher flow will be basically because if we go for a higher flow rate so then that means water is passing through much quickly through the sand bed, so the efficiency is going to be lesser that there we need to like decide on what is the optimal flow rate we want to maintain in order to get the desired efficiency.

Because we can go for low flow rate which will give us higher efficiency and as a result higher factor of safety but naturally it will be needing larger area. Whereas getting larger area in cities becoming increasingly difficult so the filtration practices nowaday we see is actually moving towards more of a high rate of filtration as high as 10 meter per hour with use of coarser sand means we use sand of the size around 1 mm with a pre treated water.

The choice of the design rate of filtration required a judgment based on the various factors which affect the filter design its construction as well as its operation.

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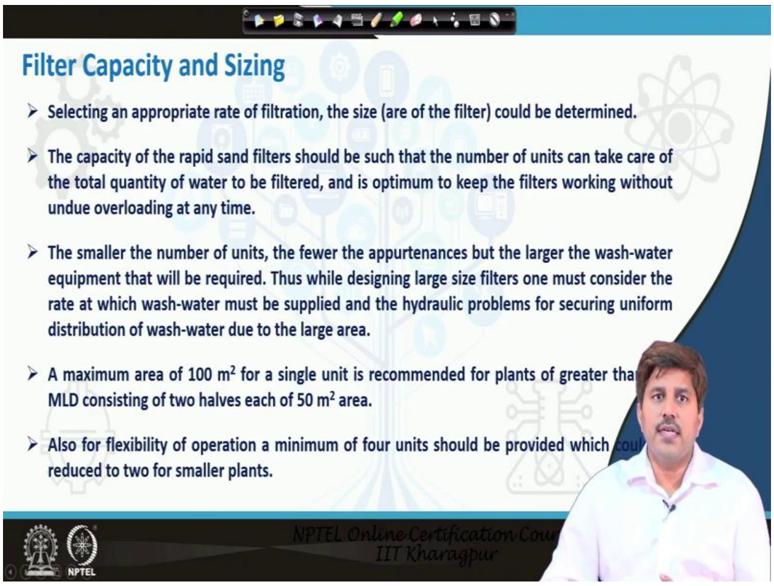

Now the how do we size the filter again sizing the filter is the similar approach is followed as we looked in the previous class for the slow sand filter. So, we need to kind of identify which flow rate at which rate of filtration we want to work upon and then we have a discharge coming in so we can actually select we can determine the area of the filter required. However selecting an appropriate rate of filtration and the size which is basically the area of the filter we can determine when we select the appropriate rate of filtration.

This appropriate rate of filtration will depend on various things more so ever whatever the sand size that we are choosing, so the capacity of these sand filters would be such that the number of units take care of the total quantity of water that we need to filter. So, it is not that we size one filter too big instead we go we say like if we get the total area for say if total area requirement is 500 meter square.

So 500 meter square we do not provide just one single filter of 500 meter square rather will be providing 10 filter beds of 50 meter square each may be assembled in a battery form. So, that is how we kind of size these reactors. The we need to like optimize what is the good number of filter beds which we can use and what is the optimum size so that we can actually get the desired flow rate out of that filter.

The smaller the number of units the fewer the like other Arrangements like valve, the gauges and those things will be required but we are going to have a larger wash water equipments because we need to flow wash water at a much larger rate. So, we need to like while designing we need to see that what is the optimum range of a filter bed which we should choose. Generally the maximum area of 100 meter square for a single unit is recommended.

And greater than 100 particularly if plants that are treating with a greater than 100 million litres of water so then we can go for like higher a higher size area otherwise for plants with 100 meter square area for a single unit we can have with 50 meter square on each side. So, typically a filter bed also can be of this type like we will have a filter bed and then in between we have like two halves through which our main manifold pass so we can keep each side area as 50 meter square so that the area of one bed becomes 100 meter square.

Also for the flexibility of operation generally 4 units are recommended we should provide around four units but we if the plant size is too small we can reduce that to 2 instead of 4 we can just go for the 2 units.

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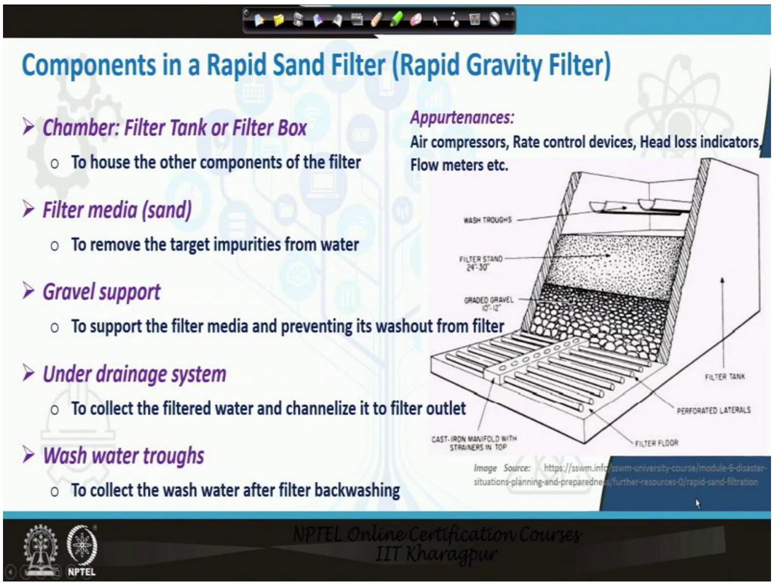

The typical rapid gravity filter or rapid sand filter has several components. These components the first thing will there has to be a filter tank. So, everything is kind of encased in a filter tank. There has to be a chamber which is a filter tank or filter box and this chamber houses all other components of the filter. Then we have to have a filter media or sand which is basically very important because of the removal of the contaminant takes place only when the water passes through the media.

So that is another very important or in fact the most important component in a way and then we have the gravel support which is basically to support the filter media and prevent its wash out from the filter. So, it basically supports the filter media the sand is supported by the gravel layer and it also prevents the washout of the sands along with the flow. Then we have to have an under drainage system.

So this is kind; these are kind of under drainage systems which is usually like although there are a few options available for under drainage system but the most common is one is this there is a base there would be a basically central manifold and then perforated laterals attached to this manifold. So, these are laterals which are perforated and this is the manifold so water enters through these perforations in this manifold and then treated water is collected through the central manifold.

So under drainage system is aimed to collect the treated water as well as it aims to channelize the like it aims to provide the water during the back washing. So, this is the two roles and then washes water traps which is to collect the wash water after the filter back washing. So, there will be wash water traps at the top and when we back was the filter so this back washed water is collected into the into these wash water traps.

Apart from that we will be having various other appliances like air compressors rate control devices there would be head loss indicators flow meter. So, these kind of things might also be there in a typical rapid sand filter.

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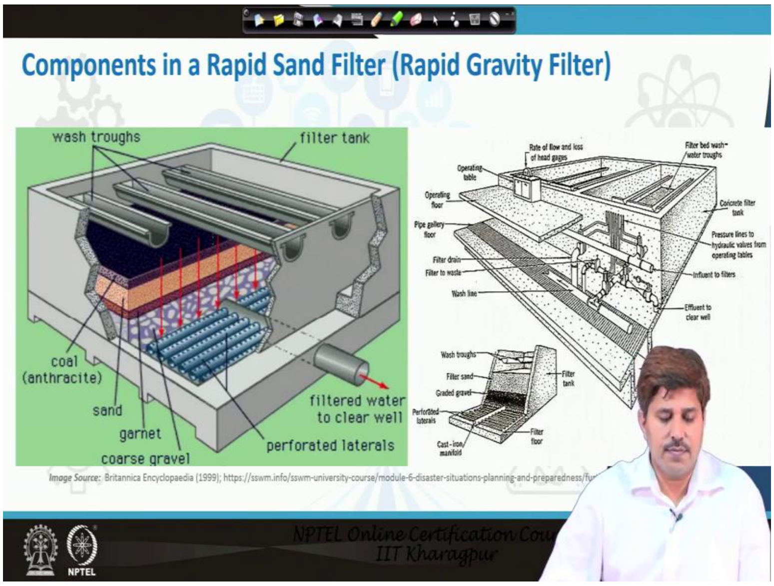

So, if you see the components again like this is you will have the the kind of filter tank in the filter tank we will having a media now this media could be just a simple sand or it could be a multimedia like we can have a coal sand and grenade. So, that would be the media and then water will be basically passing through the media in then we have the gravel layer to support this and these are the perforated laterals connected to a central manifold.

And all these like there could be different arrangements of the filters and then we can have a much larger filter module.

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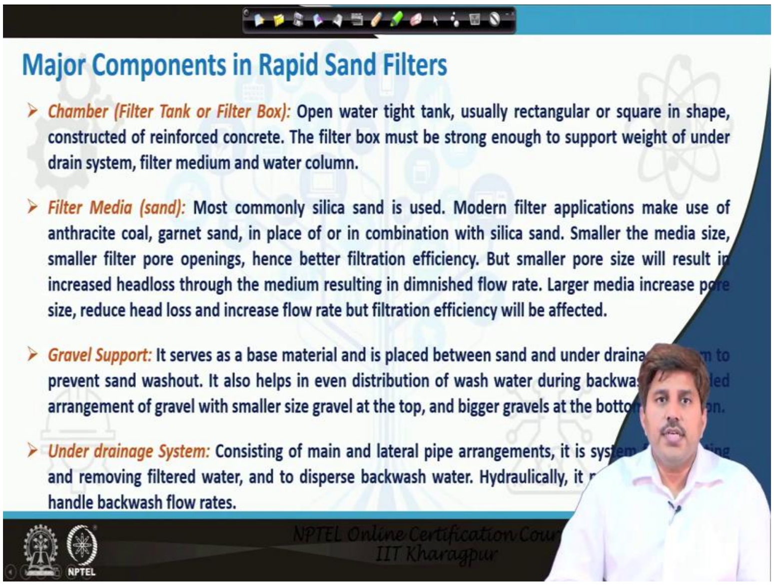

The major components again as just we were discussing there has to be a chamber we discussed that it has to be a watertight chamber. It is usually rectangular or square in shape and it is constructed of the reinforced concrete most of the times. The filter box must be strong enough to support the weight of under drainage and kind of under drainage system weight of filter medium and weight of water column which is there coming on today.

Everything is basically coming everything is back in the filter tank so it has to be basically strong enough or designed to have enough strength to bear all the loads. Then filter media which is sand is the most common filter media mostly silica sand is used generally. Modern filter applications make use of the anthracite coal granite sand also in place of the silica sand or in combination of silica sand mostly in combination of the silica sands.

For filter media the smaller the media size the smaller will be the pore openings and there will be better filtration efficiency although the flow rate will be less. So, a smaller pore sizes which will actually result in lesser flow and the head loss will also increase so that those problems is going to come. The larger media will increase the pore sizes, so head loss will be reduced but then flow rate will increase and however the problem is that the filtration efficiency may get affected.

So, we need to like have a optimum combination that we need to choose the gravel support which is basically supports as a base material it is placed between the sand and under drainage system as just we saw and this prevents the sand wash out it also helps in even distribution of wash water during back washing which is again one of the very important role of the gravel medium. Because through the wash water through the under drainage system water is released during washing period.

And it it passes through the gravel medium so gravel medium also kind of make sure or helps facilitates in the even distribution of the wash water. And then under drianage system which is consists of the main and literal pipe arrangement and it is basically the system for collecting and removing the filtered water also it disperses the backwash water. So, hydraulically it must be designed to handle the backwash flow rates because backwash flow rates are greater than the normal filtration rates usually.

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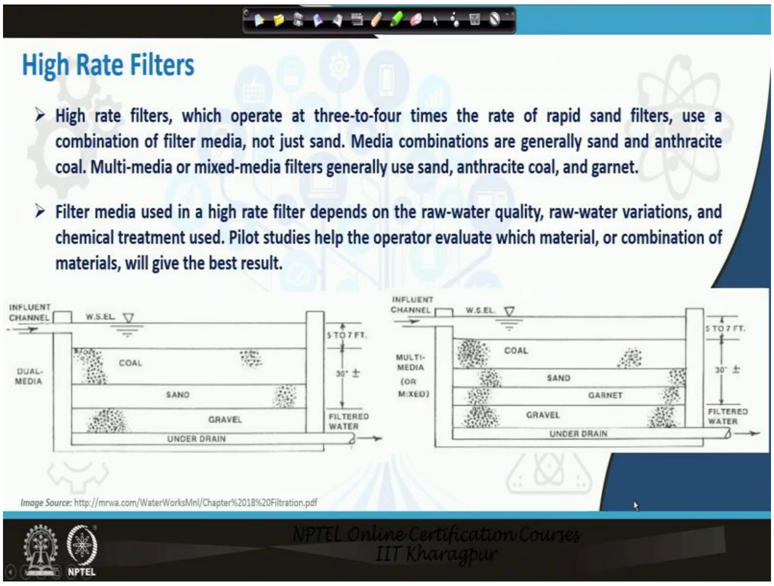

Now the rapid sand filter or rapid gravity filters generally the rapid sand filters that we are talking about can be converted to high rate filters when which usually operates at 3 to 4 times the rate of the rapid sand filters and this is done in the twelve media or multi media filters. So, instead of just using sand if we use the anthracite coal or granite which is having better flow through velocity so they facilitate larger flow rates so then we can operate this filter it is a much higher rate.

With the almost same raw water quality, so, this filter media used in high rate filters will depend on the kind of what is the raw water quality what does the raw water variation and what previous chemical treatment has been given. So, those needs to be seen and then these can be quite effective.

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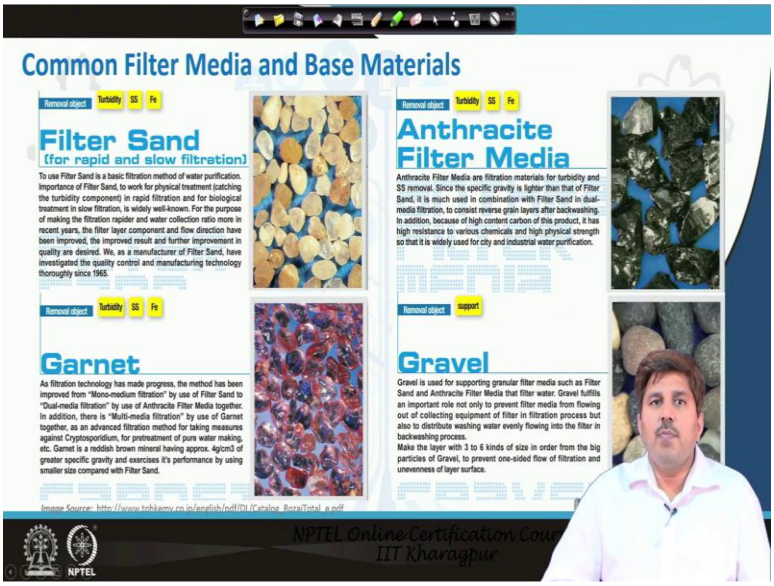

So, the common filter media and base material that we get in the rapid sand filters are the filter sand which is for rapid and slow sand filtration both the removal objective is the turbidity suspended solids and iron it can remove. Then we can use anthracite filter media it can remove turbidity suspended solids and iron we can use the granite which can use turbidity suspended solids and iron and we can the gravel is for supporting purpose.

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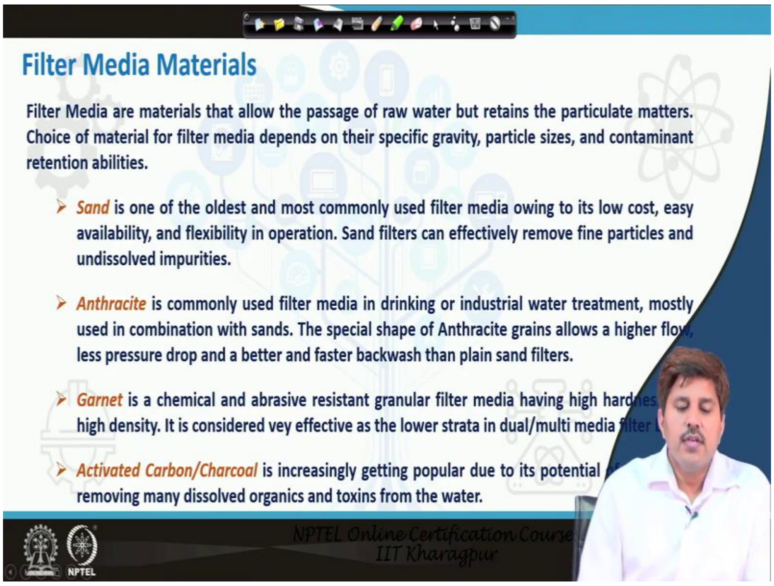

These are the major filter media with and like the kind of objective they have in the filtration process. So, sand is the one of the oldest and most commonly used filter media why so because it has very low cost it is easy available easily available it has kind of very flexible operation. So, it provides the flexibility in operation as well and it is effective in removing the fine particles and undissolved impurities generally and particularly the smaller size sand.

Then anthracite is commonly used filter media in drinking and industrial water treatment systems mostly in combination with the sand. So, if like one is planning to go for a dwell media generally anthracite is used in combination with sand. The advantage with anthracite is that the special shapes of these anthracite grains allow the higher flow at lesser pressure drop and that way a better and faster backwash then simple plain sand filters.

So, that way it is advantageous the granite is again a chemical is a substance which is chemically resistance, it is resistance to abrasive as well. So, this kind of granular medium has very high hardness and very high density. So, the specific properties are like it has a very high specific gravity means the density is also very high obviously and it is quite hard as well. And the other added advantage is that it is resistance to any chemical or any chemical or physical abrasion any chemical reaction or physical abrasion.

So that way it is considered very effective as lower strata in the dual or multimedia filter beds. Then we can use activated carbon or charcoal which is again increasingly getting popular due to its potential. And it can actually effectively remove many dissolved organics and toxins also from the water. So, that further kind of promotes the use of the activated charcoal or activated carbon for the filtration purpose.

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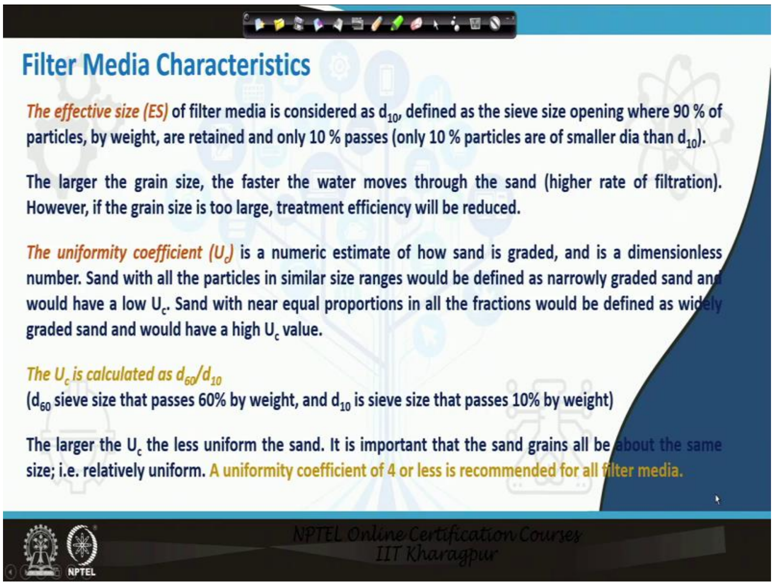

Now the filter media is just we briefly discussed in the previous lecture also that the media is characterized based on the effective size and the uniformity coefficient. So, the effective size of the media is actually it is considered as d 10. Now d 10 is the is defined as when we pass let us say we pass some aggregate on a sieve size whatever the sieve size could be let us say the sieve size is the sieve opening is say of M Psi.

Now were like if only 10% of amounts only 10%, of the particles are passing 10% by weight actually. If only 10% of particles are passing by weight. So, the size which allows only 10% particles to pass by weight we call that size as d 10 which is the effective size or effective diameter. So, effective size means most of the particles 90% of the particles are actually of size bigger than this size that is why they have not passed.

Only 10% of particles could be of smaller size and that is why the 10% particles have passed when received using this particular size, so, that that is known as d 10. Similarly we can have d 50, d 60, d 90, d 90 means the 90% particles have passed only 10% particles retained. Similarly d 60 means that like 60% particles have passed by weight 40% particles are only retained. So, that is why we like define and the effective size is defined as d 60 sorry d 10.

So means only means this particles and particles or media particles whatever we are referring to should be of 90% of the mass or 90% of the weight of the sand should be of size greater than this size d 10, so let us say if we are saying that d 10 is 0.5 mm, so that means 90% of the particles by weight are of size greater than 0.5 mm only 10% by weight could be less than 0.5 mm. So, the larger the grain size the faster the water will move through this and that means higher rate of filtration.

However if the grain size is too large that will not get very good treatment efficiency because water will pass through quickly and there will be very less retention. Then the other parameter is uniformity coefficient, this uniformity coefficient is a numeric estimate of how well graded the sand is? So, it is actually a ratio of d 60 by d 10. Now d 60 again means the 60% particles have passed by weight and d 10 is the 10% particles that have passed by weight.

So it is a dimensionless number of these 2 sizes the sand which is having all the particles in the similar range would be defined as a narrowly graded sand and will have a low uniformity coefficient. The uniformity coefficient is going to be low because all the particles are of say similar size. The sand which is having particles equal proportion of the particles of all sizes or different fractions will have high value of UC and a high value of uniformity coefficients and will be considered as well graded.

So the larger the uniformity coefficient the less uniform the sand, now for filtration purpose we want that sand to be of more or less uniform size it is relatively uniform size. So, we should attempt for a low uniformity coefficient. In any case a uniformity coefficient should be 4 or less generally it is preferred around like less than 2.

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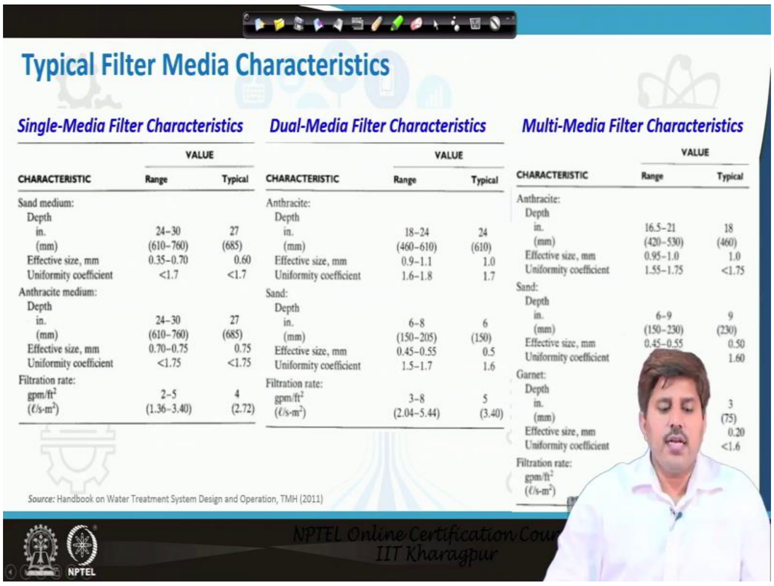

This is the typical media characteristics for single media filter dual media filter and multi media filter again this is just from one source the different source recommends different values. So, we can see that for single media ranges if we are using the sand medium the typical values typical depth of the sand layer should be 727 inch or close to 700 mm. The effective size has to be 0.6 mm and uniformity coefficient should be less than 1.7.

If we are using anthracite medium, so again we almost follow these things only the effective size can be higher. So, 0.75 and the uniformity coefficient would be again less than 0.175. The rate of filtration that we can use is 2.72 liter per second per meter square. For dual media filters when we are using both anthracite as well as coal don't get confused this one is either this or this. So, either we are using sand medium or we are using anthracite medium we are not using both.

Whereas in dual media filter we are using this and this, so we are using both here. So, that is why the depth here is kept 610 close to 600 mm and the anthracite depth is kept 150. The effective size of anthracite 0.5 the uniformity coefficient less than 1.6 here it is less than 1.7 and effective size we can go higher if you using a dual media filter. So, we can go up to one and the rate also we can you apply higher rate 3.40 liters per meter square per second in multimedia filter when we are using say anthracite and sand and granite all the three medium.

So for this the depth of anthracite can be kept as 460 mm the effective size 1, uniformity coefficient less than 1.75. Similarly for sand and granite medium we can choose these specification and it allows even higher flow rate so we can use flow rates up to 4 liters per second per meter squared.

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The layering of the filter media is for mono media like for single medium filtration of course there is just sand for dual media we put anthracite on the top and then sand at the bottom in tri media we put anthracite at the tops sand in the middle and granite in the bottom generally. So, that is how we generate we can layer we can see that this is the anthracite sand granite all those mediums layered in that way.

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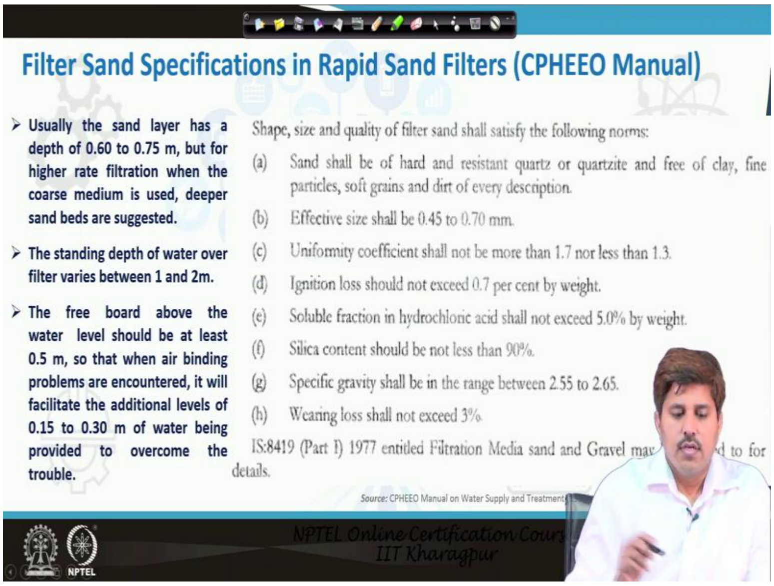

The specification for the filter sand is again as per CPHO generally it has to be between 0.6 to 0.75 meter depth. The standing depth of the water over the filter varies between 1 to 2 meters over the filter the lip depth of the water can be 1 to 2 meter. The freeboard above this can be up to around 0.5 meter the safe size and the quality of the filter sand should follow these criteria. So, effective size can be 0.45 to 0.7 mm the uniformity coefficient should be not be more than 1.7 and should not be less than 1.3.

So, it should be generally between 1.7 to 1.3, ignition losses should not exceed 0.7% by weight that means when we are burning the sand the total weight loss should not be more than 0.7 % by weight silica content should not be less than 90% soluble fraction should not exceed 5% by weight in hydrochloric acid the specific gravity between 2.5 and 2.65. The varying losses should not exceed 3%.

So, these are the specification of the sands which is recommended to be used in a rapid gravity filter.

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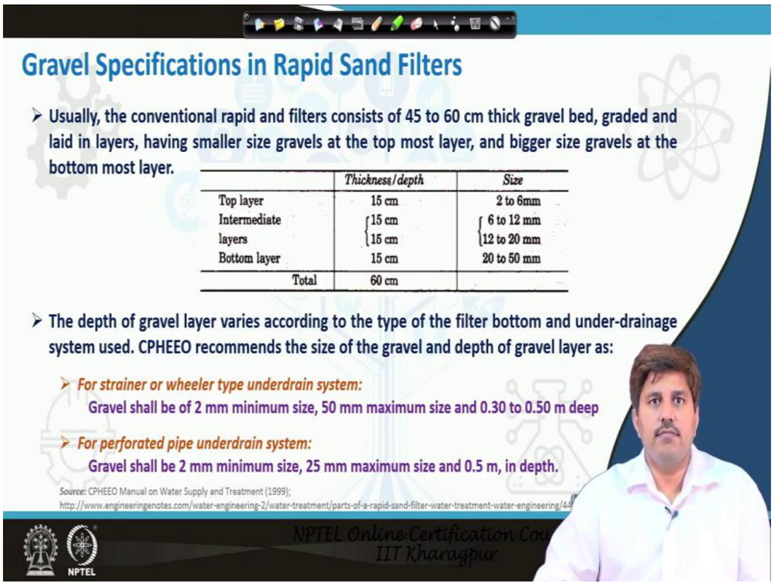

The gravel is specification in rapid sand filters again similarly so usually the conventional rapid sand filter consists of 45 to 60 centimeter means around half a meter thick gravel bed which would be graded in layers having smaller sizes at the top and the bigger gravel sizes at the bottom most layer. So, typical gradation can be like this we can have a 15 centimeter top layer of 2 to 6 mm size and then intermediate layers of 15, 15 centimeter 6 to 12 and 12 to 20 and the bottom layer of 15 centimeter of 20 to 50 mm gravel sizes.

The depth of the gravel layer varies according to what type of under drainage system we are using. So, as per CPHO recommends that for strainer and wheeler type of under drainage system the gravel shall be like 2mm minimum size and 50 mm maximum size and 0.3 to 0.5 meter deep for perforated pipe under drainage system, which is the most common one actually the gravel should be 2 mm minimum size 25 mm maximum size and 0.5 meter in depth.

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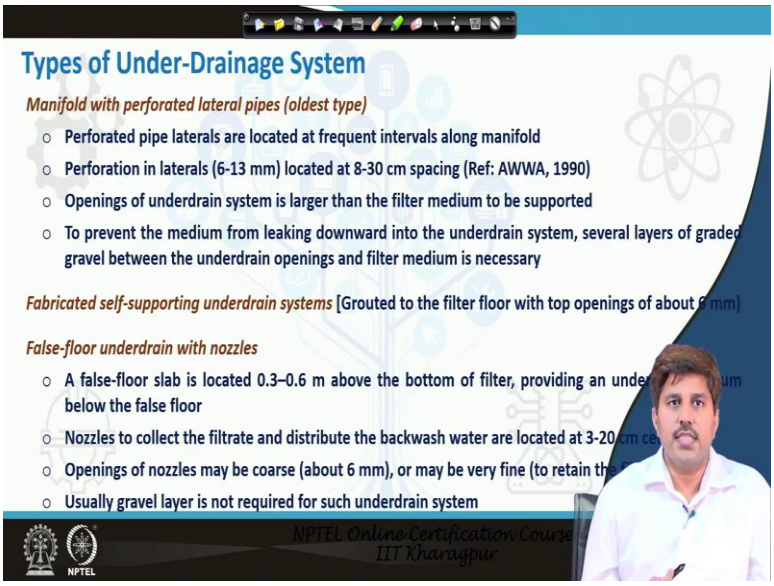

So, if you see the different type of under drainage system the manifold with perforated lateral pipes is the oldest under drainage system. So, here what happens that as just we discussed earlier also we will have a central manifold and then attached to this t here will be lot of like there will be several laterals and these letters will have perforations. So, there will be like perforations on these laterals so water enters through these perforations into these laterals and through these perforations water will enter into the lateral.

And then this literal or the central like and this lateral will connect to the central manifold so lateral connects to the central manifold and then central manifold connects to the outlet. So, perforated pipe laterals are located at frequent intervals along the manifold the perforations in the lateral could be 6 to 13 mm of size located at 8 to 30 centimeters spacing as per me American Water Works Association guidelines.

So, opening of the under drainage like under drain system a larger than the filter made medium to be supported now this is interesting that filter media filter sizes we are using is smaller less than 1 mm however opening we are having much larger but still because of the gravel layer and all that packing we do not get the filter sand washout. This prevents the medium from leaking downward into the under drainage system several layers of graded gravel between the under drainage opening and filter medium is necessary as just we were discussing.

Then there could be a fabricated self-supporting under drainage systems which is actually like it is a self supported means we grout the filter floor with top opening about 6 millimeter so instead of like having a under drainage and perforated pipe systems we have a floor and there there is 6 mm opening on the floor itself and then over and over that we may actually have some layer of gravels and on that sand. So, we do not need any sort of this kind of arrangement for that.

Then there is a false floor under drainage with nozzles so which is basically a slab located at 0.3 to 0.6 meter above the bottom of the filter and that is why we call that as a false floor it provides an under drained kinda plenum below of the false floor so nozzles collect this filtrate and distribute the backwash water that are located 2 to 30 centimeters from center to center. Opening of the nozzles may be coarse about 6 mm maybe very fine to retain the filter medium.

Usually gravel layer is not required in this false floor under drainage system, so we can get away with that layer as well. However it is most popular as we said is the manifolds with perforated lateral pipe system are the most popular one. So, we conclude this discussion here and in the next class we will be talking about more on the operation of the filter. How it is operated what are the challenges that are encountered. And then about the back washing and the hydraulics of the filter so see you in the next class thank you for joining