Water Supply Engineering
Prof. Manoj Kumar Tiwari
School of Water Resources
Indian Institute of Technology-Kharagpur

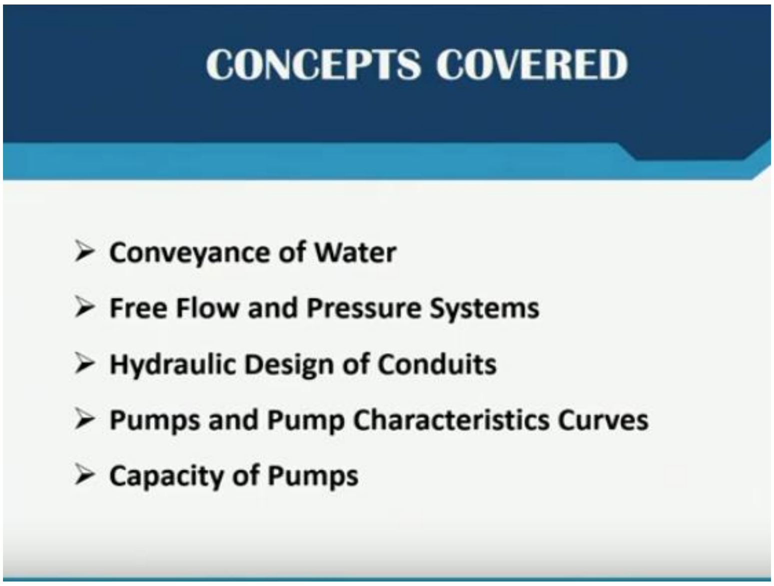
Lecture - 16
Raw Water Conveyance and Pumping

Hello friends and welcome back. So we have been discussing about the various water sources, intake and conveyance in this week. So far we did talk about the sources of water and how we withdraw water from the sources for surface water sources as well as groundwater sources, which we just covered in the last couple of lectures. This class we will be talking about conveyance and pumping.

So once we identify a source, whether it is a surface water source or a groundwater source, and we set up a mechanism for withdrawing water, couple more important components is because water is there at the source if it is in a groundwater system, so it is in the aquifer. If it is in a surface water system, so it is either in the lake, river, reservoir wherever it is.

So for the purpose of withdrawing water from these sources, we set up a kind of structure which we discussed we can go for wells for groundwater abstraction or we can go for different type of intakes what we discussed earlier in the week. But setting up a structure is one aspect, but for withdrawing water we need to pump that water from the source for that purpose we need pumping and we need to convey that water, we need to transport that water to the next unit which is treatment facility.

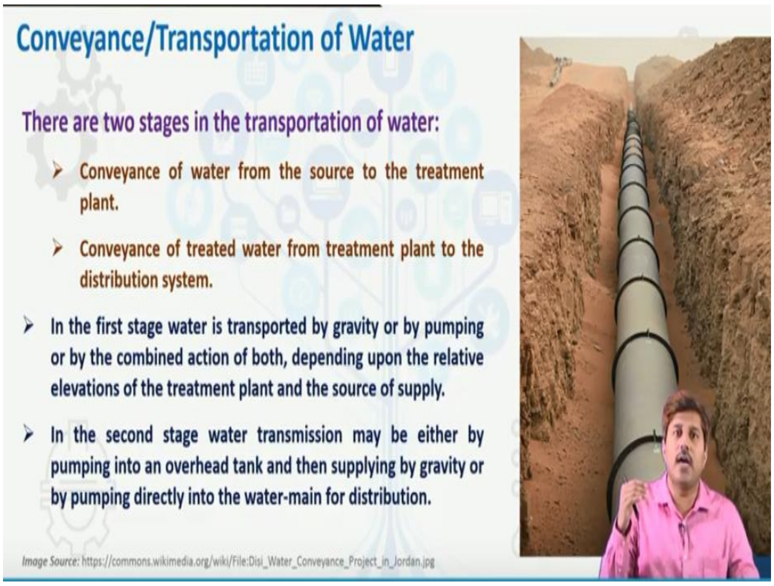
(Refer Slide Time: 01:47)



So this is what we are going to discuss this week about the pumps that is used for pumping the water and the conveyance of water. So the concepts that we are going to discuss is the conveyance of water and how basically the free flow and pressure systems are used for conveying the water. Then we are going to talk about hydraulic design of the conduits, major conduits.

And we will discuss about pumps and its characteristic curves and about the capacity of pumps as well.

(Refer Slide Time: 02:17)

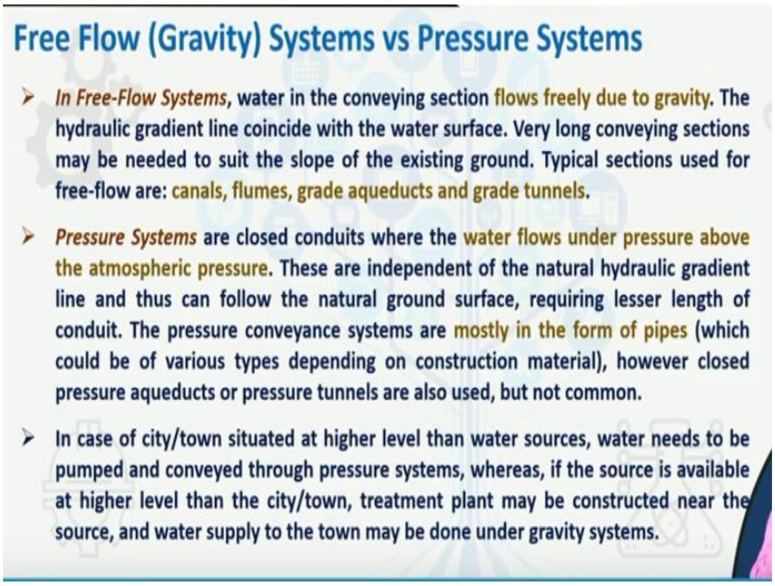


So to begin with, there are two stages when we need the transportation of water in the usual urban water systems, okay. The first stage is the conveyance of water from the source to the treatment plant what we will be basically discussing and then second stage is the transport of water from the treatment plant to the distribution system, which is usually done through a water distribution network which we will be talking about in the later weeks.

So in first stage water is transported by gravity or by pumping or by combined action of both which basically depend on the relative elevation of the source and the next stage which is the treatment facilities, so where we are going to install the treatment facility. In the second stage it is usually done by pumping in most cases okay or at least pumping is used to done, to send water up to the overhead reservoir.

And from there it can actually be sent by gravity okay or it can be directly pumped to the water mains for the distribution purpose.

(Refer Slide Time: 03:27)



Now there are two ways for water conveyance or water transport, the free flow systems and the pressure systems. So free flow systems are essentially the gravity feed systems, okay. So in the free flow system, the conveying section flows freely, water will actually flow freely in these conveying sections by gravity, okay.

When it is flowing by the gravity so we know that the hydraulic gradient line will coincide with the water surface okay and many times we need longer sections because if the slope is too steep, we cannot use directly it in a free flow system. So we have to basically keep a check on the slope as well. So based on the existing ground and the required slope of the conveying section, many times we need to kind of divert our the pipes or generally the channels okay in free flow systems.

So many times it becomes quite long as well. The example can be canal, flumes or grade aqueduct, grade tunnels which uses the free flow system. Then there are pressure systems which typically are closed conduits. The pressure system as the name itself suggests that water will flow under the pressure and this pressure will be higher than the normal atmospheric pressure, okay.

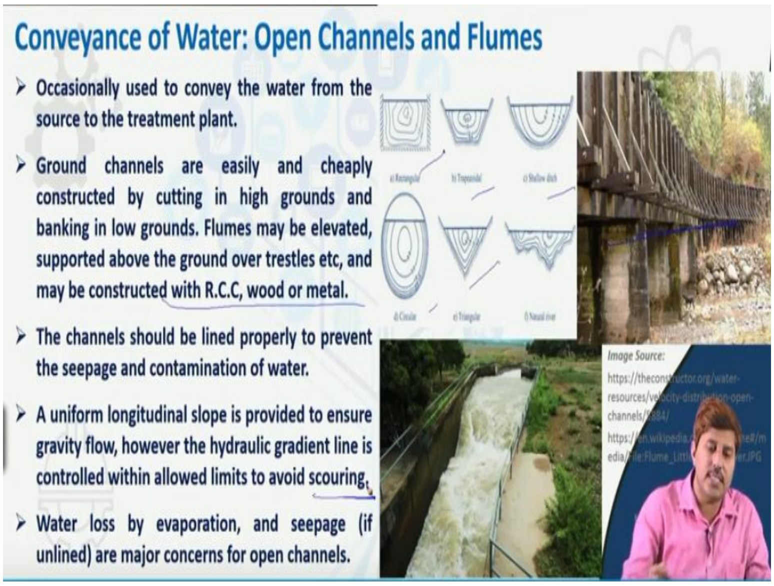
So these are independent of the natural hydraulic gradient because any way we are going to push water through the pressure. So we do not need to align along with the surface or like look for the slope. So we can use the just natural ground surface or slope and then even that way we can cut down the length of the total conduit, okay. So mostly these are in the form of pipes okay which are of various types and made of various material, but there are other like pressure system as well.

So particularly in the earlier times the closed pressure aqueducts or pressure tunnels were also used but these days it is quite uncommon to see these kind of structures, okay. Typically in city town which is situated at higher level of the water source, okay, if water source is higher level than the city town so that means our water sources is at higher elevation and city and town is at a lower elevation.

So we are already getting a natural hydraulic gradient. So water can be means if city is situated at higher level and source is at lower level, so there is basically no way we can lift water except then pumping. So we will require pressure system, but if it is opposite means if city is situated at a lower level and source is at a higher level which is case in hilly terrain side places, so then there is adequate natural gradient is available.

So we can actually build the treatment plant right near the source and then it is good to basically have water supply in a gravity fed systems.

(Refer Slide Time: 06:33)



So in open channels or basically flumes, the water is generally flowed by gravity, okay. These channels, these like channels being open channel. There are various cross sections are used for these open channels. It could be rectangular, it could be trapezoidal or kind of shallow ditch okay, triangular, circular or natural river kind of slope may also be used.

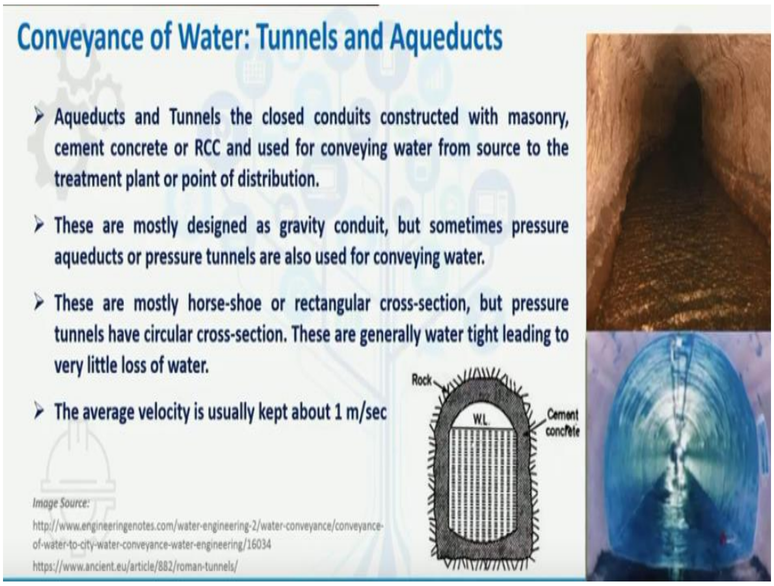
So these are generally occasionally used to convey the water from source to treatment plant, okay. There has to have a kind of natural slope because then only it will be possible to flow in the open channel right? These, particularly if we are making at a ground, so it is quite easy to construct these channel okay. The high grounds can be cut and low grounds can be filled in order to get a proper channels okay.

Many times flumes could be elevated also, so like you see here. So there is possibility of having elevated flumes okay, which will be supported over the ground over kind of trestles and it could be basically constructed with RCC wood or metals. There are channel which needs to be generally in order to avoid the seepage losses these channels should be lined properly okay.

And a uniform longitudinal slope must be provided so that the proper gravity flow takes place and hydraulic gradient line should be controlled within the allowed limit because if the slope is too steep, like there is a possibility of high degree of scouring okay. If slope is, if the channel is lined seepage losses we can reduce, but if channel is unlined there is going to be huge seepage losses.

And in any case whether it is line or unline, in most cases the evaporation losses are one of the major problems of such systems.

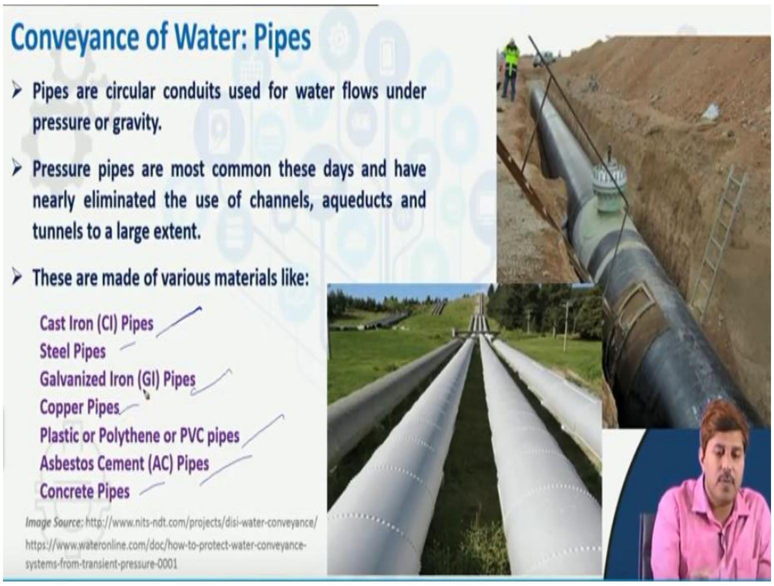
(Refer Slide Time: 08:35)



Then there are tunnels and aqueducts, okay. These are basically the closed conduits which are constructed with masonry, cement or concrete or RCC, okay. And they use to convey water from source to the treatment plant or the point of distribution. These kind of conduits are mostly designed as gravity conduit. But some time pressure aqueducts or pressure tunnels can also be used, okay.

Mostly horseshoe or rectangular cross-section is preferred but tunnels can be of circular cross-section as well okay? And the velocity in these tunnels is usually kept around one meter per second.

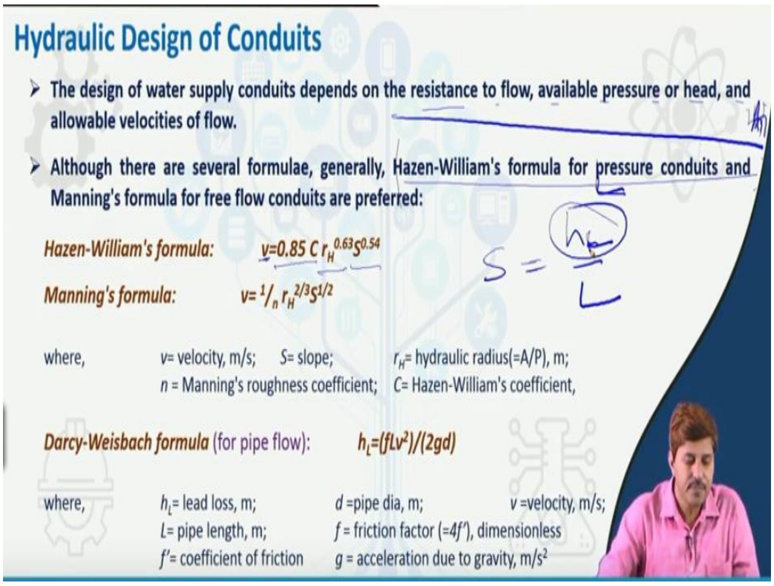
(Refer Slide Time: 09:22)



But again, these kind of structures are also turning obsolete day by day. And in fact it is the pipe which is by far the most popular means of conveying water okay. So generally, the pipes are circular conduits okay which are used to flow water, either under pressure or under gravity. The pressure pipes are the most common as and kind of pressure aqueducts, tunnels, and those things have almost completely eliminated now, okay. Older structures were used to be like that.

The pipes could be made of various materials. The more common materials include the cast iron, which is known as CI pipes or galvanized iron GI pipes or PVC pipe, which is plastic or polyethylene and then asbestos cement pipe, concrete pipe, steel pipe, copper pipe. So depending on the cost, size, scale we can actually choose the appropriate pipe for our purpose.

(Refer Slide Time: 10:17)



Now how when the flow takes place in these conduits, okay there is going to be a head loss and when we go to the designing these conduits, we must see that how much head loss is there, because we will have to cover that head loss through applying pressure okay or pumping water with that much pressure so that it can actually overcome the head loss.

So this will help in basically estimating the capacity of the pumps which is to be used, okay. Now there is this head loss typically take place because of the resistance to flow okay and available pressure or head whatsoever is there and the velocities which are there in the system. So although there are various formulas for this the three popular formula are Hazen-William formula, Manning’s formula and Darcy-Weisbach formula.

The Hazen-William formula is preferred for pressure conduits and Manning's formula is good for the free flow conduits okay. Darcy-Weisbach formula for pipe flow is also one of the very common equations which is used, okay. So as per Hazen-William formula it is actually the velocity in the pipe can be given as 0.85 C r to the power 0.63 and S to the power 0.54, okay.

Now here, velocity is something which we can estimate but many times like if you want to design or say set up a system we may actually assume a velocity okay? Here C is the Hazen-William constant r H is the hydraulic radius which is basically A/P or generally weighted parameter is taken, okay if it is a, but being a pipe flow if the pipe is say fully covered so it becomes the perimeter of that.

So A/P is taken as the hydraulic radius r H and S is the slope which is equal to the head loss by the length okay. So the systems are to be laid as way that your slope becomes actually whatever is the head loss divided by the length. So if say this is our pipe system, so net slope, like the from flow from here to here if this is the head loss okay, if this is the net head loss and this is the length of the pipe L, so our slope becomes h/L okay.

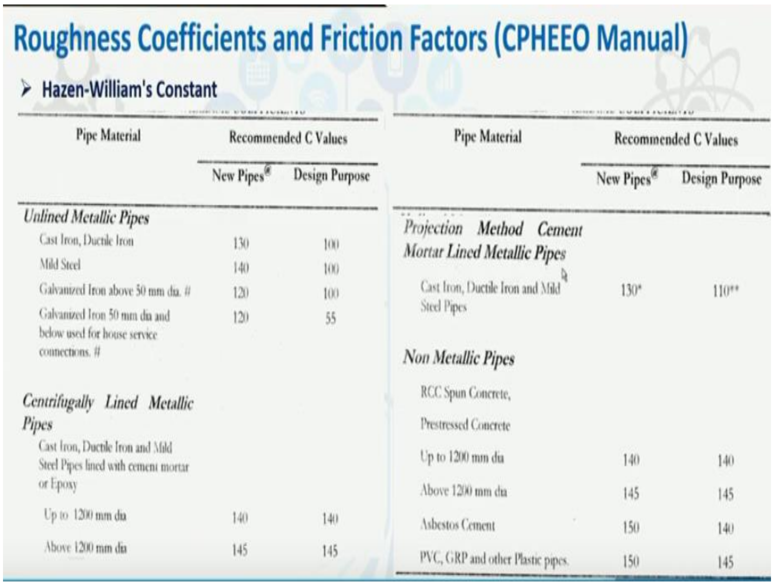
So that way we can have an idea estimate an idea of head loss. So if we assume a velocity, suitable velocity in the pipe or in the conduit then we can use this equation in order to get the head loss if we know the length, radius and other aspects of it. Manning's formula is good for the free flow conduits. So for channels like rectangular channels, circular channels or trapezoidal channels, it is v is equal to 1 upon n r H to the power 2 by 3, S to the power 1 by 2.

Again the same thing over here and Darcy-Weisbach formula which is used for pipe is h L is equal to fLv square by 2gd okay. So here h L is the head loss okay. Again if you want to kind of get the slope. So slope can be head loss by L so that in the Darcy-Weisbach formula can be written as fv square by 2gd okay. So this will become the formula for slope which is h L by L.

So h L is the head loss, L is the pipe length okay, d is the pipe dia, f is the friction factor here okay, which is equal to 4f prime. So in Darcy-Weisbach formula there are two type of friction factor or coefficient of friction are used. So one is friction factor which is usually taken as four times of the coefficient of friction which f prime.

So the Darcy-Weisbach formula another form of the Darcy-Weisbach formula is h L is equal to f prime we can say. If we are using coefficient of friction instead of friction factor, so it becomes 4f prime Lv square by 2gd. Now this 4f prime is actually replaced by f, if we are using friction factor directly while if you are using coefficient of friction, so the formula becomes 4f prime Lv square by 2gd, okay. And g is the acceleration due to gravity here.

(Refer Slide Time: 15:24)

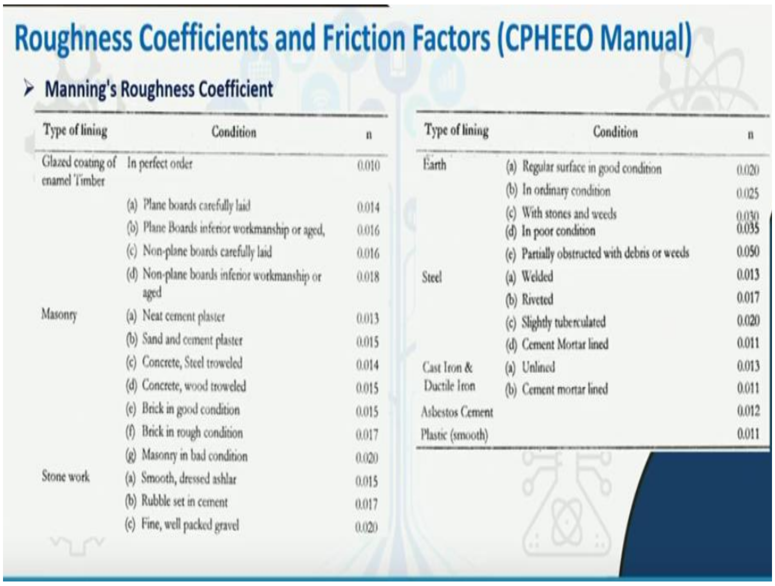


Pipe Material	Recommended C Values	
	New Pipes[@]	Design Purpose
Unlined Metallic Pipes		
Cast Iron, Ductile Iron	130	100
Mild Steel	140	100
Galvanized Iron above 50 mm dia. #	120	100
Galvanized Iron 50 mm dia and below used for house service connections. #	120	55
Centrifugally Lined Metallic Pipes		
Cast Iron, Ductile Iron and Mild Steel Pipes lined with cement mortar or Epoxy		
Up to 1200 mm dia	140	140
Above 1200 mm dia	145	145
Projection Method Cement Mortar Lined Metallic Pipes		
Cast Iron, Ductile Iron and Mild Steel Pipes	130*	110**
Non Metallic Pipes		
RCC Spun Concrete,		
Prestressed Concrete		
Up to 1200 mm dia	140	140
Above 1200 mm dia	145	145
Asbestos Cement	150	140
PVC, GRP and other Plastic pipes.	150	145

So these are some of the formulas which are used for the hydraulic design and the coefficients used in this formula can be estimated or generally it is actually assumed based on the certain characteristic of the material, age and those kind of thing. So like CPHEEO manual suggests that Hazen-William constant for depending on the pipe materials, for different kind of pipe material.

If it is unlined metallic pipe of cast iron ductile iron for new pipes it is to be 130. For design purpose, it can be taken as 100. Galvanized iron again 120 55. So centrifugally lined metallic pipe, then nonmetallic pipes, then projection method cement mortar line metallic pipe. So for the different type of materials, what the design value may be taken and what is typically available when the pipe is new.

(Refer Slide Time: 16:19)



Roughness Coefficients and Friction Factors (CPHEEO Manual)

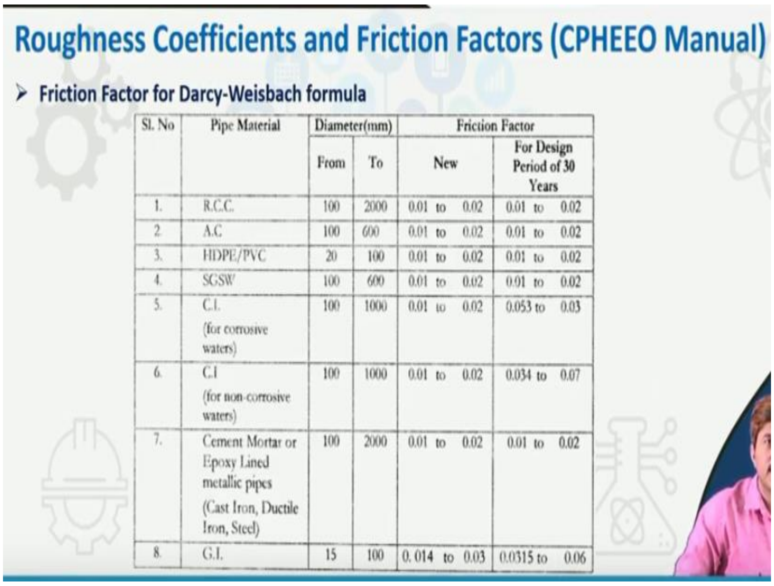
➢ Manning's Roughness Coefficient

Type of lining	Condition	n
Glazed coating of enamel Timber	In perfect order	0.010
	(a) Plane boards carefully laid	0.014
	(b) Plane Boards inferior workmanship or aged,	0.016
	(c) Non-plane boards carefully laid	0.016
	(d) Non-plane boards inferior workmanship or aged	0.018
Masonry	(a) Neat cement plaster	0.013
	(b) Sand and cement plaster	0.015
	(c) Concrete, Steel troweled	0.014
	(d) Concrete, wood troweled	0.015
	(e) Brick in good condition	0.015
	(f) Brick in rough condition	0.017
	(g) Masonry in bad condition	0.020
Stone work	(a) Smooth, dressed ashlar	0.015
	(b) Rubble set in cement	0.017
	(c) Fine, well packed gravel	0.020

Type of lining	Condition	n
Earth	(a) Regular surface in good condition	0.020
	(b) In ordinary condition	0.025
	(c) With stones and weeds	0.030
	(d) In poor condition	0.035
	(e) Partially obstructed with debris or weeds	0.050
Steel	(a) Welded	0.013
	(b) Riveted	0.017
	(c) Slightly tuberculated	0.020
	(d) Cement Mortar lined	0.011
Cast Iron & Ductile Iron	(a) Unlined	0.013
	(b) Cement mortar lined	0.011
Asbestos Cement		0.012
Plastic (smooth)		0.011

Similarly, there is available values of Manning's roughness coefficient okay. So for glazed coating of enamel timber, these are the values; masonry, stone work, earth, steel, cast iron. So far the different values and the different conditions whether they are smooth, they are rough, they are fine, well packed, so for different conditions, the end values have been suggested.

(Refer Slide Time: 16:50)



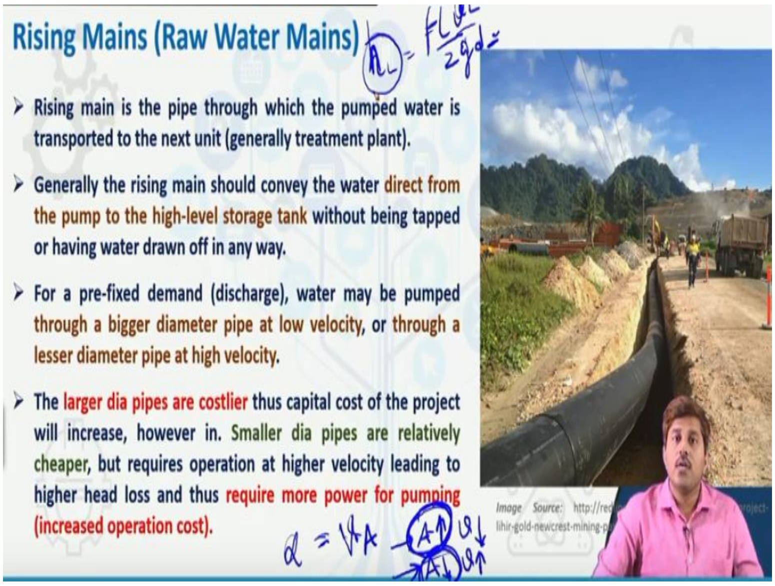
Roughness Coefficients and Friction Factors (CPHEEO Manual)

➢ Friction Factor for Darcy-Weisbach formula

Sl. No	Pipe Material	Diameter(mm)		Friction Factor	
		From	To	New	For Design Period of 30 Years
1.	R.C.C.	100	2000	0.01 to 0.02	0.01 to 0.02
2.	A.C	100	600	0.01 to 0.02	0.01 to 0.02
3.	HDPE/PVC	20	100	0.01 to 0.02	0.01 to 0.02
4.	SGSW	100	600	0.01 to 0.02	0.01 to 0.02
5.	C.I. (for corrosive waters)	100	1000	0.01 to 0.02	0.053 to 0.03
6.	C.I (for non-corrosive waters)	100	1000	0.01 to 0.02	0.034 to 0.07
7.	Cement Mortar or Epoxy Lined metallic pipes (Cast Iron, Ductile Iron, Steel)	100	2000	0.01 to 0.02	0.01 to 0.02
8.	G.I.	15	100	0. 014 to 0.03	0.0315 to 0.06

Similarly, the friction factor for Darcy-Weisbach formula is also available, okay. So depending on the pipe material and the diameter ranging we can get the friction factor for new pipes or for design period of 30 years what value we can actually assume for the friction factor in the Darcy-Weisbach formula. So these are the recommended value from CPHEEO manual.

(Refer Slide Time: 17:16)



The other sources are also there which might actually guide on some different numbers as well, but, still they are pretty close and more or less in the range, similar ranges. Now these are the different kind of system and this is how we design but, as we said that one of the major part of the conveyance or transportation is transporting water from the withdrawal and or withdrawal sump to the treatment facility.

And that is usually done using rising main or which is also known as raw water mains, okay. So rising main is basically the pipe through which the pumped water is transported to the next unit, generally treatment plant okay. The rising main should convey the water directly from the pump to the high level storage at the treatment plant and it is not advisable to basically tap water from the rising main in the midway.

But many times if say there is a small locality and there is no alternate source, many times like not many times though but few times rising main serves directly for supplying water to some community but otherwise usually the common practice or the advisable mechanism is that we take the water directly from the sump or from the withdrawal point to the treatment facility okay.

Where we can store in a high level storage tank and from there the water can be treated. Now for a fixed demand like we know how much water is to be supplied to a city or community or town okay. As we discussed we can estimate the water demand. So once we know the demand we know that what flow rate needs to be pumped through a rising main. So there are two options okay.

We can go for a rising main of a bigger dia and then keep the velocity small or we can go for a smaller dia and have the higher velocity, okay? Because we know once the discharge is fixed, okay if we know the discharge is fixed, so we know Q is equal to V into A okay. So it is actually the velocity times cross-section area of the pipe. So we have two options. We can have a bigger A and smaller velocity, okay?

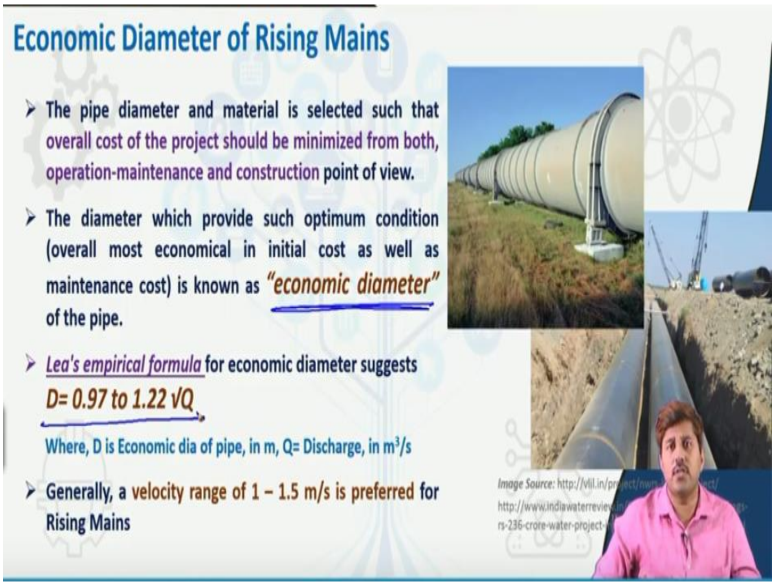
Or we can have a smaller area and higher velocity in the rising main. Now both of these cases have their own advantages and disadvantages and which one to choose will actually be governed by the overall cost of the system, okay. Why both have advantages and disadvantages because if we are going for a more area, bigger area which means bigger dia pipe okay.

So of course, if you are going for a bigger dia pipe, the pipe is going to come costlier okay like having a 200 mm dia pipe versus 1000 mm dia pipe or one meter dia pipe. Of course one meter dia pipe is going to be much more costlier okay. So the capital cost of the project will increase, okay. If we are going for smaller dia pipe, we can actually save on the capital cost front.

Now coming to the velocity, if we are going for a bigger dia pipe we are going to have the low velocity in the rising main. Now low velocity means that head losses are going to be lower, okay. Remember, head loss in the pipe is equal to as we just saw if you follow that formula f Lv square by 2gd, right? So a bigger dia pipe means d is high and v is low, so we are going to eventually get less head loss for bigger dia pipe .

For smaller dia pipe we are going to have d less and v high, so the head loss will be quite high. So higher head loss means more power would be required for pumping and that will increase the operation cost. So at one end, we are going to get the high capital cost, low operation cost, at other end we are going to get low capital cost, but high operation cost, okay. So which one is to be chosen is depend on the overall cost okay.

(Refer Slide Time: 22:19)



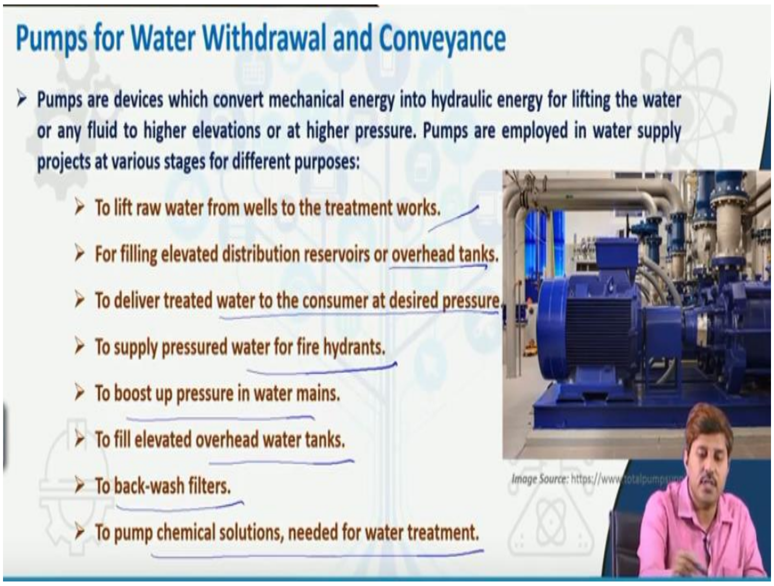
So when we basically include both the pipe diameter will be selected such that the overall cost of the project is minimized from both operation maintenance as well as construction point of view. Generally, the diameter which provides such optimum condition which is basically overall most economical in initial cost as well as maintenance cost is typically known as the economic diameter of the pipe.

And there is a Lea's empirical formula for getting this economic diameter of pipe, so Lee has suggested that D = 0.97 to 1.22 which is a factor, in between any factor can be chosen square root of Q gives the economic dia of pipe okay where Q is the discharge in meter cube per second.

Generally velocity in the range of 1 to 1.5 meter is preferred for rising mains, but at times we can go higher up to 2 meter or so, or at times we can go a little lower also up to 0.8 meter or so. It is not advisable to have very high or very low velocity in the rising main for reasons that very high velocity, again as you saw that head losses is going to be very high and there is a possibility of like scouring due to the turbulent flow if the velocity is too high in the rising main.

And very low velocity might lead to some sedimentation in the pipe which will reduce the capacity of the pipe okay which is unintentional in fact. So, that way it is to be seen that even the very low velocity is also not preferable. So ideally 1 to 1.5 meter range is preferred. Again this number fluctuates based on the place to place. Generally not too low or not too high a velocity is recommended in the rising mains and we can get the overall economic dia of the pipe that way.

(Refer Slide Time: 24:21)



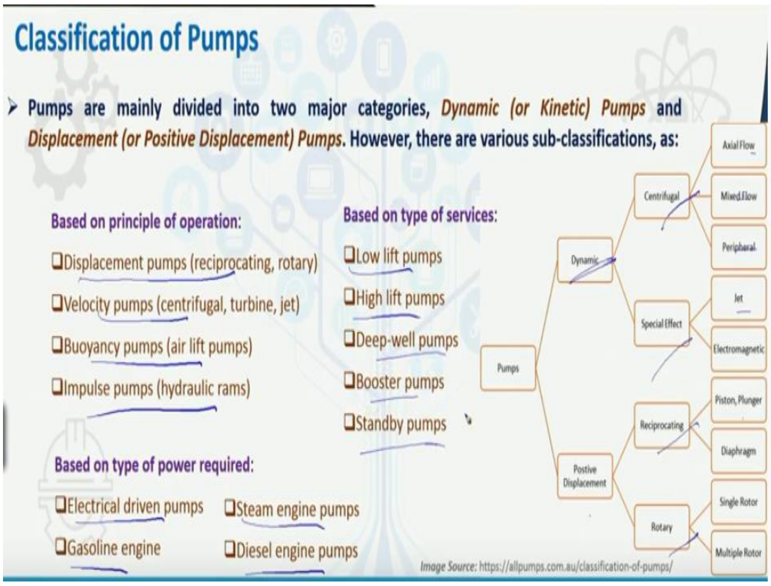
Now for flowing water through these systems mains or the conveyance systems that we discussed, we need pump okay. So pump is required for water withdrawal and conveyance and pump are typically devices which convert mechanical energy into hydraulic energy for lifting water okay when we are talking about in terms of water pumping.

So water or any fluid can be lifted that way to higher elevation or higher pressure, okay. In water supply projects pump are used at several different locations for different purposes, okay. So water can be used, the pump can be used to lift the raw water from well to treatment works. It can be used for filling the elevated distribution reservoir or overhead tank.

It can be used for delivering the treated water to the consumer at desired pressure means in the water distribution system. It can be used for supply pressure water for fire hydrants. It boost up pressure in the water mains also at times. So booster pump are required in the rising mains or the mains in the water distribution system, okay. It is used to fill the overhead water tanks.

It used to basically back-wash filters. Small pumps are used to feed the chemical solutions which are needed for the water treatment purpose. So there are different applications of pump in a overall water supply projects.

(Refer Slide Time: 25:52)



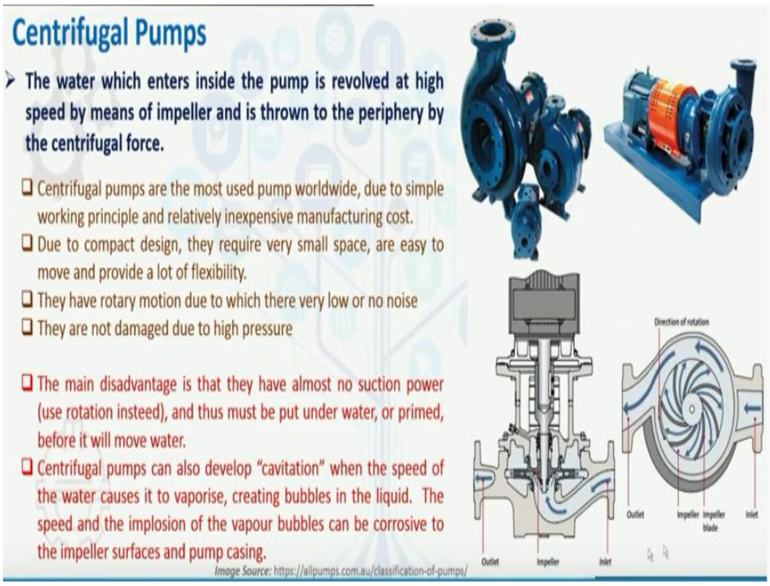
The pumps are mainly divided into two major categories which are dynamic or kinetic pumps, okay and the other are the displacement or positive displacement pumps. However, there are various sub classes okay. So pump can be classified in many ways. So rotodynamic or dynamic pumps like centrifugal pumps or a special effect pumps can come under this category.

So jet pumps, peripheral pumps, mixed low axial flow, different type of centrifugal pumps and then the positive displacement pumps can be reciprocating or rotary and reciprocating pumps can be of the form of piston or plunger or diaphragm and rotary pumps can be like single rotor or multiple rotor that way. Apart from this, if we look again like the other aspects, so the principle of operation for that matter.

So there are there could be displacement pumps, the velocity pumps, buoyancy pump, impulse pump. If we see the power requirement criteria so electrical driven pump, gasoline driven pump, steam engine pump, diesel engine pump and then if we leave the type of services so then we have low lift pump, high lift pump, deep well pump, booster pump, standby pump.

There are other aspects also like submersible pump and those kind of pump also can be there in these classes.

(Refer Slide Time: 27:15)



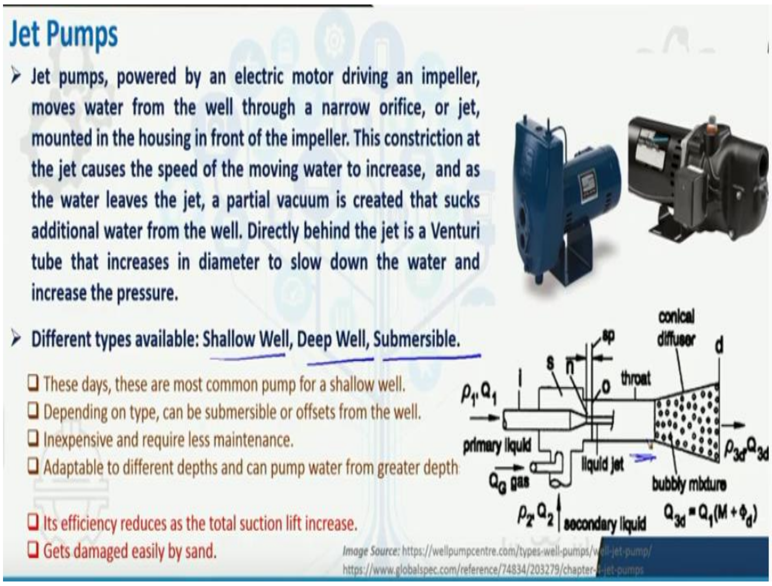
So some of the more common pumps are like centrifugal pumps which is basically works on a principle that water enters inside the pump and is basically revolved at high speed by means of the impeller. So there would be a impeller okay and there would be these are impeller blades. So if this is inlet, water enters here and then once this is rotated, so because of these rotation it actually like send water outside so on the peripheral by the action of the centrifugal force.

So these are one of the most used pump worldwide, simple working principle, relatively inexpensive manufacturing cost okay. The design is compact, very small and they offer, since there is a rotary motion okay so there is no kind of vacuum creation or that kind of thing. So there is very low or no noise. And these are generally not damaged. So works for 15, 20 years okay the life services is quite good.

There are a couple of disadvantages also that they typically have no suction power as because they do not create a vacuum or anyway. So if we are running it in a dry, so it will actually remain dry because there is no suction power. So until unless water is inside the this thing, so the pump has to be put first inside the water or water has to be put inside the pump, which is typically known as the priming.

So we have to basically prime these pumps before it actually starts moving water and at times the cavitation phenomena also happens because the speed of the water, there are like some vapor bubbles are created and these like bubbles when they create so the speed and implosion of these vapor bubbles can be corrosive for the pump life okay. So these are the couple of disadvantages of these pumps.

(Refer Slide Time: 29:23)



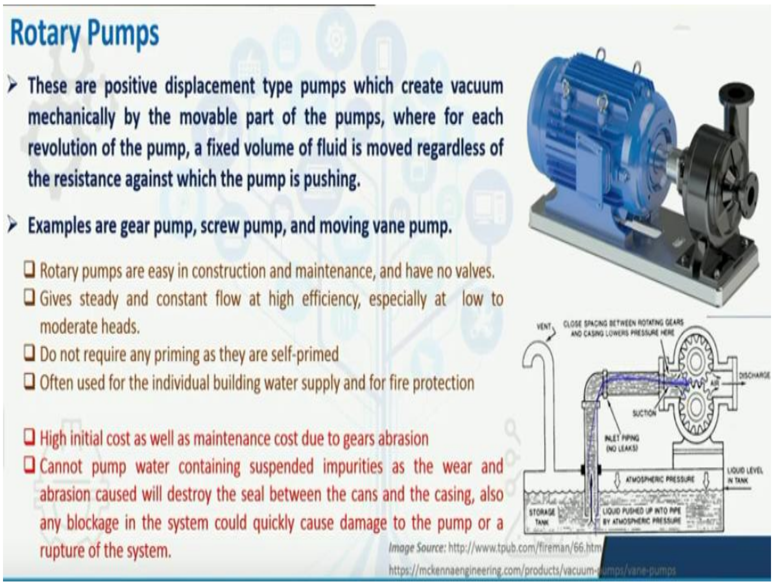
Then jet pumps are again a very popular type of pumps which are used for relatively like different level. So the jet pumps could be of different type. There are shallow well jet pumps, deep well jet pumps or submersible jet pumps okay. These are typically powered by electrical motor which drives an impeller and this impeller moves water well through a narrow orifice okay.

So there is a very narrow orifice which is jet and it moves the basically when the water is comes out of the jet okay, this contraction of the jet causes the speed of moving water to increase and as the water leaves the jet there is a partial vacuum is created and this will further suck the additional water from the well. So speed becomes very high okay.

Directly behind the jet there would be a basically Venturi tube, which will increase the diameter further okay. So if this is jet, so as we say that the diameter will be increased further and once the diameter increases further basically the speed of the water slow down and pressure is increased. So these are most common for shallow wells okay. Further depending on type it can be submersible or offset to the well.

So jet pumps can be not necessarily has to be put into the water. So there is no priming needed for these type of pumps, okay. They are adaptable to the different depth and can basically pump water from the greater depth as well. Its efficiency reduces when the total suction lift is increased and it may get damaged by sand. So these are the couple of issues with the jet pumps.

(Refer Slide Time: 31:10)



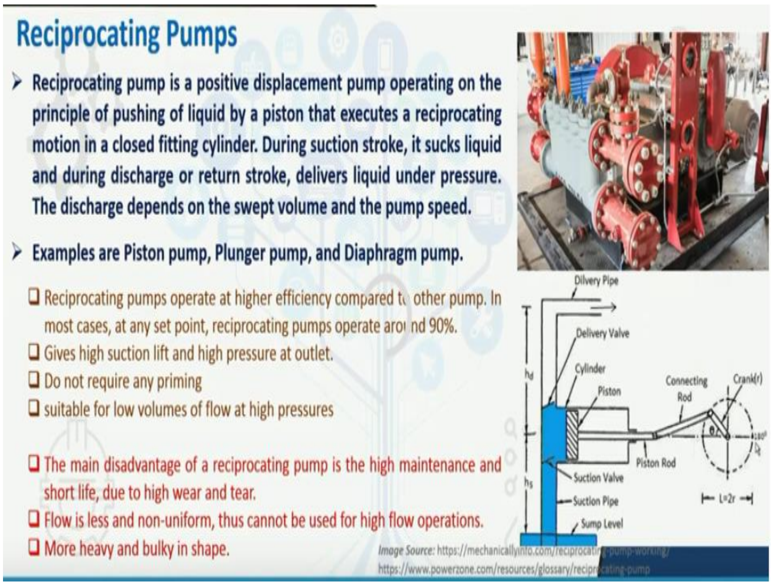
Then there are rotary pumps which are another very simple pumps like uses the concept of gear pump, screw pump or moving vane pump. So rotary pumps is a positive displacement type of pump which creates vacuum mechanically by movable parts of the pump. So when each revolution of the pump a fixed volume of fluid is moved regardless of the resistance against which the it is basically pushing.

So what happens like there would be gears and as they like moves, so a suction will be created and this suction will actually suck water from here. So as the suction is created so they do not priming any, means it is not necessary to basically put pump into the water or put like it has to be filled with water in to begin with. Because of the suction pressure it can actually suck the water directly as well okay.

So these are easy in construction and maintenance. There is no walls that way okay. Will give quite steady and constant flow at very high efficiency especially when we are operating it at the lower efficiency. As the suction pressure is created say they do not require any kind of priming and for individual buildings water supply or fire protection, these are very common type of pumps, rotary pumps.

The issues are that initial cost as well as maintenance cost is relatively higher due to the gear abrasion and if there are suspended impurities so then it is not advisable to use rotary pump because the suspended particles will come and they will basically cause the wear and abrasion and they destroy these can and casing of the pump. So that is one of the major risk of using rotary pumps particularly in the high suspended materials concentration.

(Refer Slide Time: 33:03)



Then there are reciprocating pumps. The reciprocating pumps is basically again a positive displacement pump which operates on the principle of pushing water by piston. So it is simple kind of system. There would be a piston which will be connect by a piston rod and then there is a connecting rod and this actually revolves.

So when this revolves, so when this point goes towards this direction, the direction of the piston will be this and the suction wall will be actually open. It is a two way in fact, one way wall that way. So what happens that suction wall will be open and when this piston moves here, so water will be sucked in here. The delivery wall is closed at that time, so there is no water coming in here.

And so when this reaches here, this will be piston will be at maximum position here and the water will be sucked over here and this actually this entire chamber will be filled with the water. Now what happens after that when the piston starts moving again from this point, so when it is starts then again the moment of piston becomes on the other direction and it will it becomes pushing.

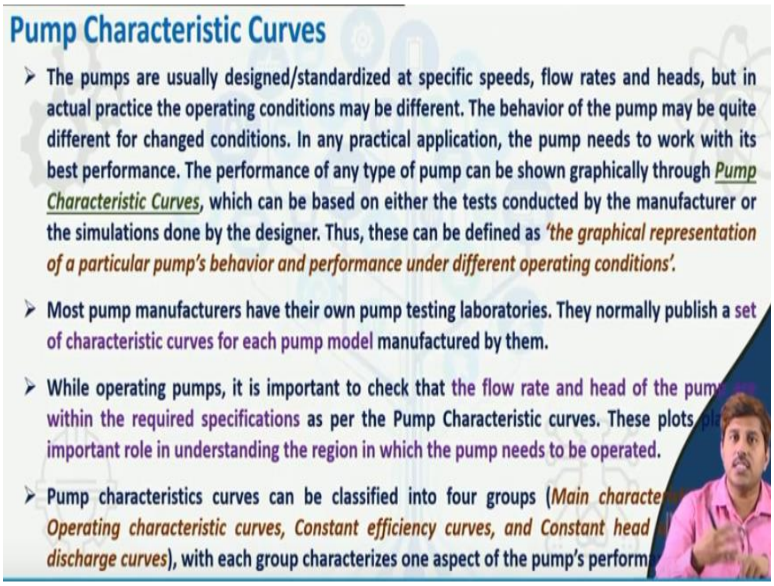
At that time the suction valve is closed and the delivery valve is open. Now whatever water is in the chamber will be actually pushed through delivery wall and it will go to the delivery pipe that way. So it is works on that simple principle, okay. It is very much like straw you can see okay. You can suck the water from the straw so that is what typically happens over here in these systems okay.

During suction stroke, it will suck liquid and during discharge or return stroke it will deliver liquid under pressure okay and the discharge will depend on the swept volume and the pump speed, how frequently it is actually pumping. There are piston pump, plunger pump and diaphragm pump which are of reciprocating type. These have a good efficiency as compared to the other pumps.

In most cases if we are setting up a point it works with a efficiency around 90% okay. This gives high suction lift and high pressure at the outlet. Again, no priming is required because this is creating a suction pressure and it is good and very suitable for low volumes of flow at high pressure. The disadvantage is that the maintenance is higher okay and the relative life of the pump is short because of too much movement of piston and wear and tear.

The flow is less and usually non-uniform. Thus cannot be used for very high flow operation, okay. So for big discharge these kind of pumps are not required okay and these are relatively more heavy and bulky in shape also.

(Refer Slide Time: 36:09)



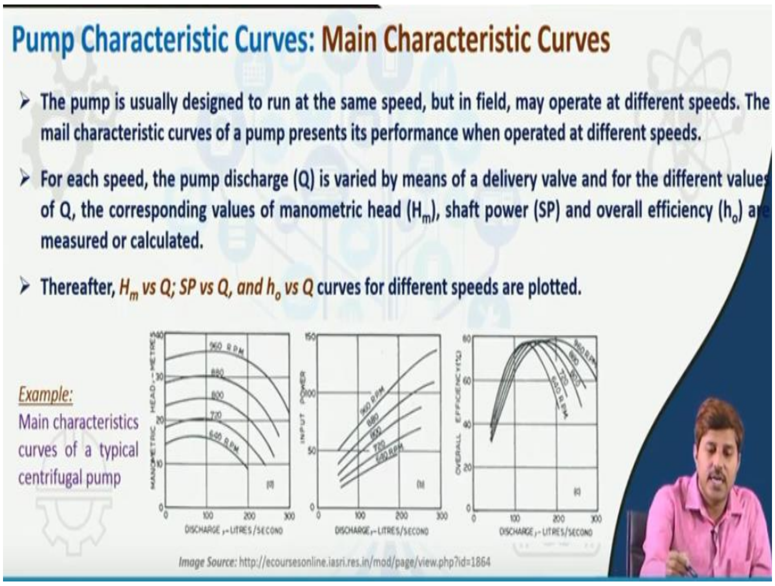
So these are the different type of pumps okay. Now these pumps actually are standardized at one particular speed generally in the manufacturer's place so as fixed speed or specific speed flow rates and heads at which these pumps are standardized. But actual operation does not take place in these ideal conditions. So the behavior of pump maybe different for these different changed conditions.

So for these practical applications pump need to work for the best performance. Now the best performance of any of the pumps are typically shown by the manufacturer to the pump characteristic curves. So pump characteristic curves are typically the graphical representation of a pump's behavior and performance under the different operating conditions, okay.

Typically, the manufacturers have their own pump testing laboratories and they do different kind of test and publish a set of characteristic curves for each pump model, which they manufacture, okay. When we are operating the pumps, we can use these characteristic curves to see the actual performance of the pump and this will also give us an idea that what is the good range to operate these pumps where we can get what kind of efficiency. So these characteristic curves are very helpful in that regard.

These characteristic curves are classified into four different groups. There are main characteristic curve, operating characteristic curve, then constant efficiency curve and constant head and constant discharge curves, okay.

(Refer Slide Time: 37:49)

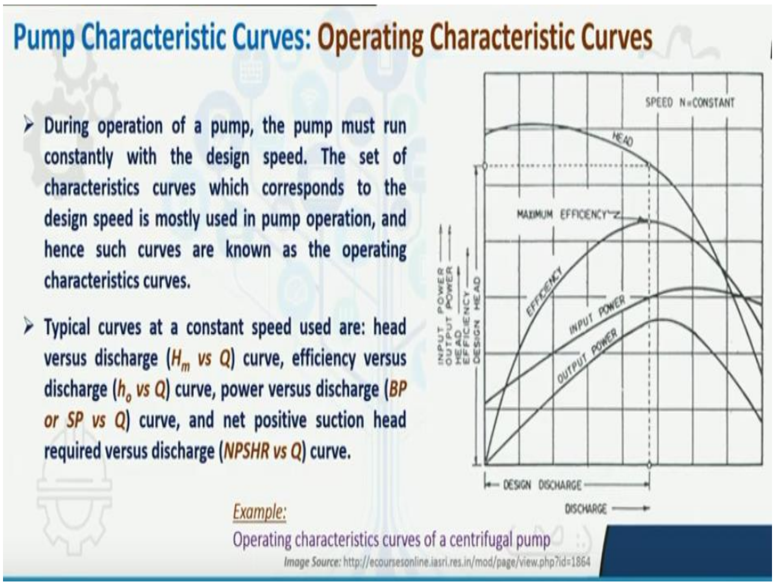


So each group basically tells about the different aspect of the pump. So the main characteristic curves are usually designed to run means, usually to show what will happen if it is running at a different speed. Because in actual the pump is designed to run at a fixed speed or same speed, but in field it may be operating at a different speed, say in field there is no power.

So you may run pump using some diesel engine or some other kind of power, many times tractor power are used for running pumps okay. So if you are running at a different power or different speed, so there the main characteristic curves are helpful in order to see how it is going to perform.

So for each speed the pump discharge Q is varied by the means of a delivery wall and the different value of Q and the corresponding values of the head which is monochromatic head then shaft power and overall efficiency is measured or calculated. And then head versus discharge, then shaft power versus discharge or overall efficiency versus discharge is calculated and plotted and that gives the main characteristic curves of the pump.

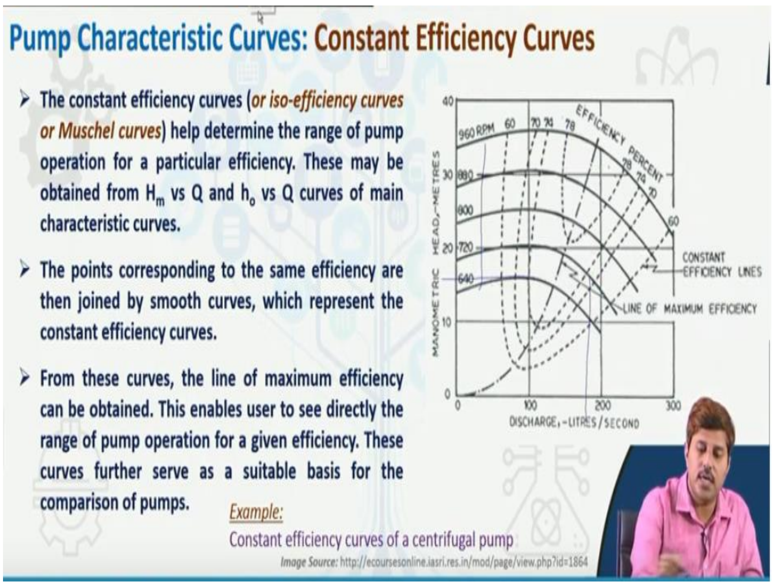
(Refer Slide Time: 39:04)



The operating characteristic curve of the pump are good for during operation purpose. So when the pump is operated, it must run on a constant with design is speed, but the set characteristic curve corresponds to the design speed is mostly used in the pump operation, okay. And that is why these curves are used as a kind of operating characteristic curves.

So the operating characteristic curves will be H m versus Q, h naught versus Q or SP versus Q. And then the positive net suction head required which is NPSHR versus Q under operating conditions under a basically constantly speed conditions, not variable speed, here the speed is constant. So these kind of curves are called operating characteristic curves.

(Refer Slide Time: 39:54)

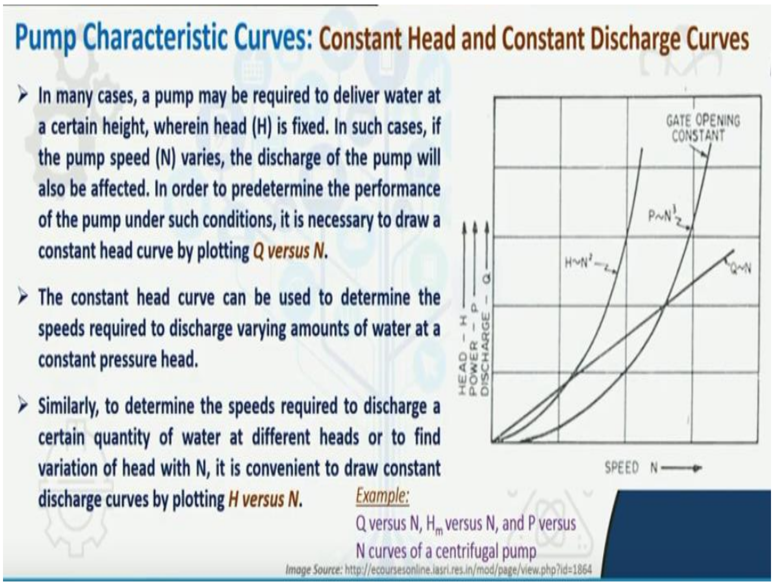


Then there are constant efficiency curves. So these are also known as iso-efficiency curve or Muschel curves. So these help in determine the range of pump operation for a particular efficiency. So you can see that there are iso-efficiency lines like this is 60% efficiency, 70% efficiency, 78% efficiency.

So if you want your pump to operate over 74% or 75% efficiency, so these are the conditions like for wearing discharge and monochromatic head. So by the combination again these are the constant efficiency line and these are the this particular is the line of the maximum efficiency of the pump. This is the RPM of the pump, the different RPMs.

So you can say that say at what discharge what head and what RPM, how much efficiency will be there and in order to operate at a constant efficiency, what the flexibility you may have for the variation.

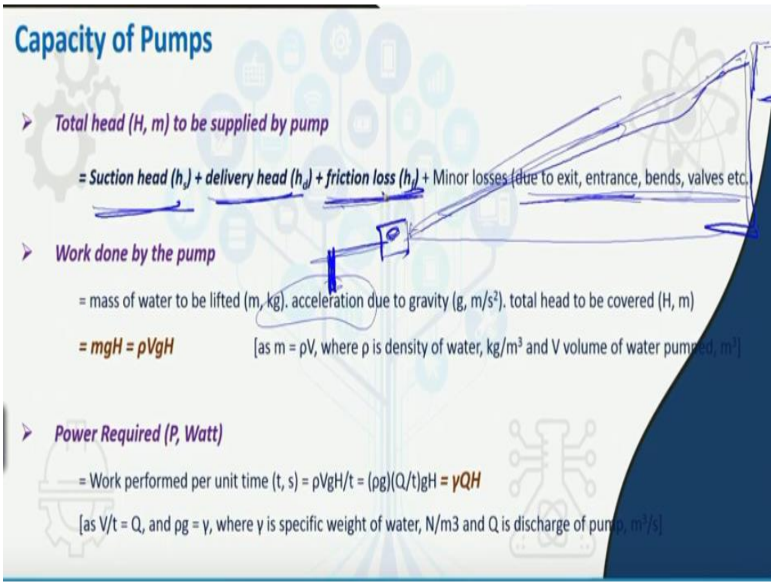
(Refer Slide Time: 40:52)



Then there are constant head and constant discharge curves. So in many cases the pump may require to deliver water at a concert head. So basically when the height is fixed like if you are pumping water from a well, so you know that from which point what point is the suction point and what point is the delivery point. So the height is fixed here.

So in such cases, if you vary the pump speed how the performance of the pump depends. So Q versus N can give you basically constant head curve and similarly, many times when we go for a constant discharge also, so we know that here the discharge amount is fixed. So we can actually plot that way.

(Refer Slide Time: 41:37)



So these constant head and constant discharge will also give us the fourth type of characteristic curve which might be quite useful in the field. Then, for determining the capacity of the pump, what we do, we first calculate the total head that needs to be supplied by the pump. Now this total head is suction head, delivery head plus friction loss head okay.

So that means like if you see a typical system if say this is my water source okay and then this is my say pumping station okay, so this becomes my suction head so from where the pump is and how deep the water is suction head and then we have to deliver the water to an overhead reservoir. So this becomes my delivery head. So this is the suction head and delivery head.

And if we are transporting this water through pipe or let us say this point is reservoir point is located at far rather far of places. So if this is my pump house, this is my source this is suction head to begin with. And then a pipe is laid down like this in order to basically send water to a delivery head.

So the difference in the head here is the delivery head and when the water will be flowed through a pipe system in here so there will be frictional losses as we discussed earlier. So there will be frictional losses which is basically the friction loss which also needs to be covered and apart from that there are minor losses due to entry, exit entrance, bend, valve etc.

So but these losses are pretty less in comparison to friction losses. So that is why friction loss is known as major loss component in pipe flow. And these are known as minor loss component in pipe flow which is very little and particularly for raw water intake can actually be neglected often. So for knowing the capacity of the pump we must know that what height it needs to be basically suck the water.

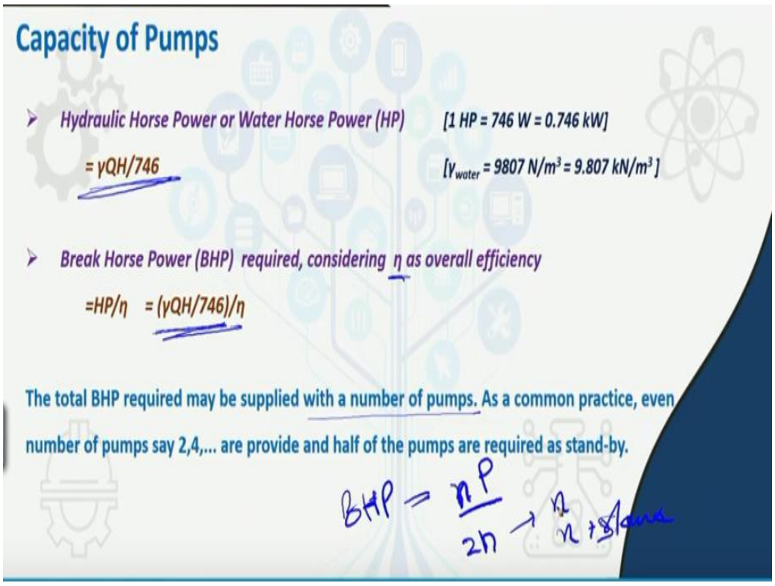
So that will be suction head, what height it needs to deliver the water so, that is my delivery head and when I will flow through this pipe, what is going to be the total friction losses at least. And then if we know the minor losses it is fine otherwise we can ignore them. So work done by the pump we know that work done is basically mass of water to be lifted, so in kg.

Then acceleration due to gravity and then total head to be covered. So mgH mass into gravity into the total head that needs to be covered is there and mass can be represented as the density of water into the volume of water pumped. So this becomes rho VgH. Now power required would be the work performed per unit time.

So rho VgH divided by t okay, which can be written as gamma QH okay because rho g can be written as gamma which is the specific weight of the water okay in Newton per meter cube and this V by t, V by t is actually the discharge okay because volume of water pumped per unit time. So that will become actually, this will become gamma and this will become Q. So gamma Q into H becomes the formula for this okay.

So the total power required is gamma QH and this power required is in watts okay. So that is how we can basically estimate the total power required by the pump.

(Refer Slide Time: 45:30)



Now the capacity of the pump further if you want to determine in the terms of water horsepower or what is the hydraulic horsepower needed for this, so for horsepower we know that watt can be converted to horsepower by dividing 746 in one HP there is 746 watts or 0.746 kilowatts typically. So it becomes gamma QH/746. That becomes horsepower and if we apply the efficiency criteria that overall efficiency of pump is say eta then the brake horsepower or BHP becomes the horsepower divided by eta.

So this is the total power that would be needed gamma QH/746 which is basically the horsepower and we divide it with the pump efficiency. So this is the total BHP required which may be supplied with the number of pumps. As a common practice even number of pumps are used like 2, 4, 6, 8 that way used. It is not mandatory though.

Many times like particularly if the number of pumps required is large we can go for odd number as well and half of the pumps are required as standby okay. So if let us say total BHP needed is known to us. So we will see that n number of pumps of say, some specific power would be actually sufficient for this.

So we provide generally 2n number of pumps where half of the pumps n number of pumps will be working and n number of pumps will be standby okay. However, if n is too large we do not need actually to just double it. For smaller like if you need just say two pumps so then it is better to provide 4 pumps, 2 working and 2 standby. But if you need say 20 pumps, so it is not necessarily to go for 20 pumps as a standby.

You can have 10 pumps as a standby and 20 pumps as a working at any time okay. So in order to see the cost, that kind of aspects can be used. So we will conclude this discussion here, okay. So we did talk about the major aspects related to the intake of water, beginning from the source. Then the how we put and take structure for surface water sources, groundwater sources, how water is pumped and then how water is conveyed and how we can estimate the pump's capacity.

So we will conclude the week's discussion here. However, in the next class we will have one more lecture in this week where we will take some practice problems or worked examples to demonstrate how some of these calculations that we discussed are done for the real field problems. So thank you for joining and see you in the next class.