Bulk Material Transport and Handling Systems
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Lecture 12
Principle of operations and applicability

Welcome. Today we will be discussing another new way of transporting. New in the sense that this is a very older system that using liquid for transporting solid material. See earlier you might have a heard about the collecting logs in the river. During the rainy season lot of logs from the hilly areas are collected by the riverside people. So that is exactly the whole solid logs is being transported by the river fleet.

So, like that in an open channel sometimes we want to get the using the liquid flow ability or the flowing liquid for carrying materials. So that means just like your boat can float through the river. Like, if you can get some of the things mixed and then allowing them to go through a pipeline that is giving a making the material to flow in water suspended manner that in other way we can tell that sometimes it to face flow.

Or we are making the material to be conveyed through a pipeline. So that type of transportation system is called Hydraulic transportation system

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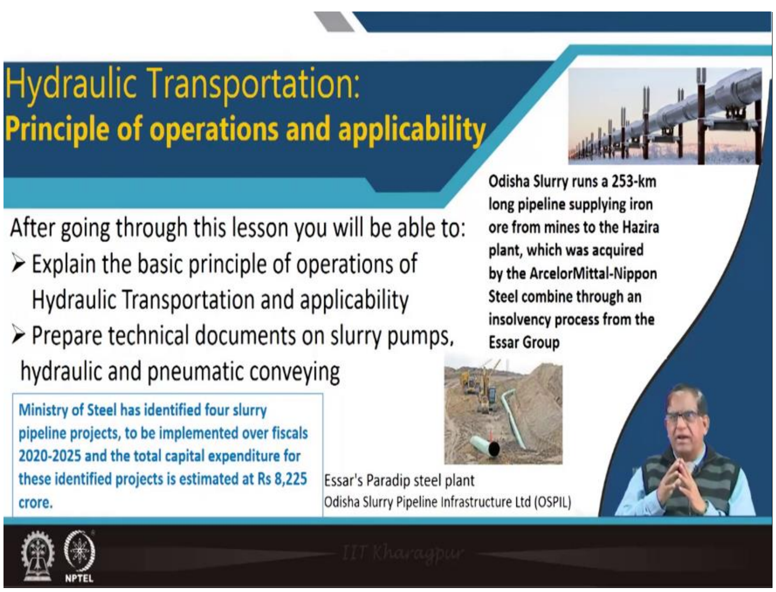

Now, in a Hydraulic transportation system, we will be discussing various aspects of it but mostly after going through this lecture you will be able to explain the basic principle of operation how exactly the hydraulic transportation takes place. That means the solid is a suspended in fluid can be transported through pipelines and that live fleet can be either water or it could be gas or air. So that is why we have got two basic hydraulic transport system.

One is your slurry transport system with solid mixed in water and other transportation system is the pneumatic conveying or suspended in air. Just like in some of the cement pipeline, flyash pipeline, you are just making them to be pushed through pipeline by air. That is a pneumatic conveying is another hydraulic or another free transport system. Now, in water slurry hydraulic transport system we use the pumps and then you allow the material to be introduced to the pipeline

And then we at the end, we dewater it and then take it back. So that is how it works but after this lecture you should be able to prepare some technical document. You should be learning how to get the information from internet, from book and from other sources and then compile a technical writer. So, after this lecture you should take up that activity so that you can write a technical note on the slurry transport system.

So, you know that slurry transport system in India is now, getting a boost because the government has cleared four slurry pipeline system and which will be completed by 2025 were an investment of more than 8000 crores are being done. So, this is another area and it is of course in Odisha one major state of mineral producing state in India, there Essar Paradip steel plant they started in a big way with Odisha study pipeline infrastructure limited a company.

Which started working with new metal of Maurice's. Now, of course that company has been taken over by ArcelorMittal and Nippon group and this is going to be having more than 253 kilometer of pipelines will be working in over there. So, this invites that there should be a lot of the studies regarding the design of it, regarding maintenance of it, regarding operation of it, regarding it is a that is your how the productivity can be managed with it. So, those are the things which will be coming in near future.

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So, this is the area which is really important for our bulk material transportations. Because as we see that whether it is the tailings of a mineral processing plant, or a say for example in a bauxite processing plant in Illumine plan the red mud is deposited into the tank. Similarly, in a (())(5:22) they are also transported like this. So, there are many areas particularly when some of the tailing dams where we have good steel.

Some of the iron ore that hematite content is still there up to 40 to 45% those tailings, if it is to be remined and taken over there they are the hydraulic mining may come in which will have to transport the material in the slurry form. Similarly, you know about this in the dredgers operating in the ports that are the rare earth minerals that is being mined all are by in a slurry form.

And then there we are using it but, if some of the other transportation system by truck or by rail, if it can be converted to that your hydraulic or this slurry transportation system there could be many advantages like it has got a huge capacity and then it is a very safer it does not give much that surface footprint in the sense it does not require a root surface to be maintained, it does not require a conveyor like that structures to be relayed.

It can be laid on the ground at a minimum work on the surface we can lay a pipeline and it does not obstruct other activities. So, then it can be laid in a very short time that is for eduction of a railway line or eduction of a road network or a conveying belt, there is a lot of time required for its construction but a pipelining is not much difficult and not much time taking. And it also by it can use the natural gradient many a time and then very less energy is required to transport the material.

For example, when our Kudremukh iron ore project they were having a 64 kilometer of length this iron ore transportation from the Kudremukh mines to Mangalore port that was very without having any energy because they were using the Kudremukh being at a higher elevation Mangalore port at the lower elevations, the ones that slurry form it started flowing and that is the way how exactly the advantage of using this slurry pipeline.

And it is very environmentally free that is environmental friendly because it does not give any particulate matter to the air it does not create noise like tracks or rail they will be creating so much noise and when that tracks are rails good through the forest because of the noise many times the birds cannot mate birds mating get disturbed because of the heavy noise coming all the way and then when our production rate will be increasing.

And will be more frequent movement of these tracks or rails, they can exactly give a very adverse impact on the forest but, if through the forest, a pipeline is laid, it will not be having any problem any environmental issue. So, there are a few issues regarding the water consumptions and all but easily that water which is used for there a large extent of it can be again recovered in short distance slurry transportation which is there in some plants there the water is reused.

So in that way it is overall environmental friendly. But there are disadvantages that you will have to your bigger say in a track you can take even a one meter lump size but in this case, you cannot carry this lumpy material. So, we will have to crash and grind and then prepare slurry for that again some energy consumptions will be there. So, there are certain disadvantages but you will have to judiciously think that where we can have it.

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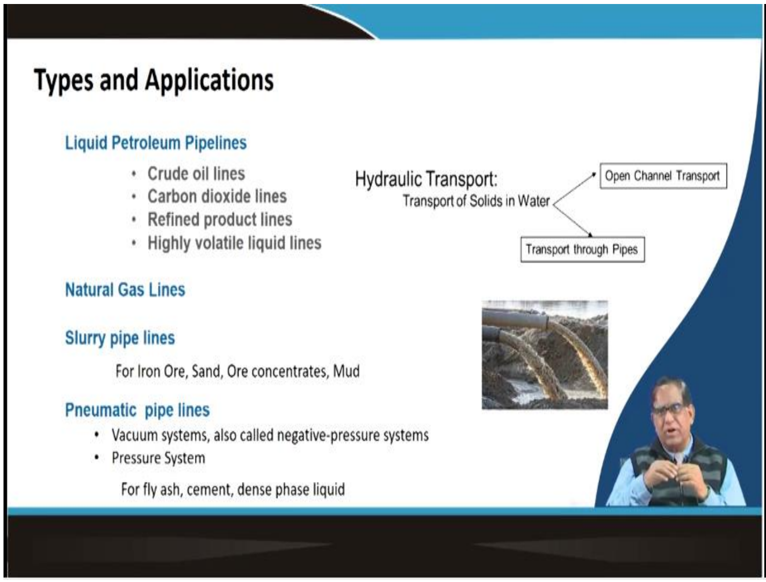

So, as I already told you that it can be different type of applications of the pipeline transportation system, where a single phase could be a water pipeline you have seen in the municipality that pipeline it is used for taking the liquid bulk. Similarly, the crude oils that is being distributed your carbon dioxide lines that is also there for your in the oil industry you will be finding that for some times.

For that your enhanced oil recovery they send the gas carbon dioxide gas, if it is available or the flue gases which are available from the thermal power stations that can be taken back to the ground and then they will be kept over there and it will be used for pushing more oil from the reservoir there you will have to transport this carbon dioxide gas. Similarly, your refined products lines that your oil from the oil refinery the oil is taken out to the tanker.

And from there it is distributed through pipelines. Similarly, there will be other highly volatile liquids also can be transported over here. So, this in the petroleum industry, pipeline transport is a very important and that is why in any field petroleum engineering studies your this pipeline study is a very, very important integral part of it but natural gas lines that gas transportation pipelines also there, those of you who are who know about the Gas Authority of India Limited GALE.

They recruit a lot of pipeline engineers for their gas networking system. Then slurry pipelines which are used in the mining and mineral industry for iron ore, for sand ore, concentrates mud as I said in the dredging and all that operations you use it over there. And the pneumatic pipelines that is in that solid in air in that form it can be used for either in a big warm line or in a pressurized line.

They are used for the flyash cement and also the danfoss liquid in the food industry there they use lot of this dense flow systems for any of this even the pastes and all they can be pushed through the pipeline by air and because the air can be very easily kept in the pure form by filtering and it will not exactly give any impurity to the food product. So that is why many pneumatic systems are used in the food industry for bulk transportation systems.

So that hydraulic transportations in a nutshell we have got mostly in a closed through the transport through pipelines and that open channel that is only for just making that as I was telling in the log floating in the river.

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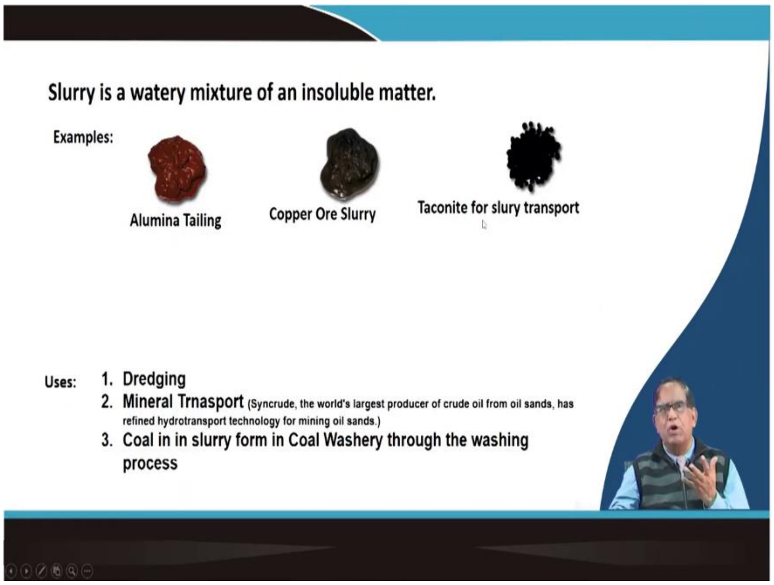

So, this is the way how the transportations through pipeline is coming. So, when we talk as a slurry. Slurry examples you can see that Illumina tailings that red mud in the aluminum industry it will find this. Similarly, the copper industry also copper ore it is in a slurry from transported in

US and all the taconitrates say iron ore this iron ore mine loads in the form of taconite it that is also made in the form of slurry and in India we have used hematite.

Also in the zinc mining rather put Dariba mines of Rajasthan they are exactly they are using the zinc ore also in the form of slurry they were transporting over there. So, other thing as I have already said in the dredging in mineral transport in a coal slurry the black mesa coal slurry pipeline was one of the first pipelines in the UK which exactly created the study transportation system as a big economic cost benefit twice so, it was very good.

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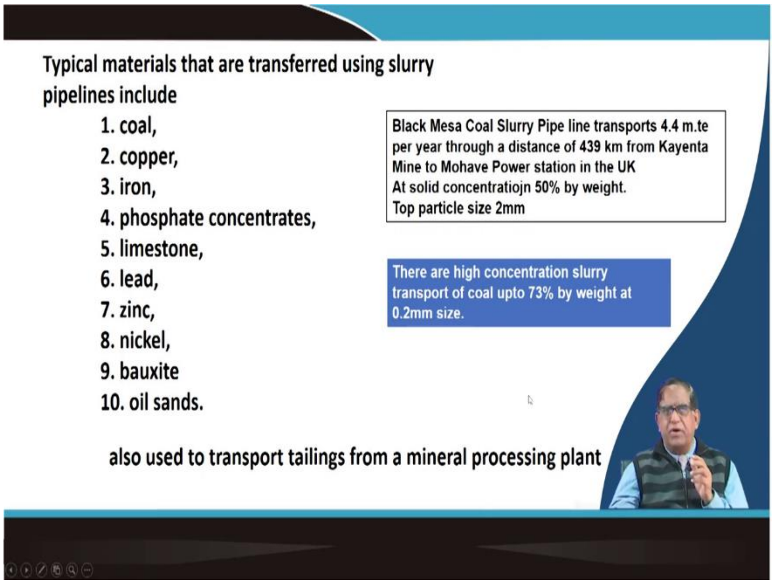

So there is a wide range of areas in which this slurry pipelines can be used and our one of the use is for our environment management that is your tailings management there also you get a lot of this use of the slurries over there. So, I told you about that black mesa pipeline is 439 kilometer pipelines where there were exactly this. This pipeline was one of the very pioneer and they were taking coal up to 73% by weight and they were crushed up to 0.2 millimeter size.

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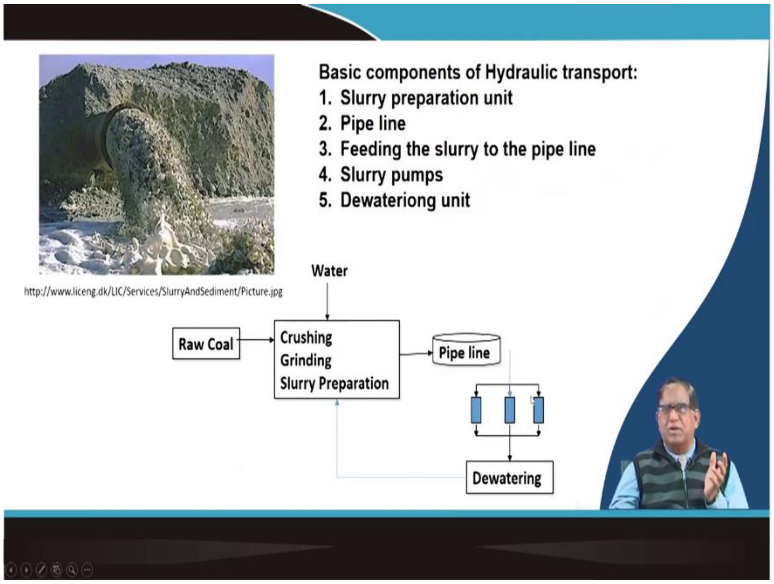

And they were being transported to the thermal power stations. And then in many of the tailing dams and tailing gestures either you can see by this slurry transportation system. Now, if you see the what are the system components? Well, I am using the word system that system means it is a total of number of different components and they are making them to work together which includes some your hardware, It includes software, it include one power.

So, when we talk of a slurry transport system will have to have some of the different ingredients particularly the raw coal or raw material, raw iron or whatever it is and then water are they will have to be mixed but the material must be cross grind and then the slurry preparation will be there where could be agitator, where it could be or sometimes in some of the cases in case of your some transportations.

You can directly just feed into force feed you can put it over there. Now, the pipeline will be going and then up to a certain distance where it is to be used again you will have to dewater. Take the water you can make the water to fill back over there you can make a different use. So, for doing all these things there are other subsystems there. So, today, if you are going to work on in a soft skill.

You can make a lot of how the whole control and operations can be made a digitalized to digitizing the whole transportation system by properly collecting the data by different information’s. That is another area you can think of some of you may be working. So, if there is a 250 kilometers or 400 kilometer long transportation line, if anywhere there is a crack or break or some accidental damage is there from your endpoint.

How it will be pinpointed and telling within a very short distance you will be locating where the problem is there. So that type of your surveillance and monitoring systems will be coming. So, these are the things as another auxiliary subsystem are there in your this whole study transport system

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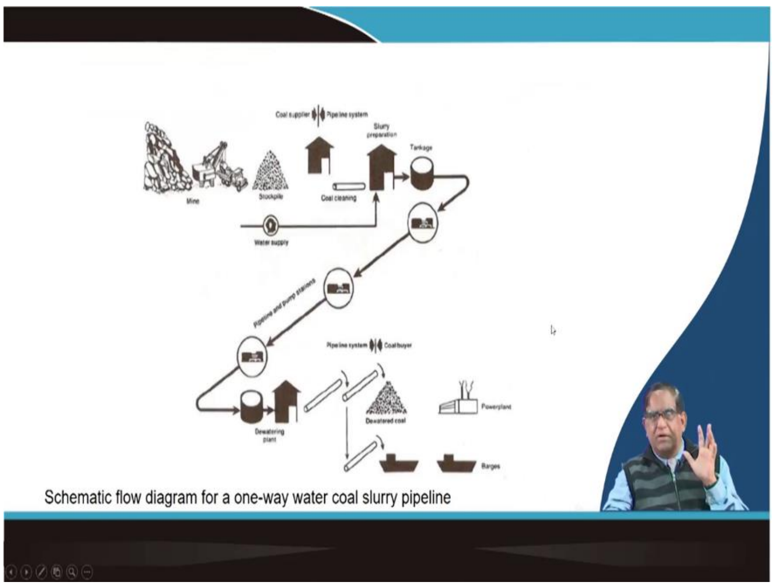

So, you can see here this diagram in which we are having a mines from the mines by your mining machinery they are producing and they are keeping the ram of mine in a stockpile from there it is exactly going to the preparation plan where they are exactly doing the required cleaning and then after that they are crushing and making the that slurry will be stored temporarily there a slurry storage tank.

From there it will be pumped there will be pumping stations from their pumping stations it will go through the pipeline. There could be in between some booster pump depending on how the losses will be there, if the pipe is making a lot of curves, lot of turns, lot of bend then there energy will be lost. So that loss of head need to be taken up, if you have to at some part of the terrain you negotiate a high elevation, there you will be giving another booster pump.

Obliged that it will be bringing up to the distant location where it will be received that receiving also will be just going to a receiving tank. So that there will be a buffer stock and from there it will be put for the dewatering plant. When the dewatered, you take the water out for other uses and that solid material they will be putting over there. They can be dried and then they will be again stored somewhere and from their stockpile you can send it to the user.

Or it can be further processing for example in the Mangalore after it was dewatering you are getting those moist iron ore that was a your mainly magnetite ore dozer again pelletized. So that in the pellet form only it was exported to Iran and Iraq in those days of good days of good iron ore Company. So this is how exactly is slurry transportation system works. So, I hope by now, you will be able to explain that what are the exactly uses of slurry transport system.

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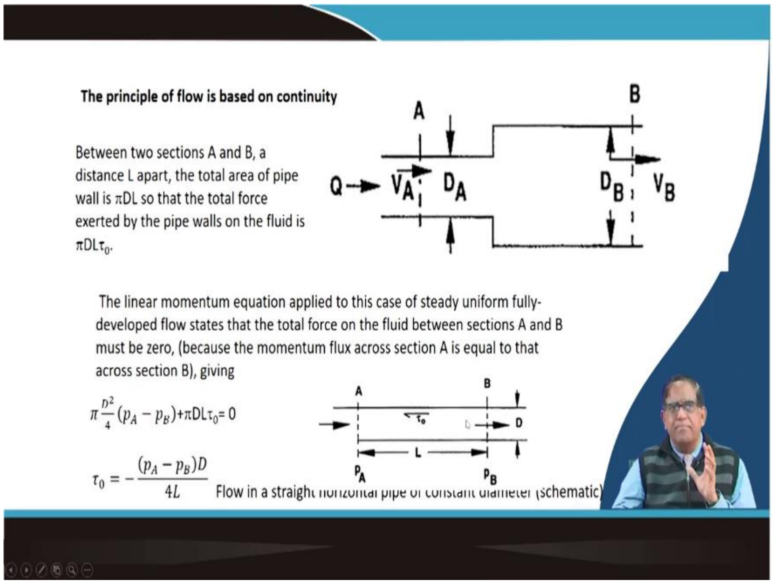

And what are their main slurry transport components. But coming to a little bit of the principle here exactly is a pipeline flow in your first year, second year your fluid mechanics class you have done all these things is little recapitulation you can do it over there when a material is flowing you know that the continuity equation that is how much amount it is coming over here the same amount will be going over here, if there is no accumulation is taking place.

So, in that conditions that exactly the diameter of the inlet and diameter of the outlet and at what velocity is going that is very important for this in a pipeline flow. Basically, it is happening a momentum transfer. Now, this wind is liquid start flowing through that you can find out that it is passing through a particular line. It is going in a straight line over here. So now, this at how it is entering it A and how it is leaving at B in between what happens.

That is one of the most important thing that exactly that you are depending on the cross sectional area. And then how much pressure it is given over that same force will be going over here, if there is no energy loss in between.

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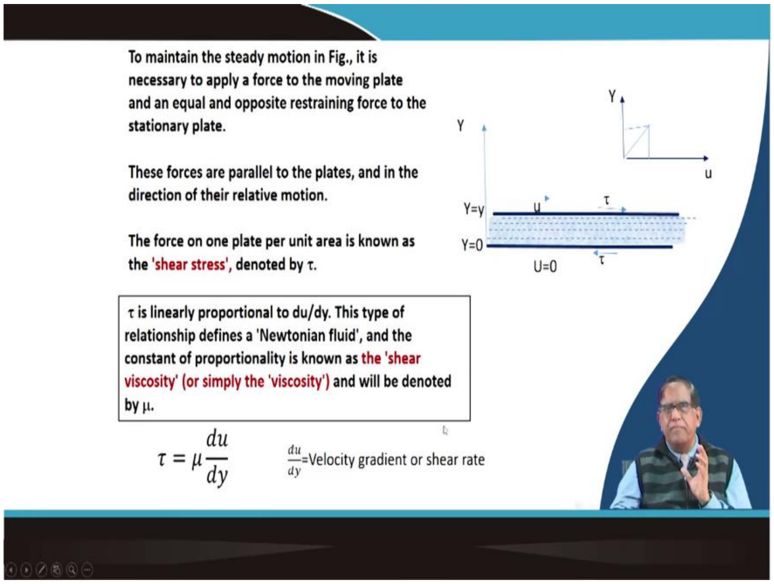

So, this was exactly you can think of suppose you are having a liquid level over here and 2 plates are there now. If this plate is moved very fast and then what will happen, there will be a shear force will be coming up that means your that whatever it is touching with this that fluid also will start flowing and then exactly a velocity gradient will come up that means initially when it is at this point the velocity is 0.

But that when this plate is moved this way, we are getting up to a velocity of U. So now, at this time there is a shear stress is coming up over here in this direction which is opposed to over here. Now, that fluid to flow there should be these 2 opposite stresses must be there then only there a shear type of things will take place and the liquid will move. Now, this to maintain a steady state motion it is necessary to apply a force to moving plate.

And then equal and opposite restraining force in the stationary plate that is a condition on which this flow will be taking place. Now, this tau this is exactly is known as the shear viscosity is the property by on which this stress development will be depending. So, you know about that this stress is calculated that is based on this viscosity and then that you are the velocity gradient what you are getting

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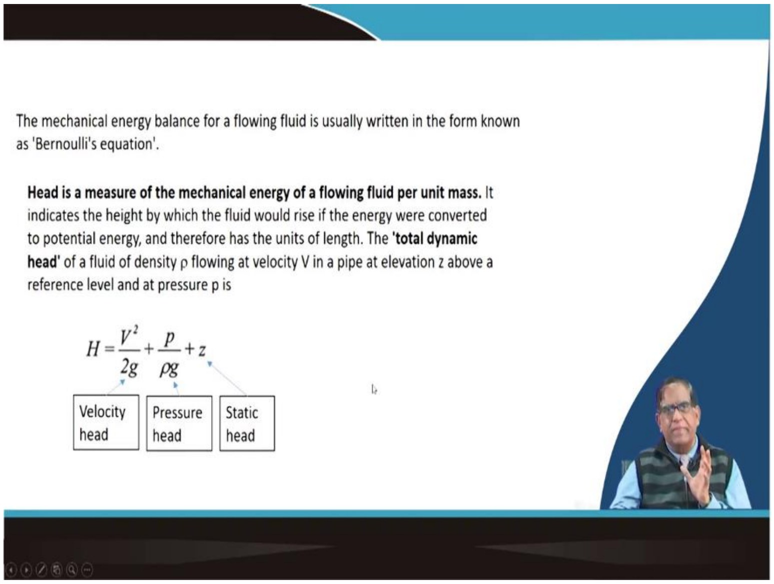

Now this velocity gradient or shear rate that will be depending. Now, whenever you are to make a pipeline flow to be there in that case, you are this mechanical balance of energy is necessary. Now, this again here you can recapitulate the Bernoulli's equation which you have said that the total head which will be there that is on the velocity head, pressure head and the steady head. So, you can just go through your second year knowledge of this fluid mechanics in which you have learned.

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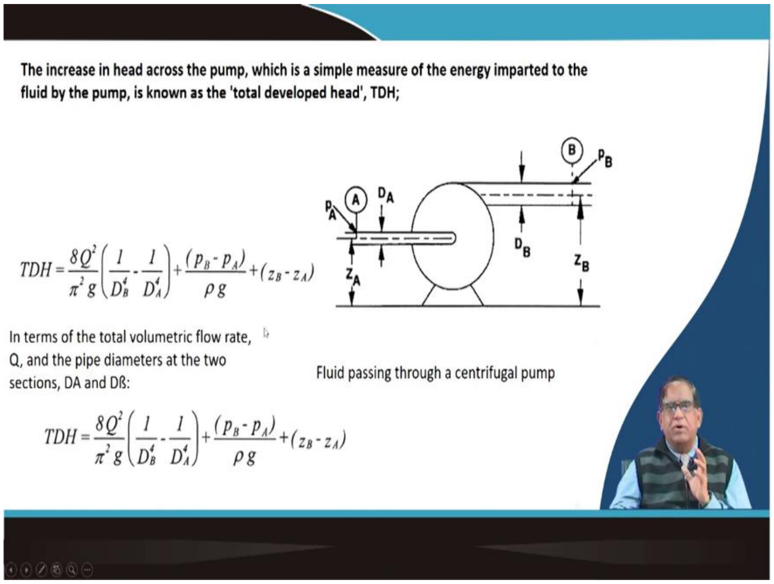

And that is how exactly in your fluid now, will be passing through a pump to get it over here. Now, that whole total movement inside this will be that how that head is created that this total head creations it depends on these different parameters that what is the flow volume and they are diameters and the pressure differences which need to be created.

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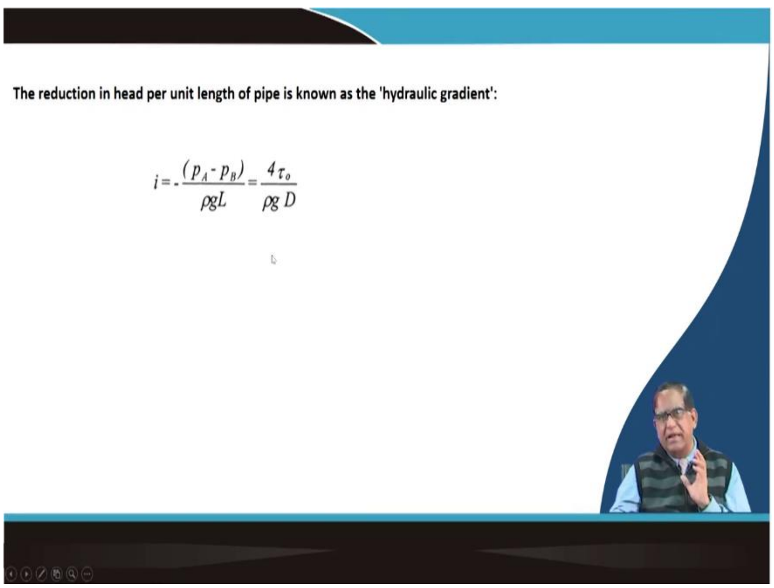

So now, that same thing when you are to do with the total head creations, there should be a gradient. That is with this hydraulic gradient is important parameter one which your whole pipeline flow will be taking. Now, here and other things whenever we are talking about the flow through a pipeline another very interesting phenomena is or you need to know about the Reynolds number.

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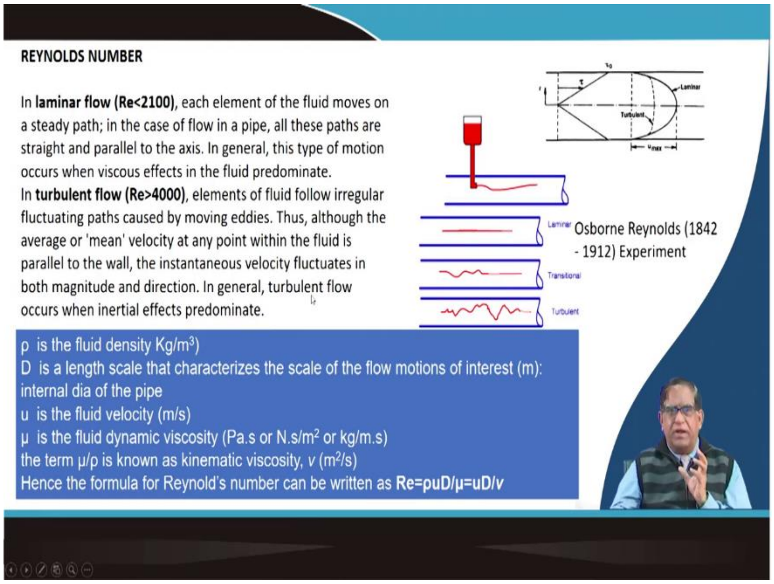

Which is again say Osborrne Reynolds in the 1842 to 1912 his life span. He did a very fundamental thing which is still continuing. One experiment what is done, if in a pipeline water is flowing over here and then you just put some color and you can see how the flow is taking place. Now, depending on that at what speed the water is moving over here there is a this color you can see here that means there the particles here is moving in a very straight line.

But here they are just giving a there is a zigzag manner it is moving over here and from this to this, there is a change too. So that means when you are increasing the speed at very high speed sometimes these things happen. Only at a particular speed it will be going like this so, these observations led to development of this Reynolds number concept that is which is defined exactly as a your V D by d u.

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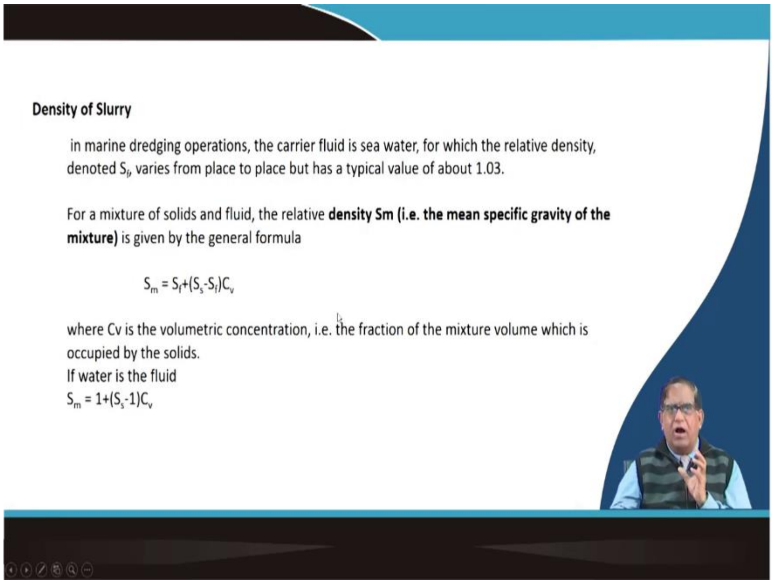

That is the formula of Reynolds number when it is calculated there when you find the number is between your less than two thousand you get this laminar flow. Now, in a laminar flow what happens over here you can see that the all particles are it is moving that is the highest maximum is there at the center point and the velocity gradient exists in both directions that means uniformly all the particles are uniformly moving.

And this when that Reynolds number is less than your 2000 below is, if it is more than 4000 then this things happens. That means your the particles will be making some eddies in between. There is a small and then the velocity profile it becomes different and it became flat and there, if you have now, some solids over there then the movement of the solids will be taking a zigzag part. So that is where you although this laminar flow and turbulent flow.

So that two material to be carried over here we will have to get in a how the particles will be moving. Now, for the particle movement, we now, need we are forming a slurry. When you make a slurry then the density of the whole that fluid which is flowing that will be determined by what is the density of the liquid and the density of the solid and you can easily vary from basic fundamental you can calculate it out.

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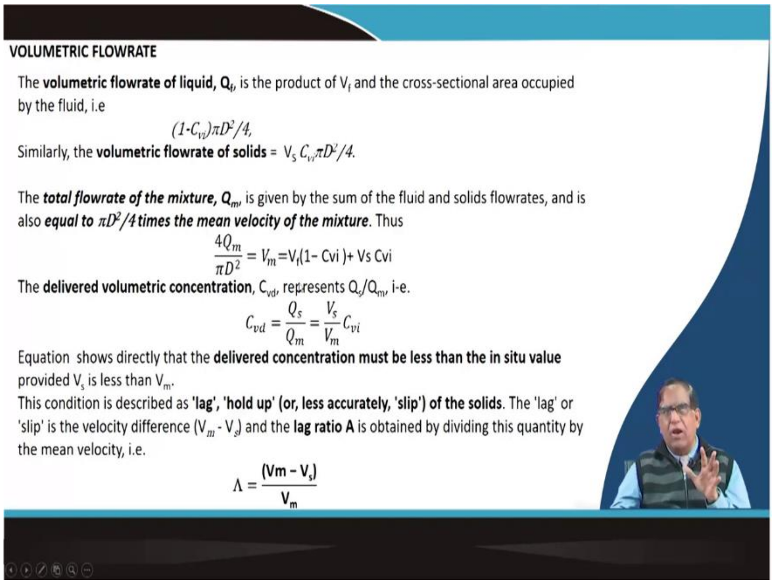

Now, once you know that density, what is more important is the flow rate. That means in a pipeline while taking the coal slurry or iron ore slurry. Now, water or in a dredger when you are doing the first collected by the dredging machines and then putting into the pipeline that we can say is that the incoming side that is your their concentrations and then what is the delivered at that time the concentration.

That concentrations will be exactly making, how much material is there in the pipeline. Now, there is a very simple calculations you can make, if the volumetric flow rate that is your what is that as there the fleet velocity and the cross sectional area, if we are making it, if you are this C v i here is the concentrations. So that means the area into this will be giving you the volumetric flow rate. Now, that in–depth because the concentration of the solid in the inlet side or it is called an insitu that C v i, if it and then at what velocity it is moving.

If it is known that is by knowing that and the diameter of the pipe is D. So, you can find out that is the volumetric flowrate of the solid. So now, the total flow rate that is in a mixed now, that there is water going as well as this your coal is going. You mind it whenever we are talking of a slurry transport we are only talking of the insoluble material. So that is why whatever the mixed things at the mixer, they will be having a different volumetric flow rate.

Their flow rate is that we are telling Q m. Now, it is given by the sum of both these things and that was we will be depending on the diameter we can find out that at what velocity this will be moving. So then, if you know that how the mixture is going at what velocity from there you can find out at the delivery side, what is the concentration of it, the total quantity of the solid and the total quantity of the mixture that will be giving that your concentration at the delivery side.

So, this gives one thing, if you are getting the concentration of the delivery side is less than what is happening that means something is getting deposited in the pipeline. Now, the flow behavior the velocity will have to maintain in such a way that a maximum that is your these deposition inside is getting minimum and that is will have to be engineered by selecting proper pump, selecting proper diameter maintaining the pressure heads.

So when you are to do that there is one factor which is called your lambda or that lag factor. That lag factor is nothing but the differences of this velocity of the mixed material and the velocity of the solid there the percentage is called as a lag factor.

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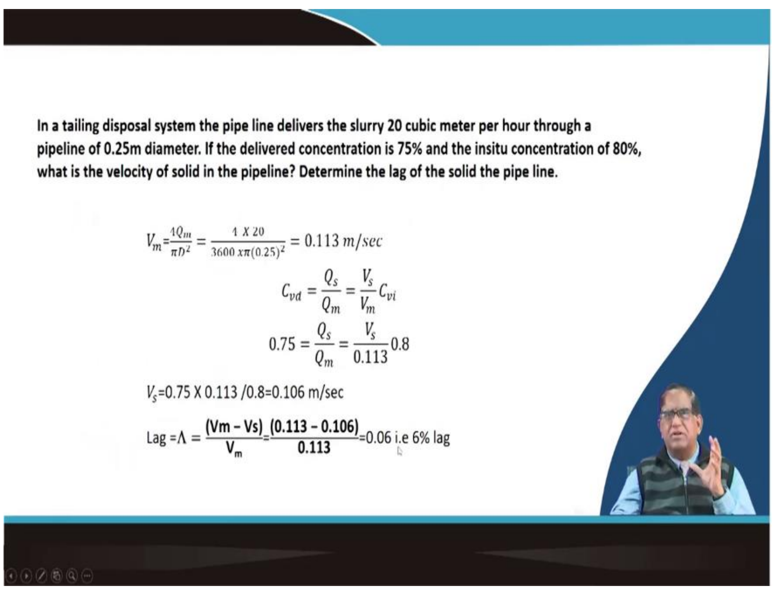

Now in a just for an example, you can think of in a tailings disposal system the pipeline delivers slurry at 20 cubic meter per hour through a pipeline of 0.25 meter diameter. If the delivery concentration is 75% and the insitu concentration is 80% what is the velocity of the solid in the pipeline? And then determine the lag. So, what in the problem you can see that, if we know the concentrations.

And, if we from there, we can find out calculate out what would have been the velocity of movement inside the pipe and then once you know there is a differences in the velocity of the solid at what speed it is going because at the end delivery side, whatever the concentration you have got that shows that exactly how the solid was moving. So, by taking this out, this simple example you can find out that once you find out this velocity of the mixed material.

And you can find out the velocity of the solid, their differences we could find in this particular example that is 0.6 that means 6% lag is there. Now, depending on the pressure and then depending on the pumping arrangements, we have got the capacity up to which we can take a lag. Otherwise after some time the whole pipe will be getting jammed.

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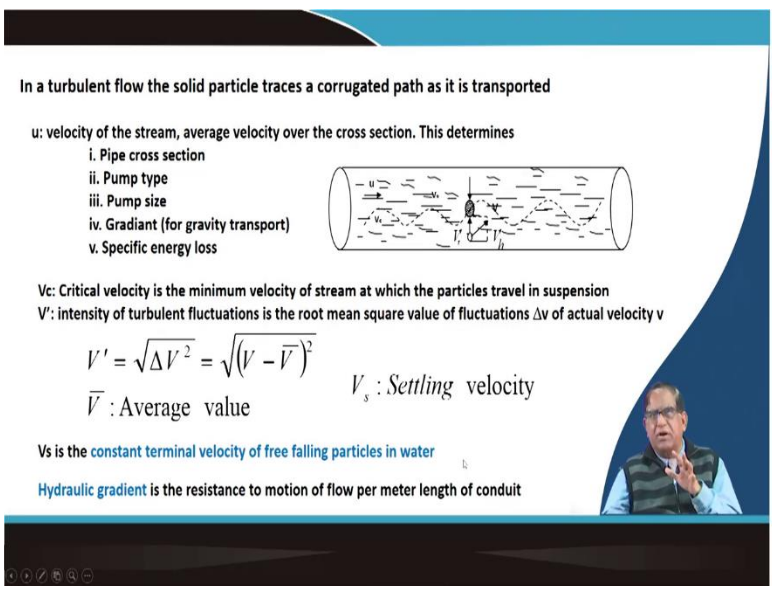

So, one of the main problem that you are in a pipeline this particular should not get shuttled and jammed. And that is again by another concept of fluid mechanics you may be knowing which is called your settling speed. When a particle is moving like this then there a; it has got U that is your that mixture velocity, if it is moving in this direction, there is a critical velocity. Below this critical velocity this particle cannot stay suspended over here.

Because it has that because of the gravity has a tendency to go and settle down. As a result what happens with this velocity the particles will be following a zigzag motion depending on that because it is the turbulent fluid. Even a laminar flow it will be very difficult to maintain this your particles to remain in a suspended form. So that is why we will have to make in the turbulent region you will have to make it to flow.

And those are the things exactly in the rheology study of slurries rheology you need to find out that how much we will get settled over here. Now, this velocity of the stream that is your average velocity velocity will be depending on the pipe construction, pump type, pump size, gradient then specific energy loss and then you can find out this critical velocity which can be calculated and then from there you can find out.

That what is that your turbulence what how much turbulence or intensity of turbulence in the fluctuation will be necessary and that will be giving how much this formula are used in fluid mechanics for calculating it out. Then this constant terminal velocity of free falling particle in water that one will have to be determined for finding out.

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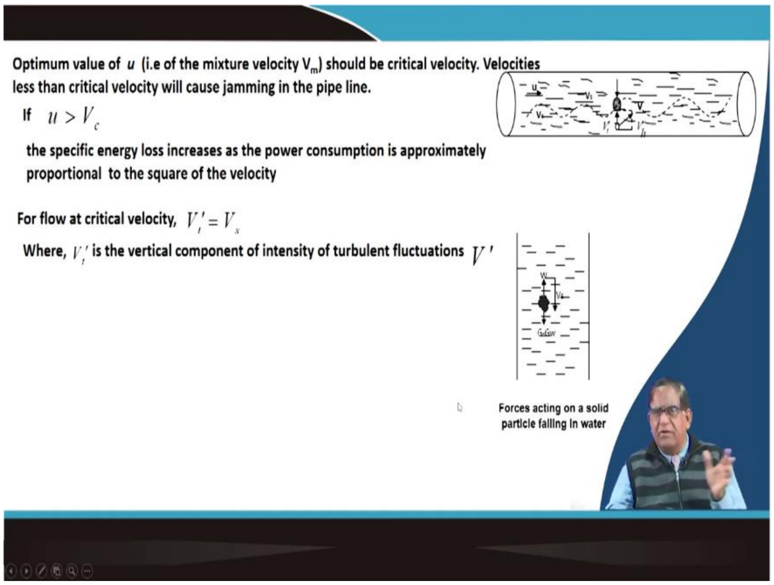

So that is what as a condition your this V U that is your the mixed velocity as in the earlier we have said as v m it must be greater than the critical velocity when it is greater than critical velocity then only the particle will be transported through a slurry pipeline.

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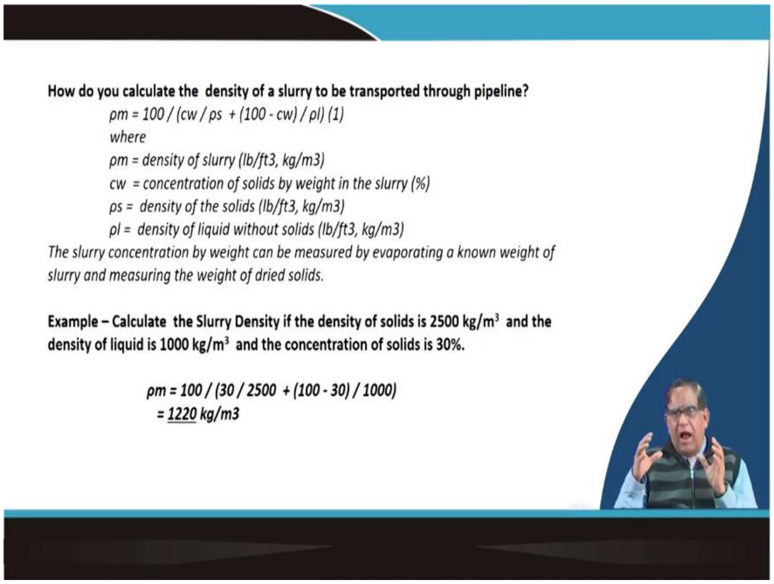

Now for then we have already known that how will you calculate the density of that at what density it will be coming. You can just see this can be easily calculated, if you know the density of the fluid and density of the particle then you can find out the density of the that slurry. And once you know that density because density will be affecting your settling speed and then the property will be raised.

So this type of simple calculations will be good for you to know that how exactly the density of the whole mixture will be coming. Now, your that whatever the pump size will be there because the total energy which will have to be imparted to the fluid to get flow will be depending on this density.

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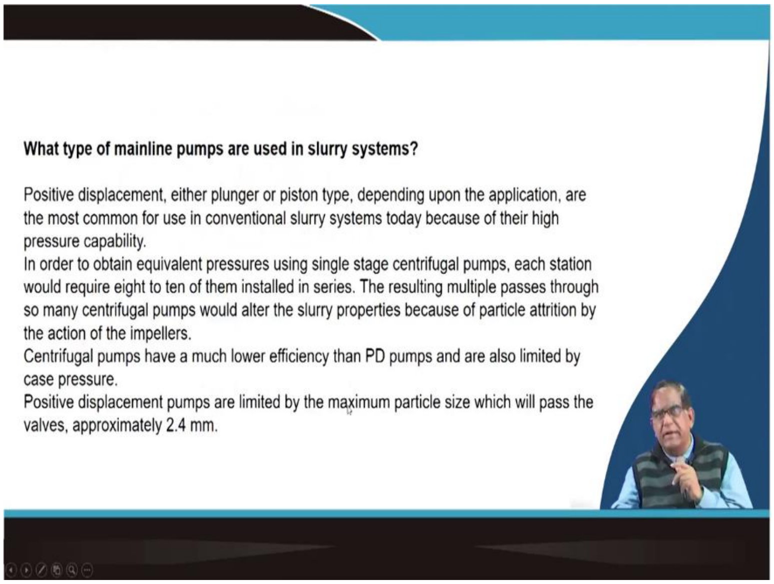

Now for that in a study pipeline system you will have to specific you will have to know about what type of pump you will be using. There are many different type of pumps which are there but this positive displacement pumps are they are found that they can be used but there are all pros and cons. That is your plunger pump and piston pumps are used say for example in a drilling industry the drilling your fluid and mud. Mud will have to be put it over there.

There most of the mud pumps are either a plunger pump or a duplex pump like that they are used over there. Now, for this centrifugal pumps, they have also that can be used but only thing is that there is a the whole fluid will have to go through the this your centrifugal to the bench. Now, in case of your plunger pump or this piston pumps, there the valve sizes that sometimes get obstructed.

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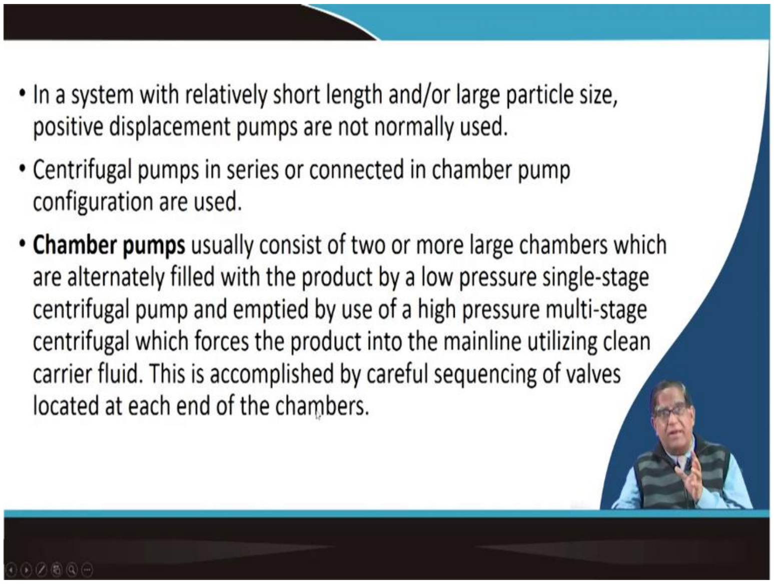

So, there are pros cons for both the types of pump but there is another things which is used in a chamber pump where number of pumps will be connected together and then they will be making to work.

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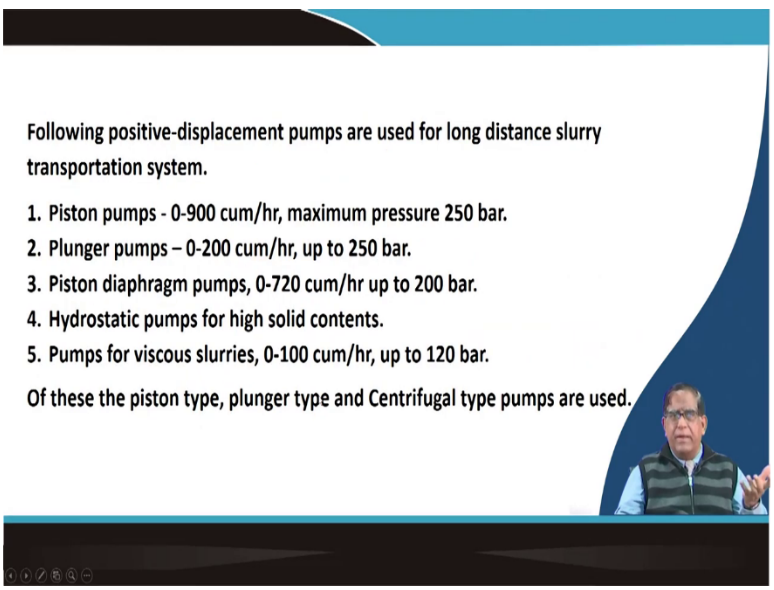

So that is exactly that for our slurry transport system you can use the piston pump up to your 0 to 900 cubic meter per hour at a maximum pressure of 250 bar it is used. Plunger pump also it can used up to 0 to 200 cubic meter. So, piston pumps can give a higher rating but the hydrostatic pumps is another high solid content pump can be used. Pumps for viscous slurries you can use up to 120 bar.

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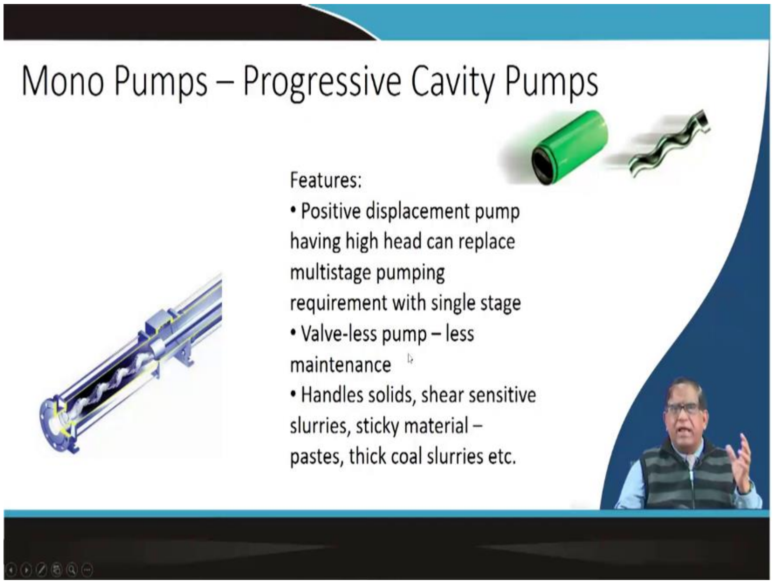

Now there are also another pump called mono pump or progressive cavity pump. These are a special type of pump for transporting cold slurry in many of the underground coal mines. So, there are wide range of pumps depending on the specific application situations you will have to make a survey of the different type of slurry pipelines and slurry pumps.

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And there are number of literatures available you will have to make use of those studies.

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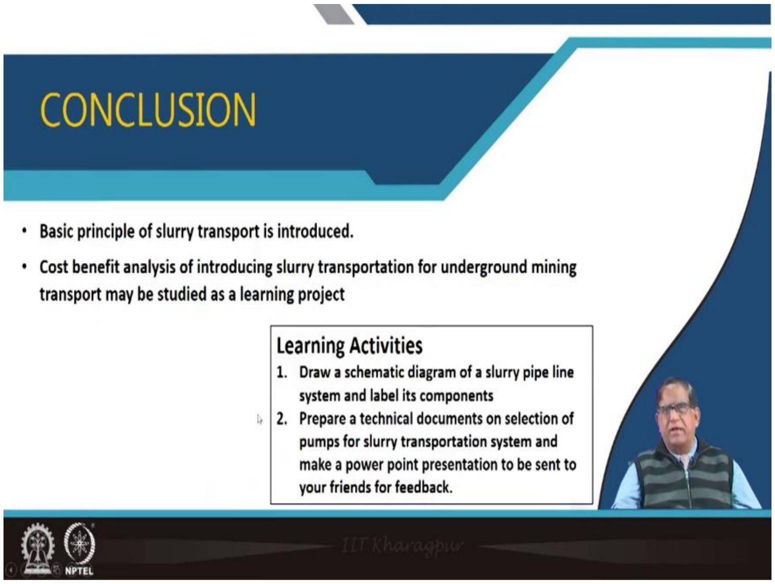

So, we have just said very briefly that what is the basic principle it is nothing but only your fluid flow there you of course it did not tell about Darcy's law how it will be used for knowing that exact pressure head loss and then on that head loss will have to be given by the pump. How the pump capacity will be selected, those are the things which are studied in the slurry pipeline. So, basically you have learnt that what are the main components to be there in a slurry pipeline transportation system?

What are the basic components in that and then of course, if you are interested you can go on studying little bit more and we can further discuss on these things but here just only to introduce you about the slurry transportation system you can start searching for drawing some schematic diagram of a slurry pipeline. And also you please try to prepare a technical document. How exactly you will be selecting a pump for a particular slurry pipeline.

Now there you will have to select or determine what will be the size requirement of the pump or pump capacity and then what is the type of pump. And that is why you will have to make a tabular form of the advantage and disadvantages of different pump systems. As because you have studied in your fluid mechanics part about this pumps and then the fluid flow motions. So, those things you can bring a little bit more over here just as a revising what you have learned.

And then you see how exactly technically it can be applied to another things and from there we can see that how exactly you can design optimum transportation system using slurry pipeline. So, thank you very much.