INDIAN INSTITUTE OF TECHNOLOGY ROORKEE
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Mechanical Operations
Lecture-20
Classification and Jigging-2

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Welcome to the second part of lecture 4 which is on classification as well as jigging. So concept of classification and the equipment related to classification that we have already covered in part 1 of this lecture. Now here we will solve some of the examples on classification and then we will discuss concept of jigging.

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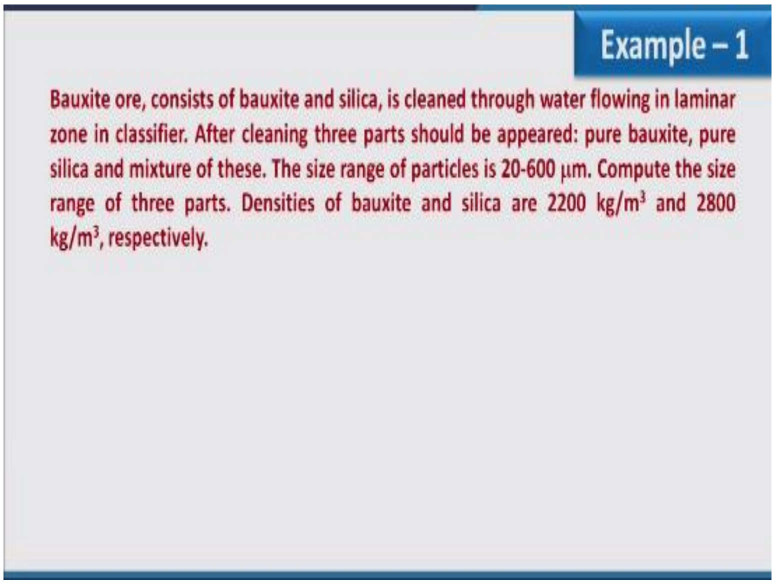

Therefore, let us start with the example 1, and in this example bauxite ore consists of bauxite and silica is cleaned through water flowing in laminar zone in a classifier. So you can see that zone is already given and we have bauxite ore which is the mixture of bauxite as well as silica. After cleaning three part should be appeared, first is pure bauxite, second is pure silica and then third is the mixture of these. The size range of particle is 20-600 μm. So this size range is applicable for three part where bauxite, silica both are having same size range from 20-600 μm.

Densities of bauxite and silica are given as 2200 kg/m^3 and 2800 kg/m^3 respectively. So what is the point over here that we have to compute the size range of three part, what is the size range of pure bauxite, what is the size range of pure silica, and what is the size range of mixture?

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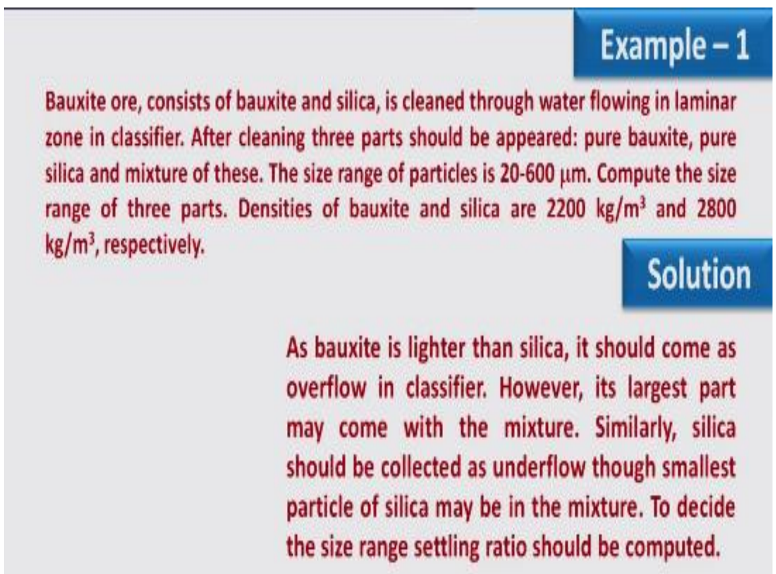

So let us start the solution of this problem and before solving it we should understand the concept of it. If you compare the densities of bauxite as well as silica, bauxite is having lesser density or it is lighter in comparison to silica. Therefore, bauxite will settle as overflow and silica will settle as underflow.

However, we can have the mixture also, because what happens the terminal velocity of largest particle of bauxite would be equal or would be larger than the terminal velocity of smallest particle of silica. So therefore, we have the mixture of the silica as well as bauxite along with the pure collection of these. Therefore, we have to decide the size range of all three sections. So these size ranges can be defined, can be decided based on the settling ratio.

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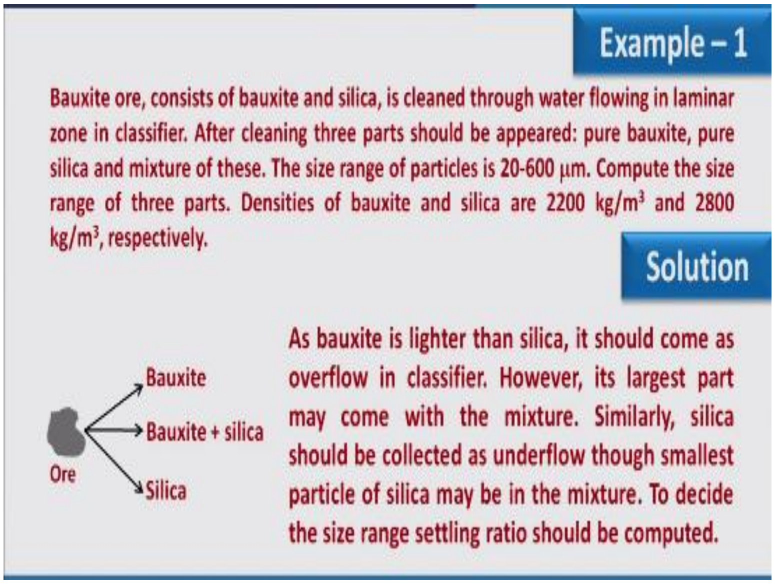

For example, we are having ore and the overflow is basically bauxite which is lighter in comparison to silica and underflow we have the silica and third section is we have the mixture of bauxite as well as silica. So we have to decide the range based on settling ratio.

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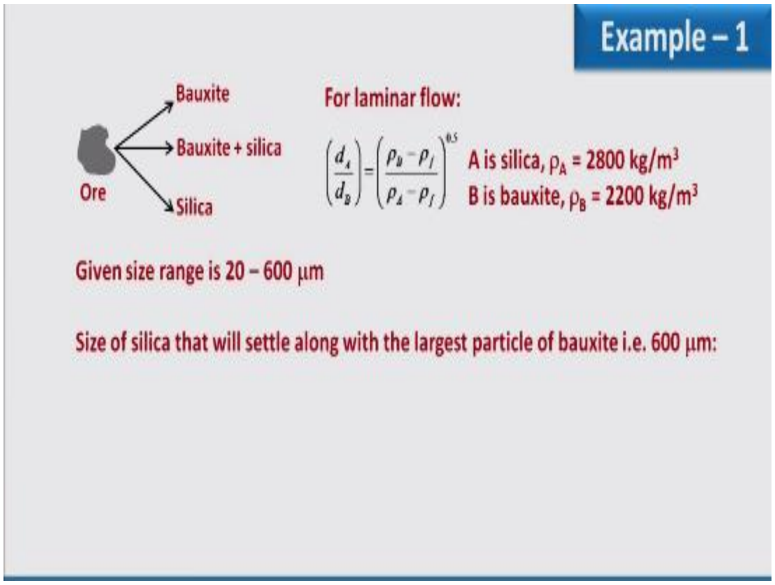

So we are already given the laminar flow where the settling ratio $[d_A/d_B] = [\rho_B - \rho_F / \rho_A - \rho_F]^{0.5}$ this equation we already have derived while studying the classification in part 1 of this lecture. So A we are referring to silica and B to bauxite, where ρ_A is 2800 and ρ_B is 2200. So given size range is 20-600 μm which is applicable for silica also and bauxite also.

So size of silica that will settle along with the largest particle of bauxite that is 600 μm. If you see this settling ratio this ratio speaks about equally falling particle, therefore when we are considering that bauxite will be collected as oversize, so it is very possible that largest particle of bauxite will come into the mixture. So what is the size of silica which will settle along with the largest particle of bauxite?

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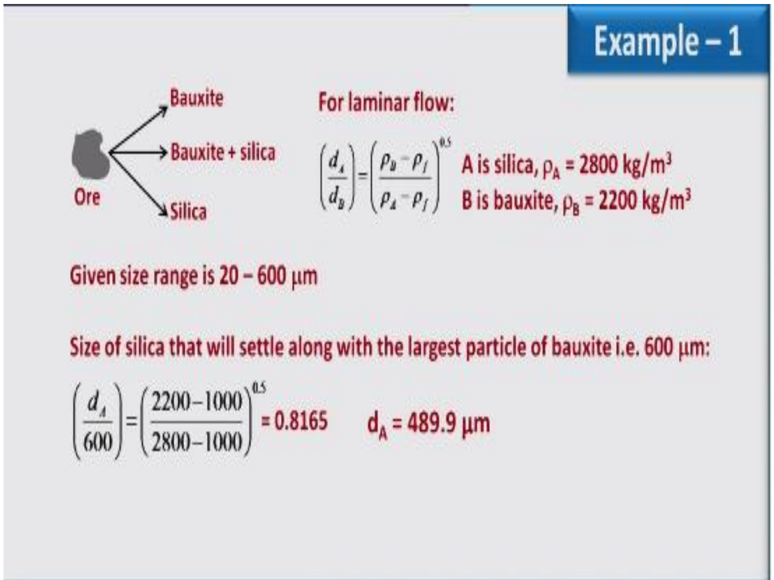

So if you see the largest particle of bauxite we have taken 600 μm and d_A we have to calculate. When we calculate d_A from this it comes out as 489.9 μm. What is the meaning of this, that when largest particle of bauxite will settle along with this silica particle will also settle which is having diameter 489.9 μm.

So what is the range of silica which will go to the underflow, the range will vary from 489.9 μm and greater than this. So you can understand up to 489.9 μm silica will found in the mixture and the larger particle then this will come in the underflow.

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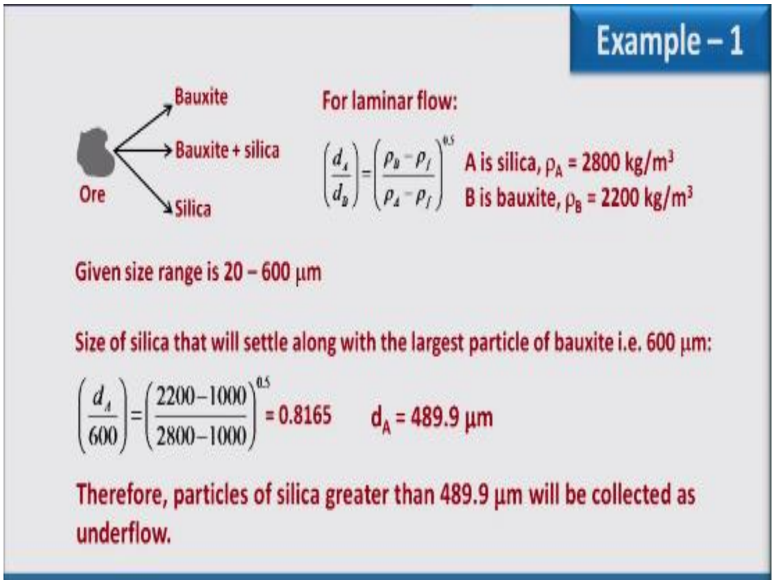

Therefore, the particles of silica greater than 489.9 μm will be collected as underflow.

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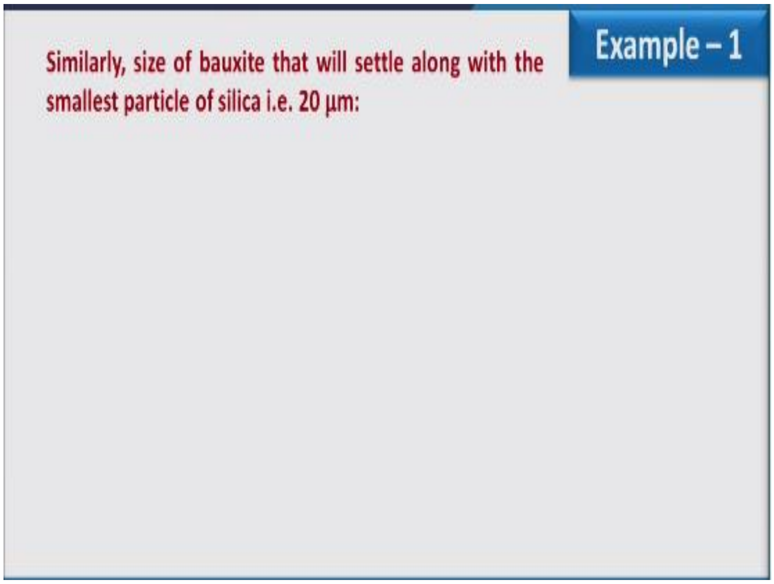

In a similar line we can calculate the size of bauxite that will settle along with the smallest particle of silica, because largest particle will definitely settle in overflow, but smallest particle will remain in the mixture. So what is the size of bauxite particle which will settle with the smallest particle of silica, and size of the smallest particle of silica is 20 μm.

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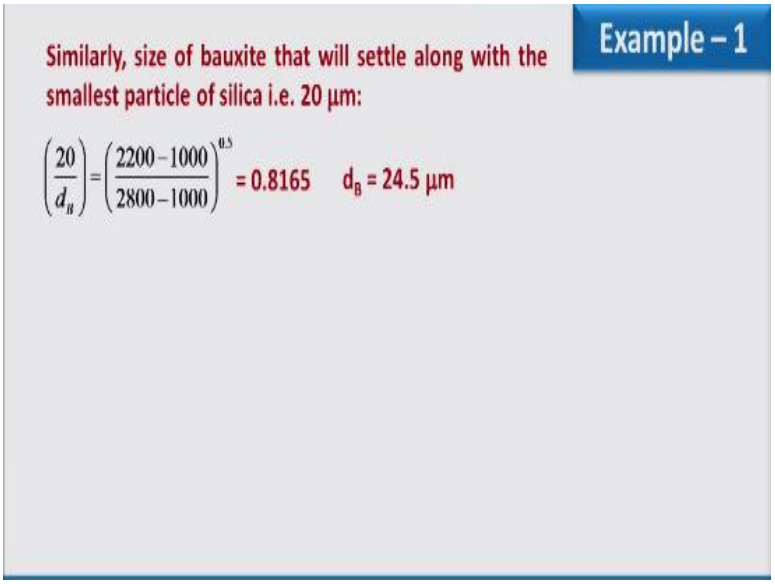

So following same equation we can calculate d_B because d_A we have fixed to 20 µm. So d_B from here we can calculate which comes out as 24.5 µm. Now what is the meaning of this, this is the size of bauxite that will settle with the smallest particle in silica, and this will fall in the mixture. So the bauxite particles having size lesser than 24.5 will go to the overflow.

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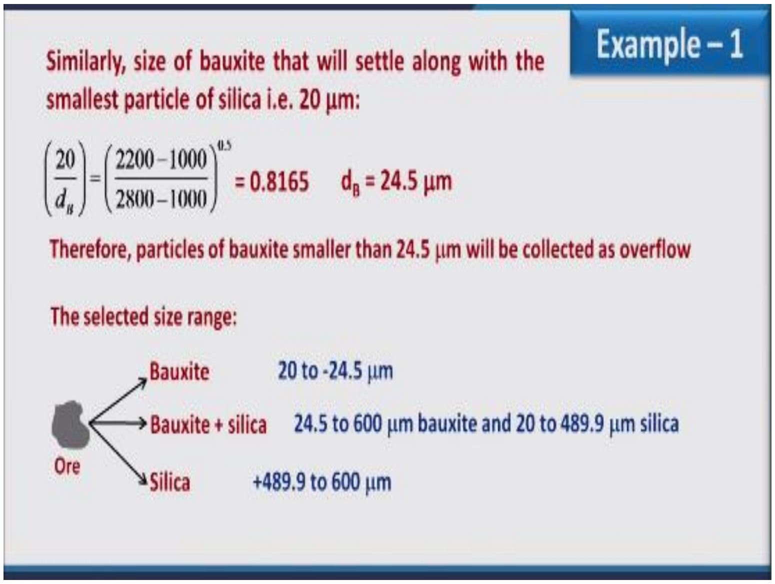

Yes, therefore the particles of bauxite is smaller than 24.5 μm will be collected as overflow. The selected size range therefore, this is the ore and we have bauxite, the size range is 20 to lesser than 24.5 μm, 20 is the minimum size. Silica that is +489.9 μm to 600 μm and mixture we are having for bauxite as well as silica where bauxite size vary 24.5 to 600 μm and silica particle size vary from 20 to 489.9 μm.

So these are the size ranges of overflow, underflow and the mixture. Now here we have second example of classification. In this example again I am having the mixture of two material that is ore and gangue, ore is having a density of 2000 kg/ m^3

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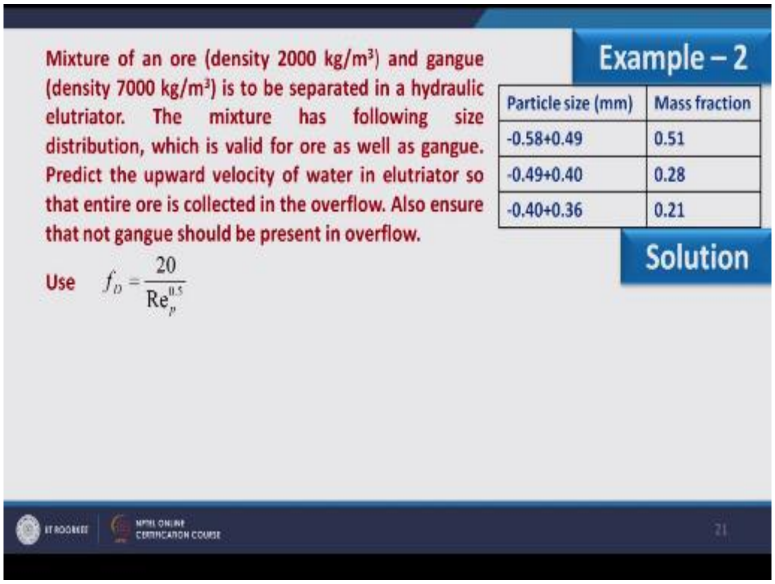

And gangue is having density 7000 kg/m^3 which we have to separate through hydraulic elutriator, so elutriator working, I guess you understand that here we have the flow of the water and the particle which are coming from the top it if the particle is having larger settling velocity then the upward velocity of the water so particle will settle down otherwise it will be collected, it will carried out by the water and collected as overflow.

So that is the concept of elutriator, so the mixture has followed the size distribution which is valid for ore as well as gangue, so if you see the associated table of this problem here we have particle size, in this the size vary from 0.36 to 0.58 mm and this range which is 0.36 to .58 it is applicable for ore also as well as for gangue, so what we have to predict over here is the upward velocity of water in elutriator so that entire ore is collected in overflow.

It means we have to make sure that sharp separation is possible for ore as well as gangue, ore should be collected as a overflow and gangue will be collected as underflow, so once we will decide that velocity we have to ensure that no gangue should be present in the overflow, and here we will use this relationship of f_D which is 20 Re$^{0.5}$ so you see here we do not know the region in which particle is falling to, for computation purpose we are given the f_D relationship with respect to Reynolds number. So the expression of terminal settling velocity.

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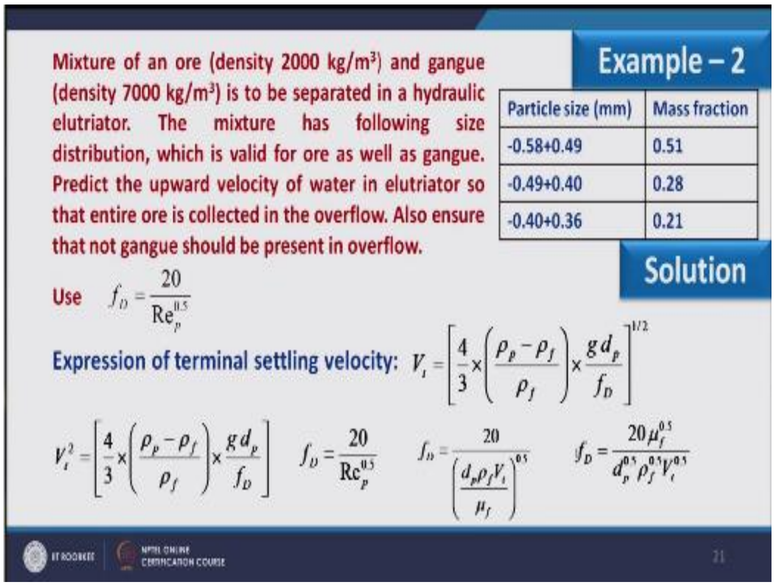

This is the generalized expression where f_D relationship is given to us so here we have rewritten the expression and f_D relation is given to us which we will put over here, so we have to calculate the terminal settling velocities so f_D relation we will put over here as a function of terminal settling velocity and therefore f_D we equated to 24/, this is Reynolds number particle where terminal velocity term is also coming so we have f_D in this form 20 $\mu_f^{0.5}$ / $d_p^{0.5}$ $\rho_f^{0.5}$ and $V_t^{0.5}$ so this f_D relationship we will use over here.

So expression of terminal falling velocity after keeping, after using the expression of f_D in terms of v_t so here we have further resolved this and finally when we see.

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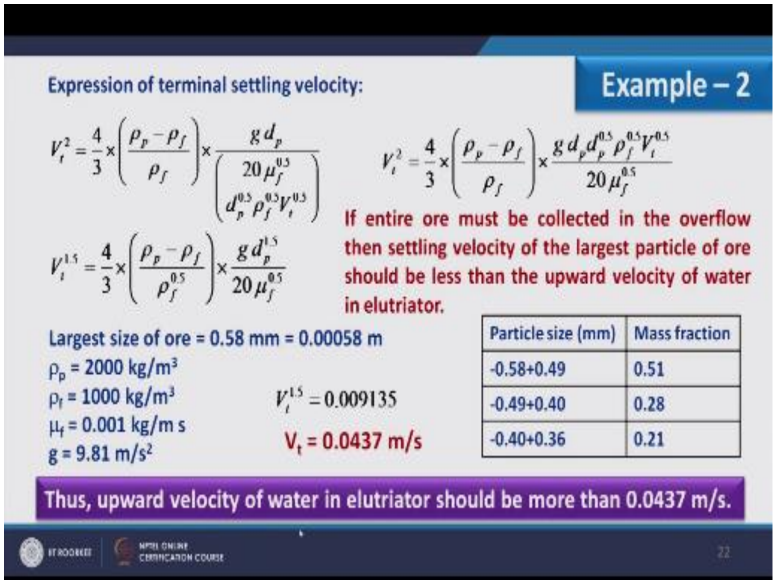

The expression this is the expression of terminal settling velocity of particle. Now what we have to do after this, we have to calculate the velocity of water which is moving upward in the sense that ore should be collected as overflow, no ore particle should come into the underflow. Now what is the meaning of this the, if we have the range of particle size and if we calculate the terminal settling velocity of largest ore particle, please try to understand this.

If we have to calculate the water velocity we have to calculate terminal settling velocity of ore, now how we will compute this, what is the size of this? From the size range we can take the largest size because when the largest size terminal settling velocity is computed and water velocity is taken just higher to this it means it will make sure that all particle will be collected as overflow. Therefore we have to calculate terminal settling velocity of ore considering largest size of ore and from this table we can see the largest size that is 0.58 which is 0.0058m and the value of parameters are given over here.

Considering this we can calculate the terminal settling velocity which is coming out as 0.0437 m/s therefore water velocity should be higher than this velocity, upward velocity of water in elutriator should be more than 0.0437 m/s. Now second part of the question is we have to make sure that no gangue should be available in overflow, so this same expression we will follow and how we will compute this, we have the size range over here, now if we.

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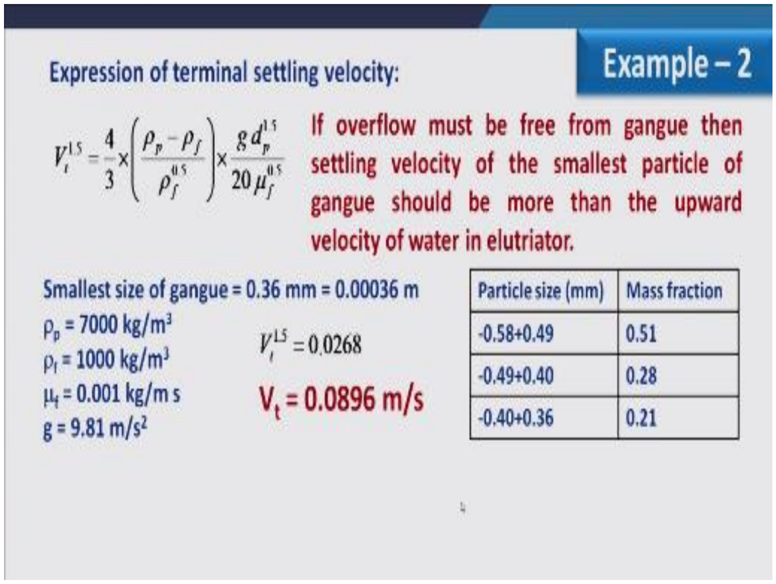

Do not want any gangue particle to be available in overflow then we have to make sure that terminal settling velocity of smallest particle of gangue should be larger than the water velocity which we have said which is just greater than 0.043m/s, so here we will calculate the terminal settling velocity of smallest particle of gangue and the smallest size is 0.00036m and here we have different parameters so we can calculate terminal settling velocity of particle which is coming out 0.0896m/s.

So you see this velocity is greater than the water velocity which were just larger than 0.0437 which we have just computed in the previous slide therefore all gangue will be collected as underflow, no gangue particle will go with the water in overflow, so in this way we compute the particle size distribution when we handle the separation through fluids, and here we have another example, in this problem the mixture of.

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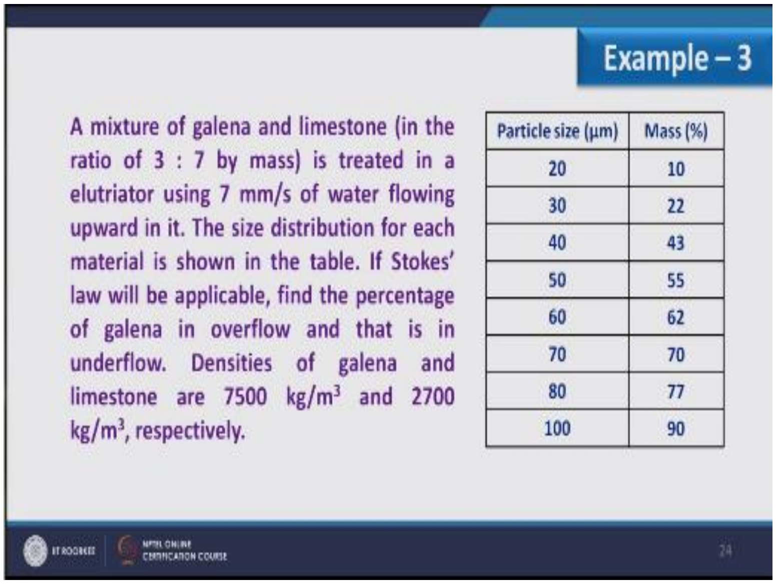

Galena and limestone having the ratio of 3:7 is treated in elutriator using 7mm/s of water flowing upward, so water velocity is given here, the size distribution of each material is shown in the table so you see different size and corresponding cumulative mass percentage is given to us so if Stokes' law will be applicable what we have to find is the percentage of galena in overflow and that is in underflow, so densities of galena and limestone are given over here which shows that galena is heavier than the limestone.

So particles of galena having settling velocity lesser than 7mm per second will be.

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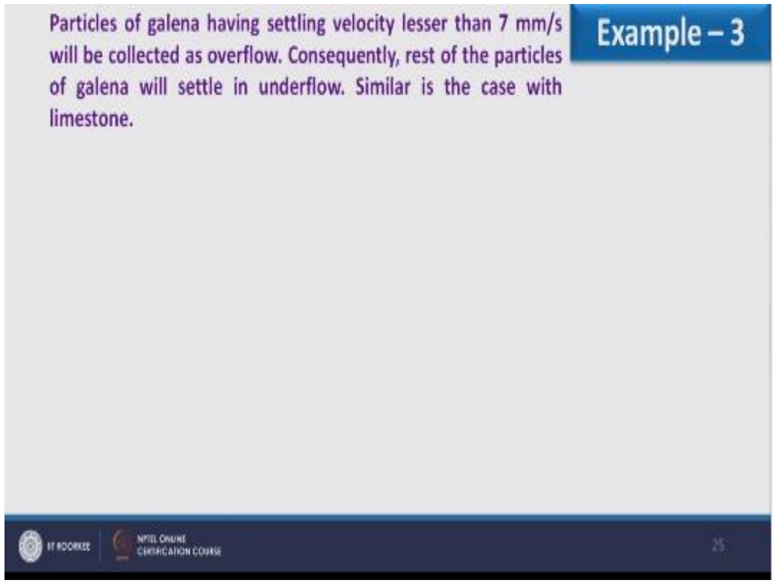

Collected as overflow, now what we have to calculate over here that how much percentage of galena is available in overflow as well as in underflow? For that purpose we should know what are the fraction of galena which is available in overflow so that can be decided by settling velocity of galena with respect to 7mm per second because that is the upward velocity, whatever velocity.

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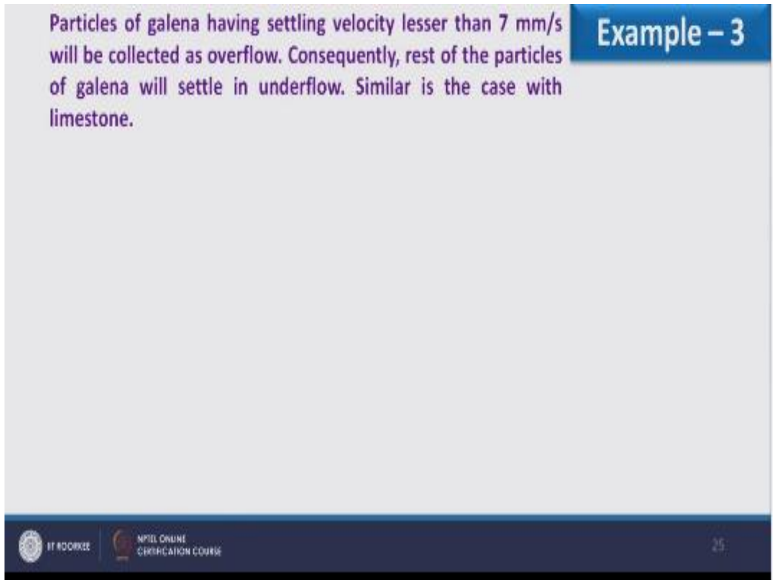

Of galena particle larger than this that will come in underflow and similarly we can have the case with the limestone, so expression of.

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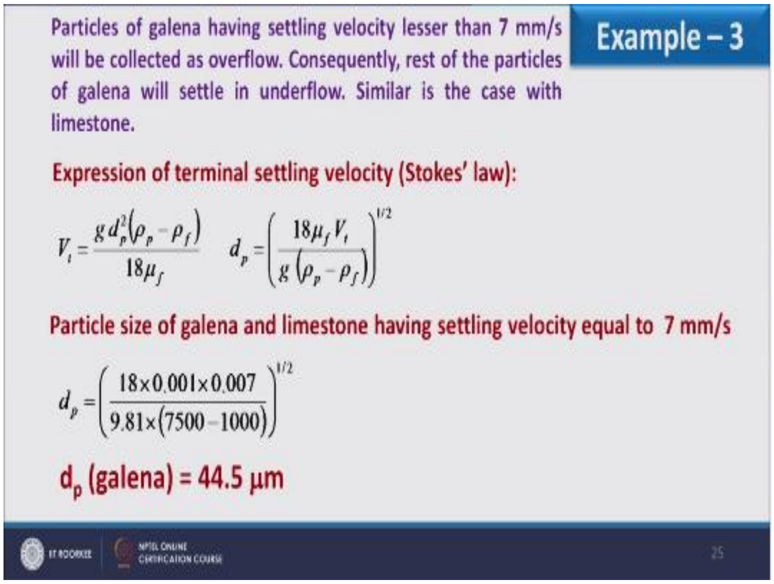

Terminal settling velocity here we have to follow the Stokes' law, this is the expression of Stokes' law and diameter of particle with known settling velocity we can calculate from this expression. So particle size of galena and limestone having settling velocity = 7mm/s so the same expression we will use but we will use different densities, here we have used density of galena so this is the particle size of galena which has settling velocity 44.5 μm so you can see when we have galena 44.5 μm the particles of galena having size larger than this will settle in underflow.

And smaller than this will settle in overflow, in the similar line we can calculate.

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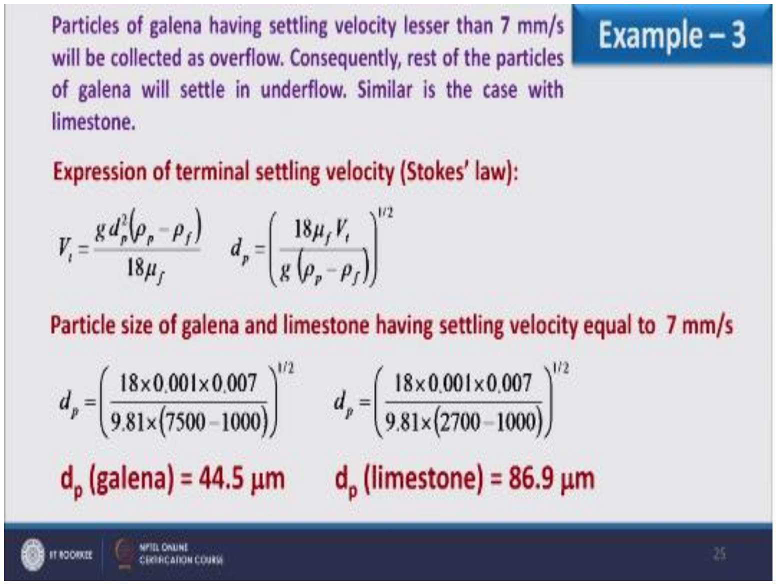

Diameter for limestone which is coming as 86.9 μm.

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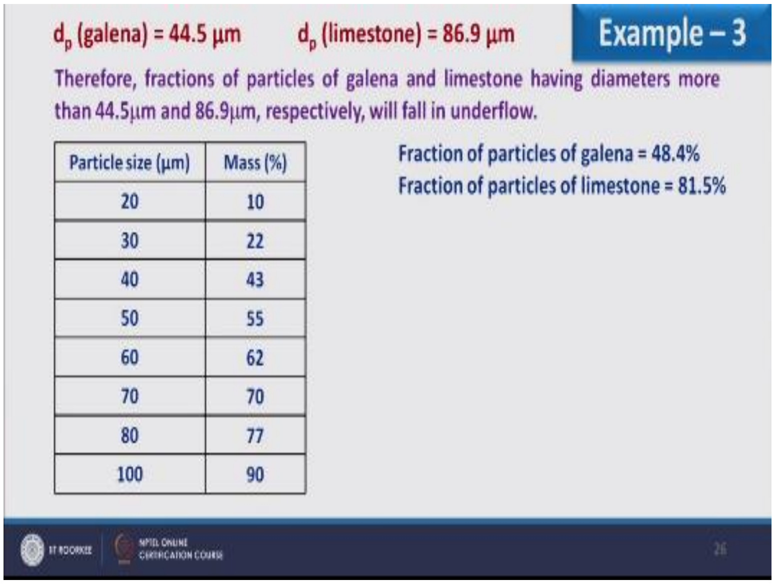

Particle size (μm)	Mass (%)
20	10
30	22
40	43
50	55
60	62
70	70
80	77
100	90

So these are the particle size of galena as well as limestone which has settling velocity = 7mm/s therefore fraction of particles of galena and limestone having diameters more than 44.5 μm and 6.9 μm will fall in underflow, so this is the particle size and respective cumulative.

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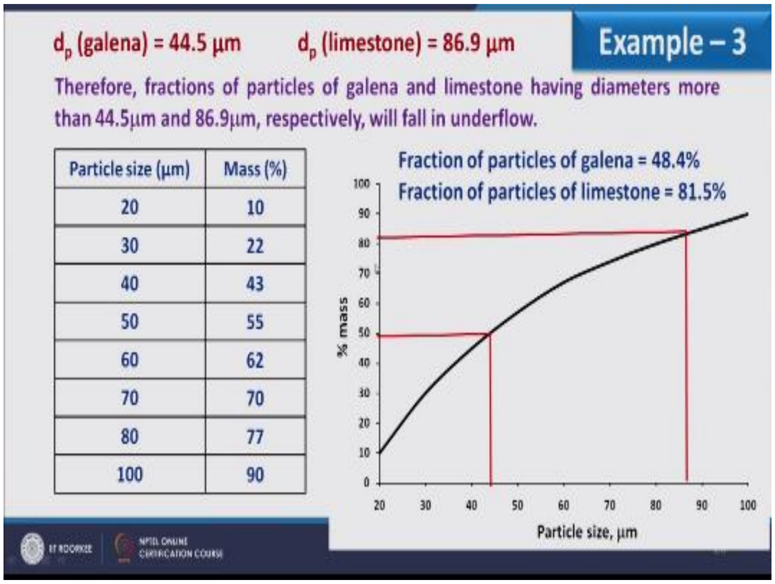

Mass percentage is given over here so here you see we have the table of particle size as well as cumulative mass percentage, we can draw this in this graph which shows that for corresponding 244.5 μm the mass percentage is 48.4 for galena and fraction corresponding to 86.9 μm for limestone the fraction is 81.5%. Therefore the percentage of mass of particles of galena in underflow which is 48.4% which we have computed from the previous graph and similar value similar mass fraction for particle of limestone in an underflow is 81.5%.

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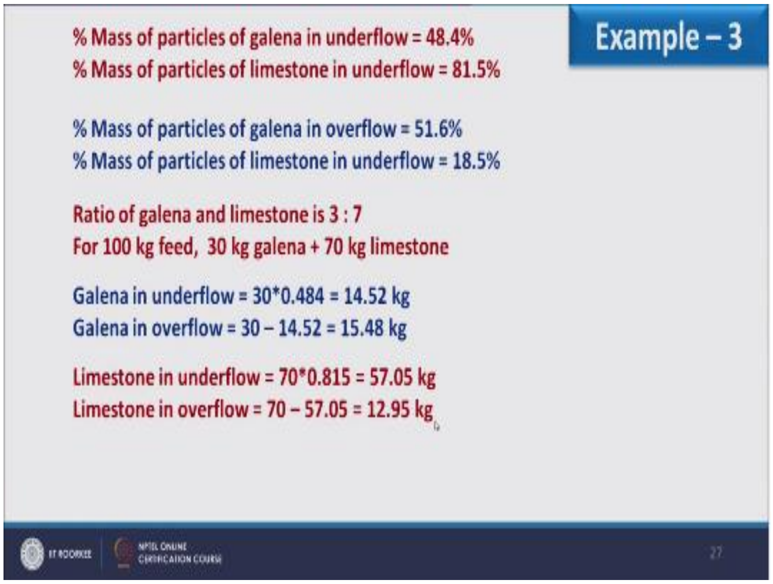

Therefore galena in overflow is basically 100 – 48.4 which is for 51.6% and limestone in underflow is 18.5%, this is the fraction and the ratio of galena as well as limestone is given as 3:7 if 100kg feed is available in this 30kgs galena + 70kg limestone is there. So galena in underflow, underflow percentage is 48.4 so 30 x 0.484 that is 14.52kg and galena in overflow is 30 – 14.52 that is 15.48kg, and similarly we can calculate the mass of limestone in underflow as well as in overflow so that is 70 into 815 57.05and 70- 57.05 which is 12.95 kg limestone is available in overflow, so the percentage of galena in underflow.

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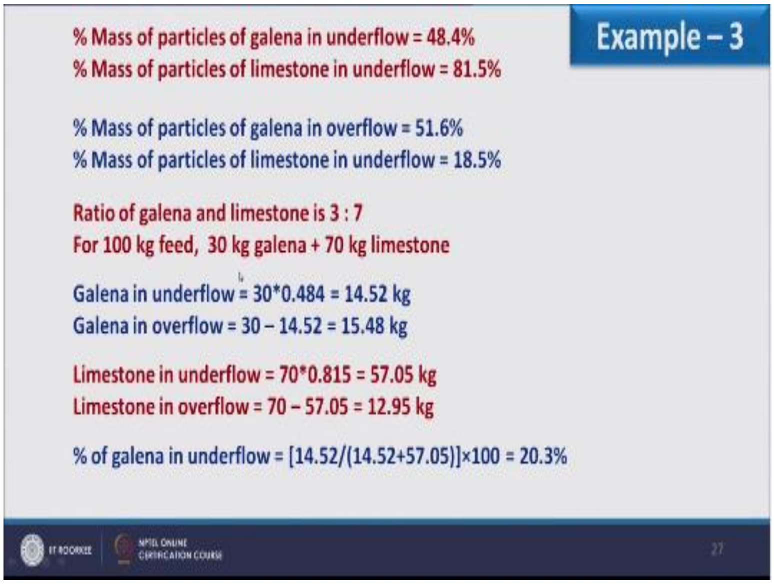

You see the underflow is having 14.52kg/ 14.52+57.05 this limestone is also available in underflow so percent of galena in underflow is 20.3% and in overflow it is coming out as 54.45%, so in this way you can calculate the percentage of a particular material in overflow.

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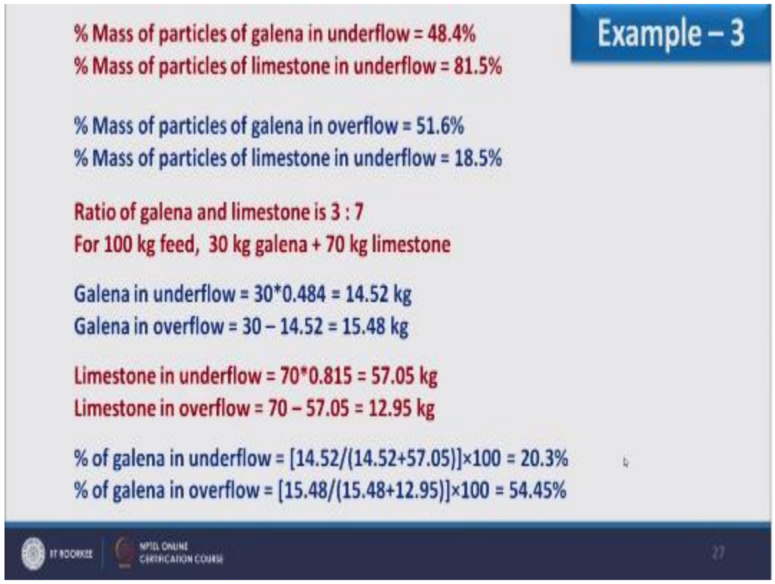

As well as in underflow, so these three examples we have considered to illustrate the computation how the classification is used to solve.

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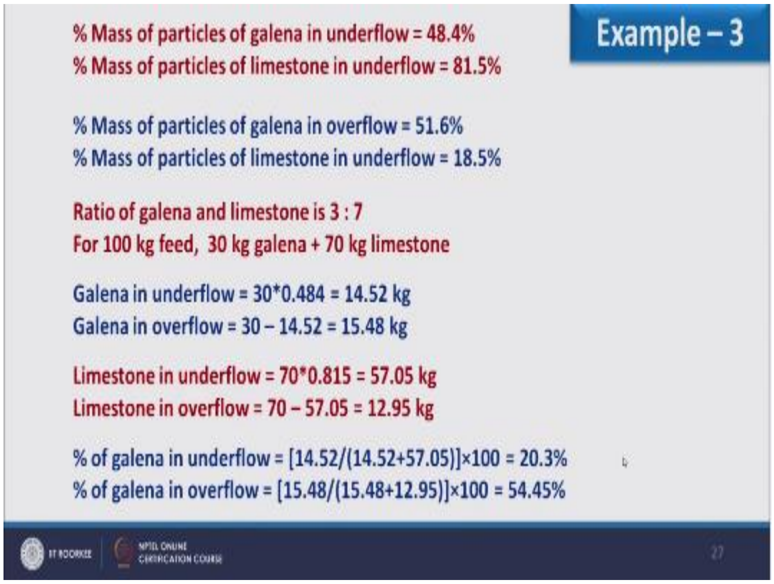

Different problems so let us start with the concept of jigging so classification which we have just.

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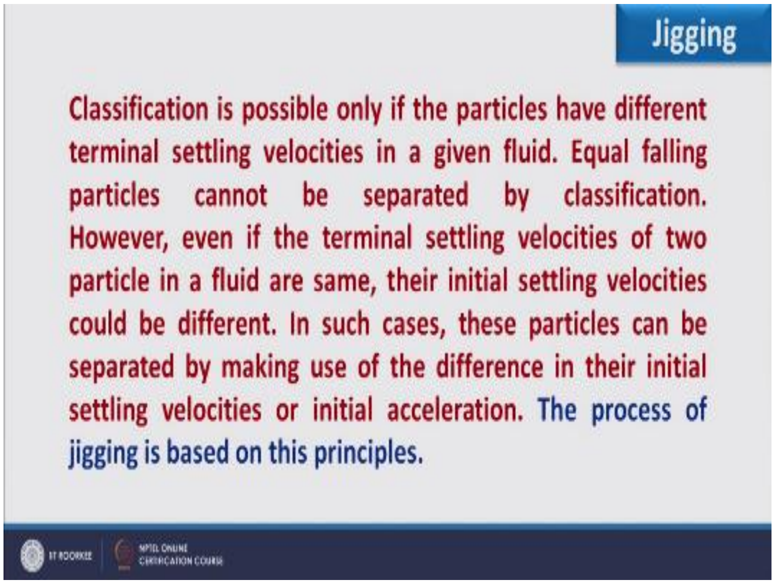

Seen is possible only if the particles have different terminal settling velocity in a given fluid, equally falling particle cannot be separated by classification however even if the terminal settling velocities of two particle in a fluid are same their initial settling velocity could be different. In such cases these particles can be separated by making use of the difference in their initial settling velocity or initial acceleration, so the process related to this which considers the concept of initial settling velocity.

We call it as jigging, so in jigging process what happens, we separate the particle based on their initial settling velocity.

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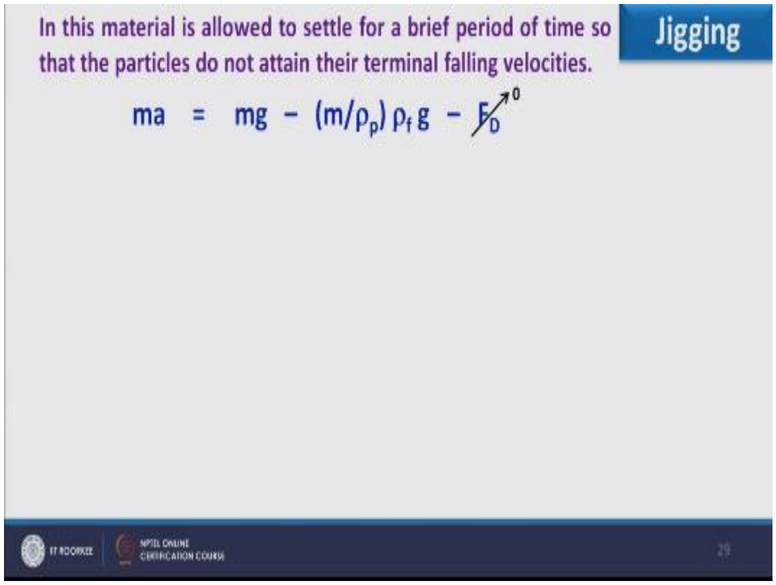

Now if I consider this concept initial settling velocity so what happen, this is the force balance equation and if you remember when we were discussing the terminal settling velocity we have discussed that when particle start settling at initial stage its velocity is not significant and therefore frictional force, therefore kinematic force offer to the particle is not significant, so in that case.

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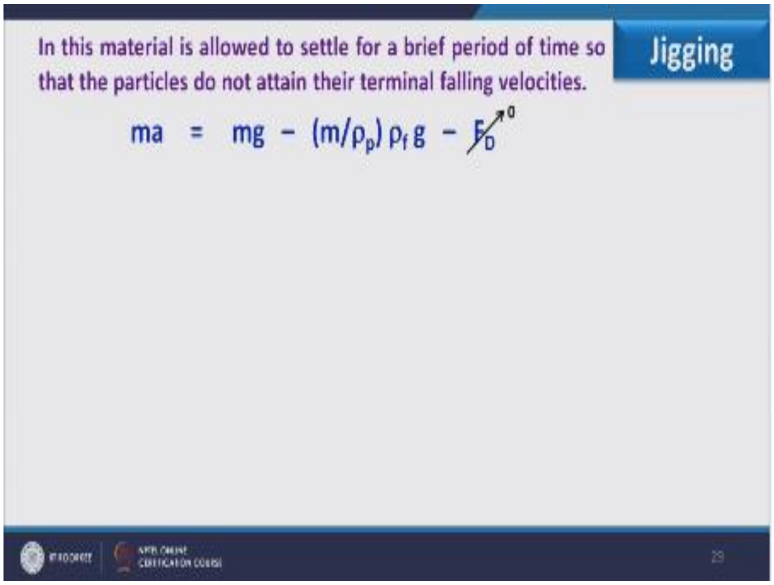

This parameter will be equal to 0, so when I consider the initial settling velocity when F_D^0 it means while jigging process particle is allowed to settle for.

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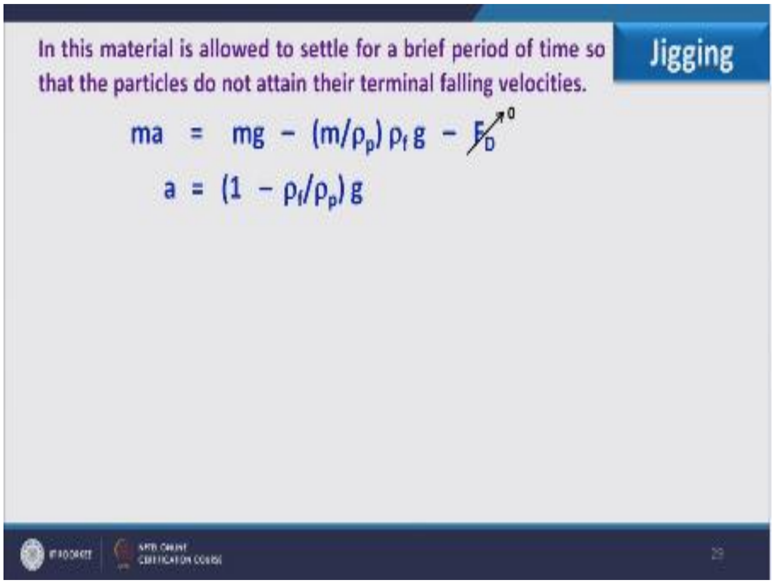

A very short period of time, so when we have equated F_D to 0, so final expression we are having as $a=(1-\rho_f/\rho_p)g$, so that a is the initial acceleration.

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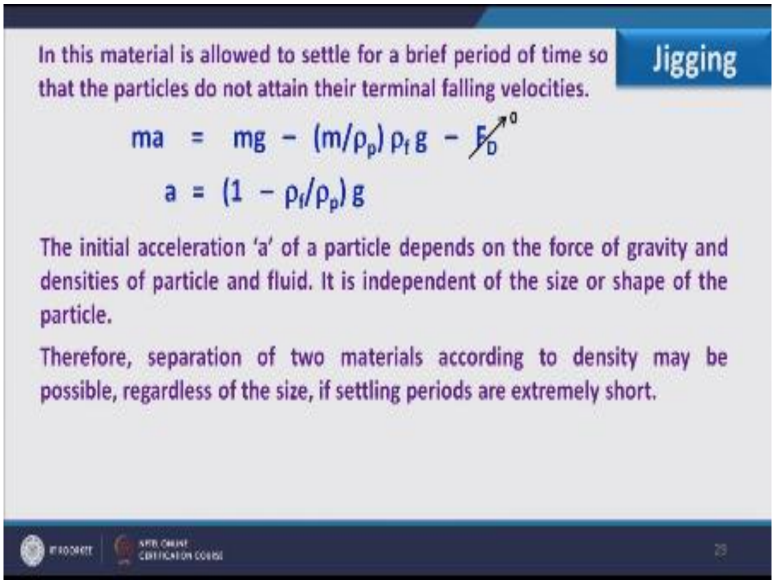

And you see the value of a, of the particle when we refer this particular expression it does not depend on the size of particle it only depends on the densities of the particle. So here the size and shape of the particle will not come into the picture, initial acceleration or initial velocity is only dependent on the densities of material not their size, therefore separation of two materials according to densities may be possible regardless of size, if settling period are therefore separation of two materials according to density maybe possible regardless of the size if settling periods are extremely short.

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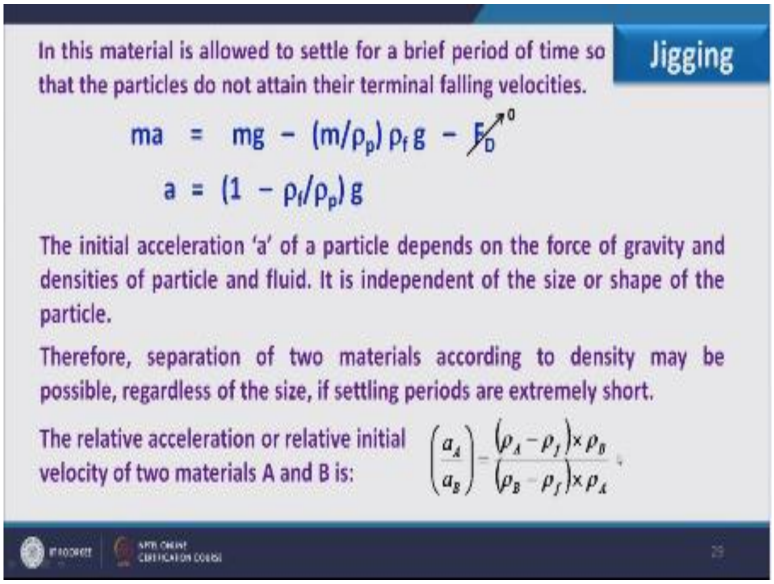

And relative acceleration or relative initial velocity of two materials we can calculate by this where a_A that is acceleration initial acceleration of particle A and this is the initial acceleration of particle B, and this is the expression. So the concept of jigging is we have to let the particle settle for very short time, and in that time separation is mainly occurred due to density.

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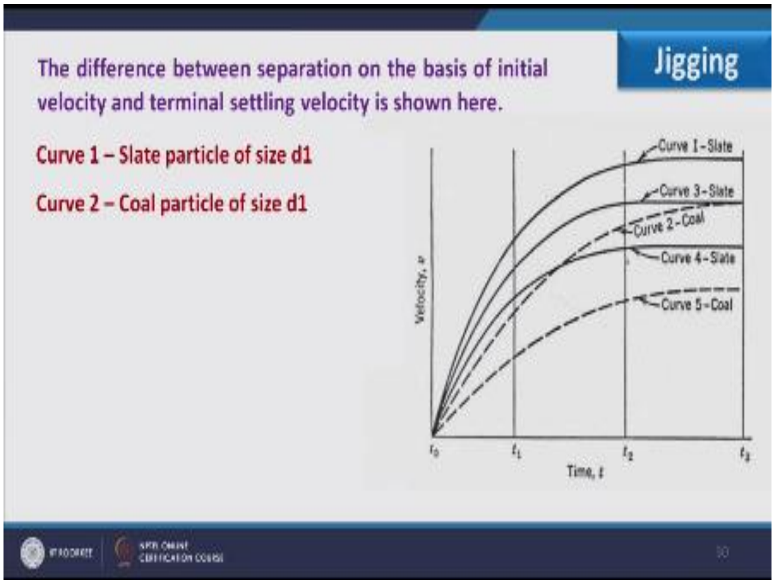

Now the difference between separation on the basis of initial velocity and terminal settling velocity is shown here, here if you see this graph here we have five different graphs. Now what is the difference between the two, difference between all these graph that we will discuss. Now if we consider this graph it is the velocity versus time plot, and curve 1 if I consider this is for slate particle of size d1. Curve 2 is coal particle of size d1, now if you see the graph of curve 1 and curve 2 in this plot here we have curve 1 is upper than curve 2, what is the meaning of this that slate particle will settle with largest velocity in comparison to coal though both particles are having same size.

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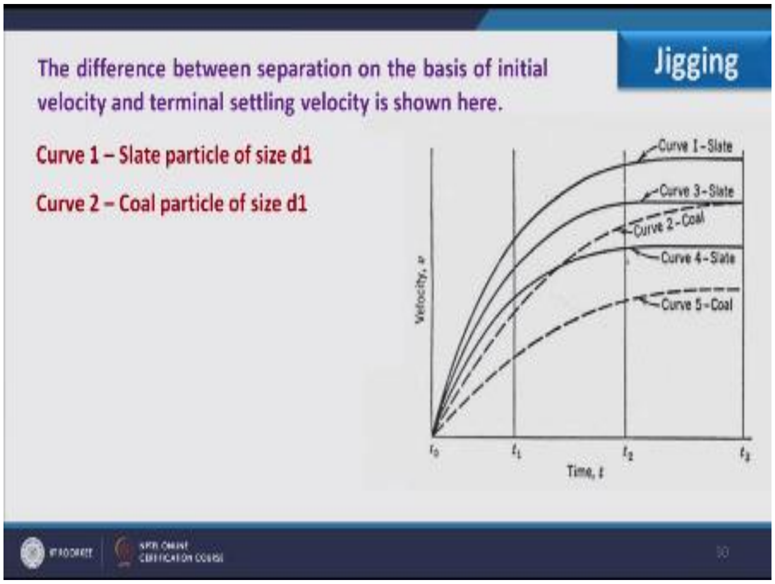

And why it is so, because slate is having more density in comparison to coal. In the similar line if we see the.

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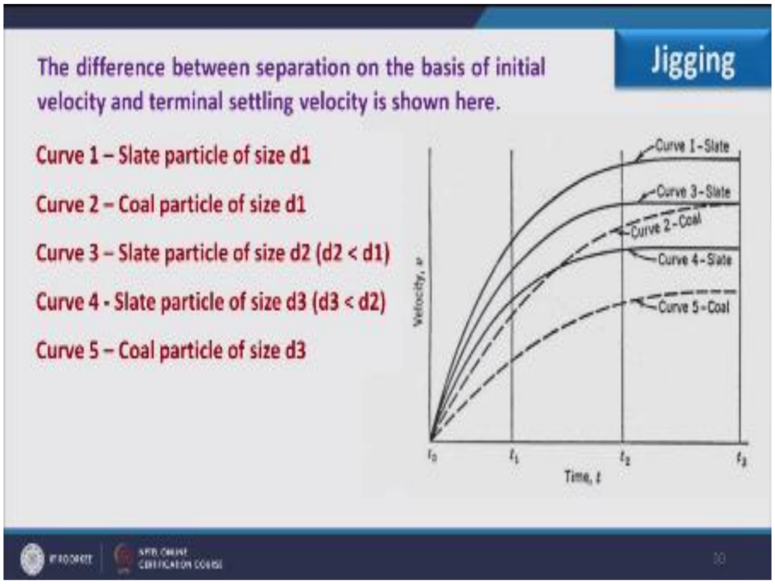

Curve 3 it has slate particle of size d2 and d2 is lesser than d1, so here you see curve 2 is having coal with size d1 and curve 3 is having slate of size lesser than that of coal, so what is the meaning of this, that smaller particle of slate will settle at the same time when the coal particle of larger size will settle, okay. And here we have curve 4 as well as curve 5, curve 4 is the slate particle of size d3 which is lesser than d2, and coal particle is having size equal to d3, so these both curve 4 and 5 is of equal size particle but as slate is.

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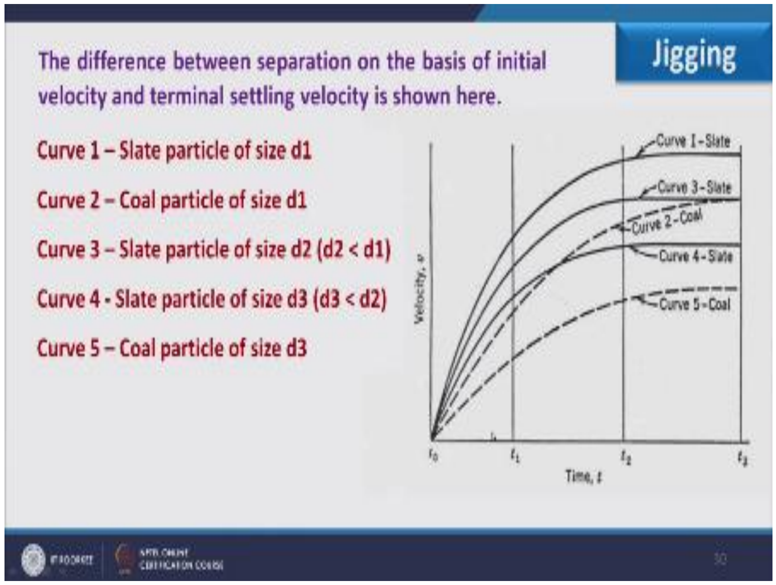

Heavier than coal it will settle with large velocity than coal. Therefore, if you consider all these curves here up to here when the particle will settle here the terminal settling velocity will achieve. However, if we consider the initial part of the settling here you see all these dotted lines are basically for coal and solid lines are basically for slate. So what is the meaning of this particular section that whatever would be the size of particle all slate particle will settle faster as far as this particular section is concerned, all slate particle will have more velocity in comparison to coal irrespective of size. So therefore we can say the initial velocity.

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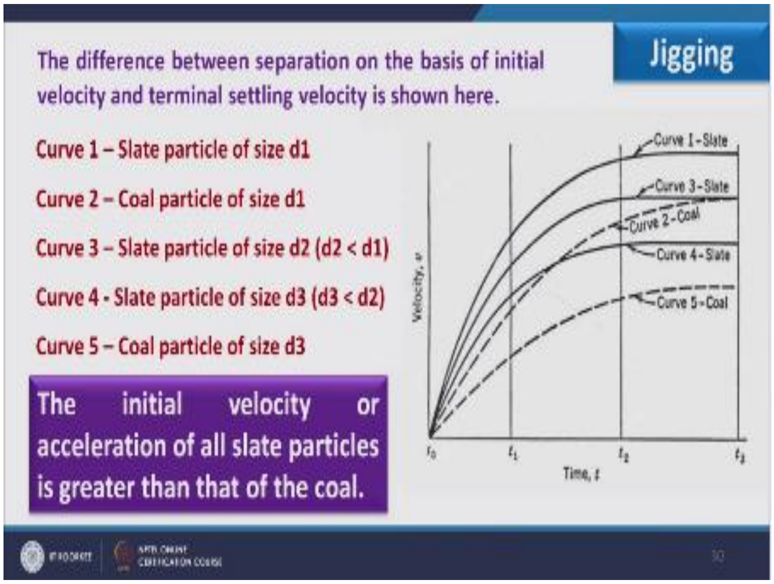

Or the initial acceleration of particle will dependent on the density which is having larger than density they will start settling faster.

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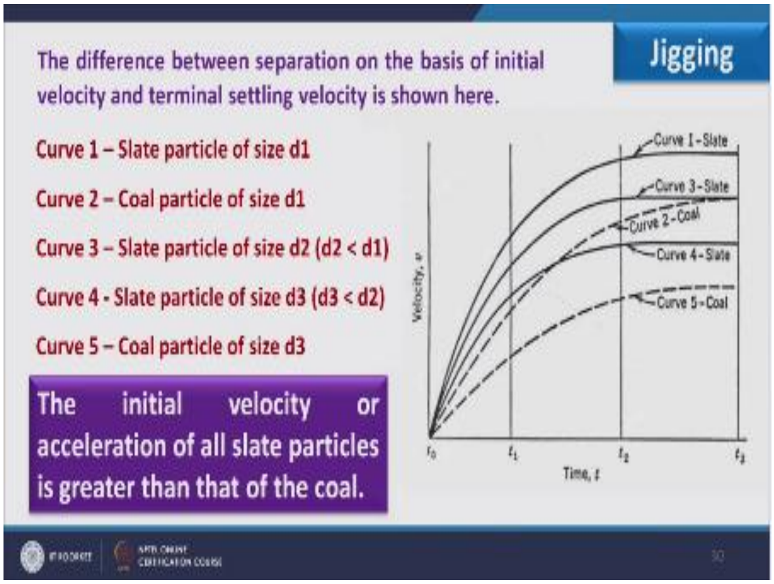

In comparison to the particle having lesser density, and here we have the industrial equipment related to the jigging and this we call the hydraulic jig.

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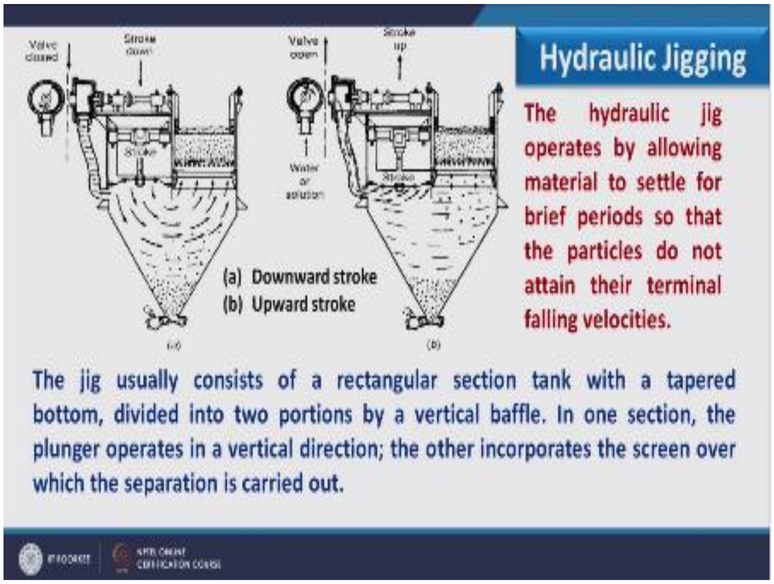

This is the hydraulic jig, so the hydraulic jig operates by allowing material to settle for brief period so that particle do not attain their terminal falling velocity. Now here what will happen, if you see these are basically the rectangular section tank in which the bottom section is tapered and the upper section is divided in two part by putting baffle in between, so this is the baffle and it is divided in two part. In one section the plunger operates in a vertical direction so if you see this figure in one section what happens here we have this diaphragm and which has the continuous stroke.

And due to this stroke the separation takes place, how it is that I will explain, and if you consider the second part of this here we have the screen and slurry will allow to enter over here. So how the jigging takes place, I do not know whether you understand the meaning of jigging in normal in dictionary or not it is related with dancing. So here the particle used to dance when we allow them to settle for very short time. So as far as functioning is concerned what happens here if you see, here we have.

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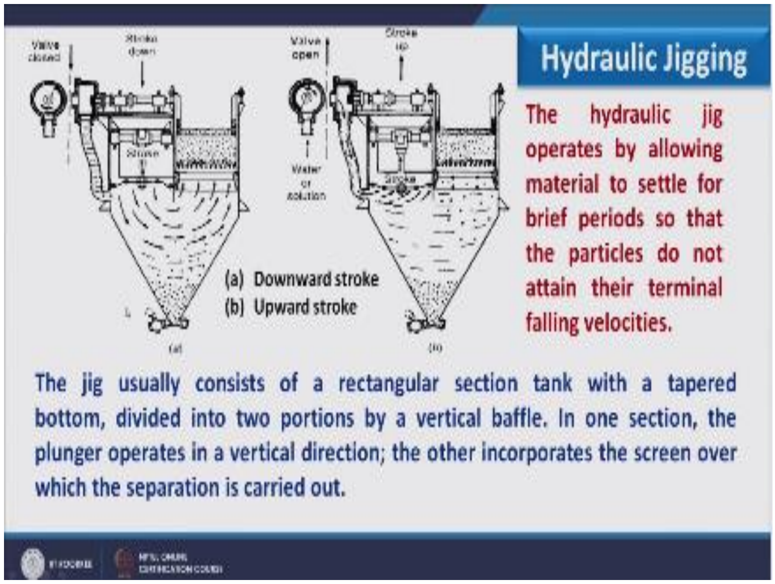

The valve, so a, the first figure shows the downward stroke and upper b figure shows the upward stroke. When we have the downward stroke it means when this section is closed it is completely filled with the liquid so when we put the stroke over here, this diaphragm gets the stroke and water which is available over here it used to moves to this place. And when water moves or fluid is moved in this side it opens the bed, bed of particle which are available over here.

So it opens the bed and for very short time the particles are allowed to settle. And when the upper stroke is concerned then this valve is open.

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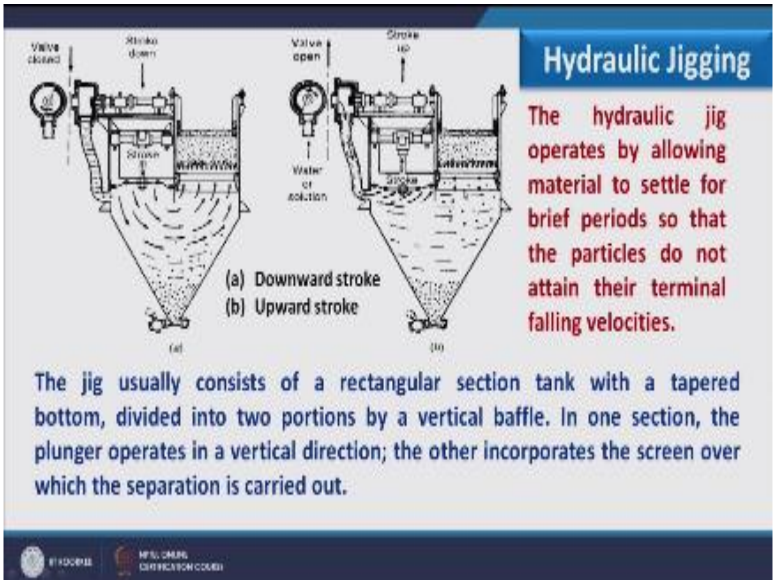

And water is allowed to enter into this, and once water is allowed to enter it comes at this position and then these valve closed we have the stroke over here, so water move from this side to this side. So the material to be separated is fed dry.

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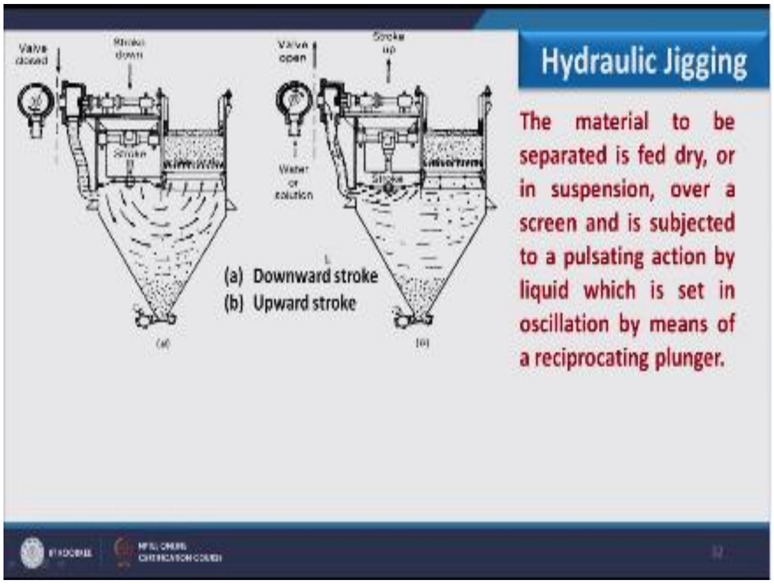

Or in suspension over the screen, and is subjected to pulsating action by liquid which is set in the oscillation by means of reciprocating plunger or diaphragm, that just I have explained. So as water passes upward the belt opens up and thus tends to rise.

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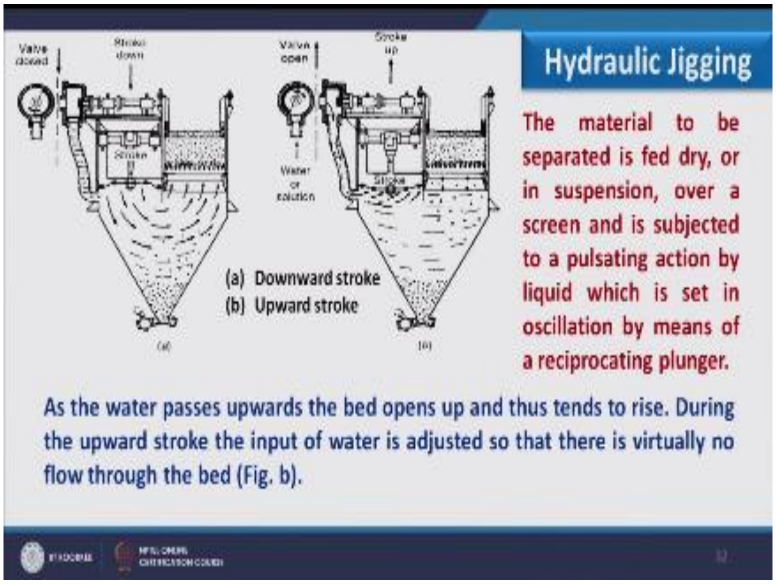

That just we have discussed. During this upward stroke the input of water is adjusted so that there is virtually no flow through the bed, it means liquid will come over here but then it come downwards so there is no flow of liquid through this bed. So during this period differential settling takes place and the denser particle tends to collect near the screen and lighter material above it. After a short time the material becomes divided in four different stages, so what happens when liquid comes to this and it opens the bed then for very short time it will start settling.

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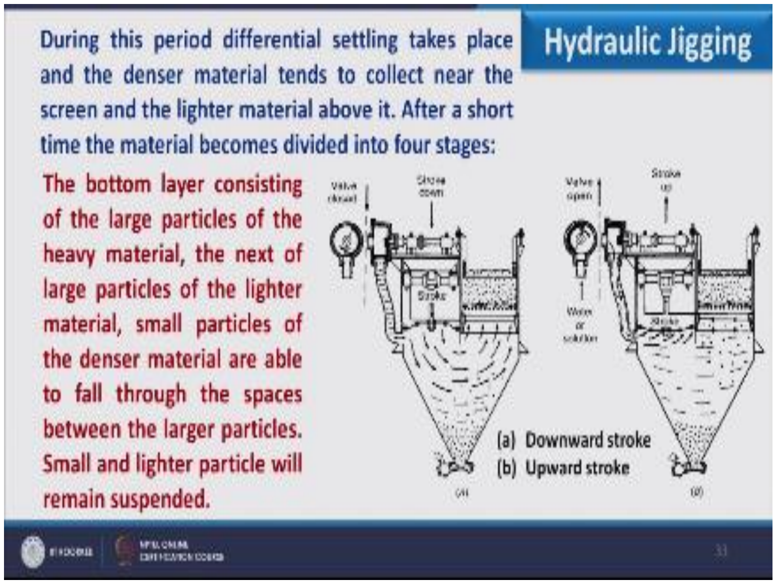

So how the settling will occur, the bottom layer, bottom layer means which is near to this screen which is just above to the screen, so bottom layer consist of large particles of heavy material and next of the large particle of lighter material so you see bottom most we have heaviest as well as lightest material, above this we have the lighter and large particle and small particle you see is small particle of higher density that can pass through the bed of large particle.

Because when large particle are collected at one place there is space in between are available for movement of fine particle of high density, so fine particle of high density moves from that bed of large particle and they are collected at the bottom. So if we consider this particular section that is heaviest and smallest particle, and further the finest, and finest as well as lightest particles which are available that remains suspended in the slurry and that can be separated.

So the four section, first is heaviest and largest second is lightest and largest third is smallest and heaviest and fourth is smallest and lightest. So four sections we are having and these was about the jigging, now in this particular lecture we have considered, we have discussed the concepts of classification and jigging

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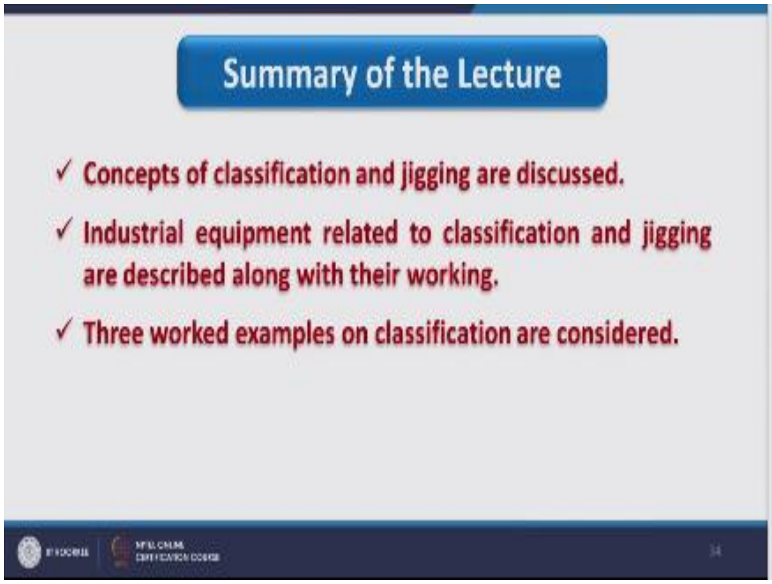

And then we have discussed the industrial equipment related to the classification and jigging along with their working and here in this the lecture four we have also discussed three work example to illustrate the use of classification concept in example in different problems.

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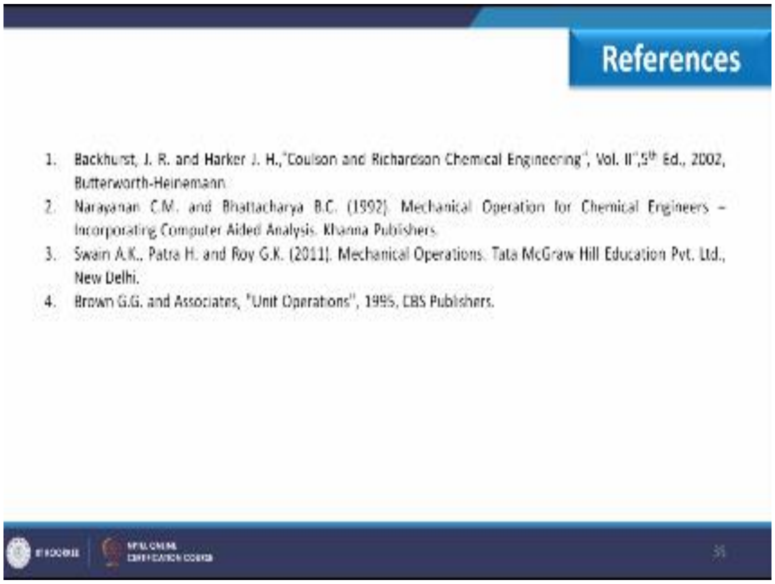

So here we have the references for lecture five and it was all about lecture five and here we are ending the course, it was a four week course. I hope you will be benefited by this course, I expect your enthusiastic participation in this course, wish you all the best, thank you.

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