INDIAN INSTITUTE OF TECHNOLOGY ROORKEE
NPTEL
NPTEL ONLINE CERTIFICATION COURSE
Mechanical Operations

Lecture-06
Fine grain size distribution

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Welcome to the second week of mechanical operations course, today we are starting lecture one which consists of fine grain size distribution. If you remember the week one lectures there we have discussed particle size distribution using sieve analysis, here we are covering the particle size distribution of very fine particles.

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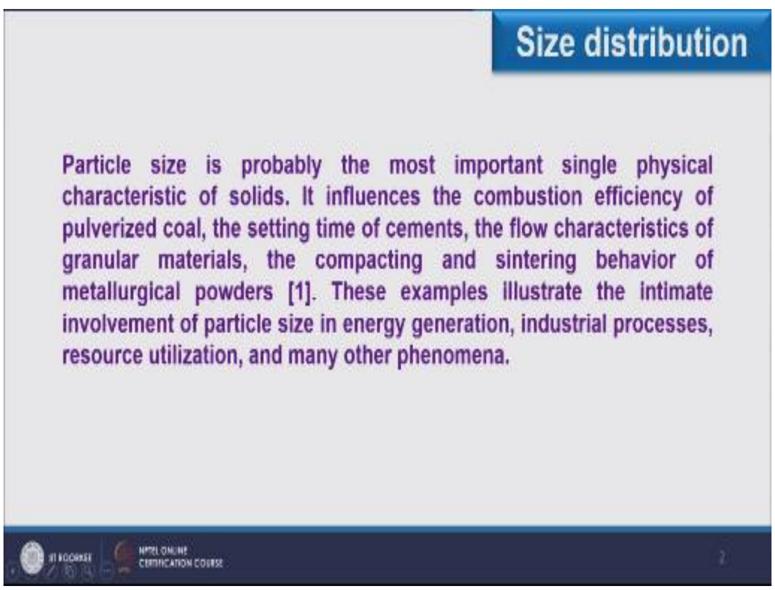

So particle size is probably the most important single physical characteristic of solids, it influences the combustion efficiency of pulverized coal, the setting time of cements, the flow characteristics of granular materials, the compacting and sintering behavior of metallurgical powders. These examples illustrate the intimate involvement of particle size in energy generation, industrial processes, resource utilization and many other phenomena. Now several mathematical models and expressions have been developed.

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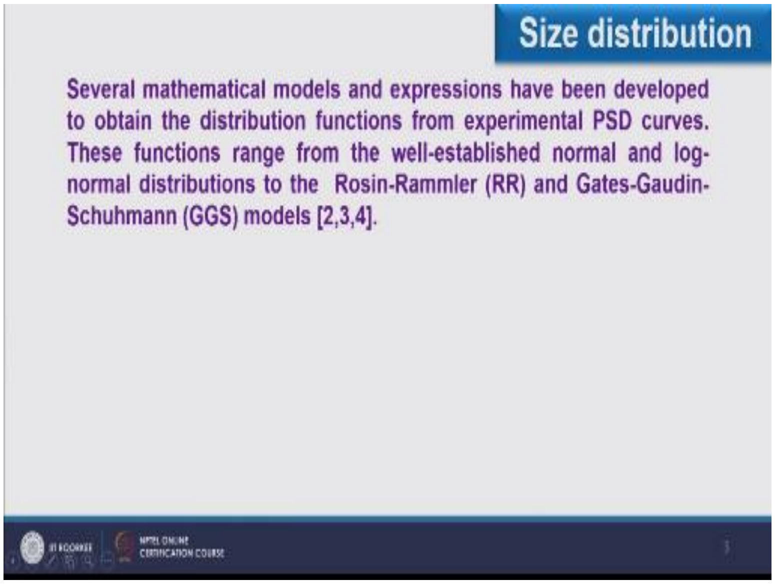

To obtain the distribution function from experimental PSD curves. Now basically what we are going to do over here is to calculate the size distribution using mathematical model, therefore when the screen analysis or.

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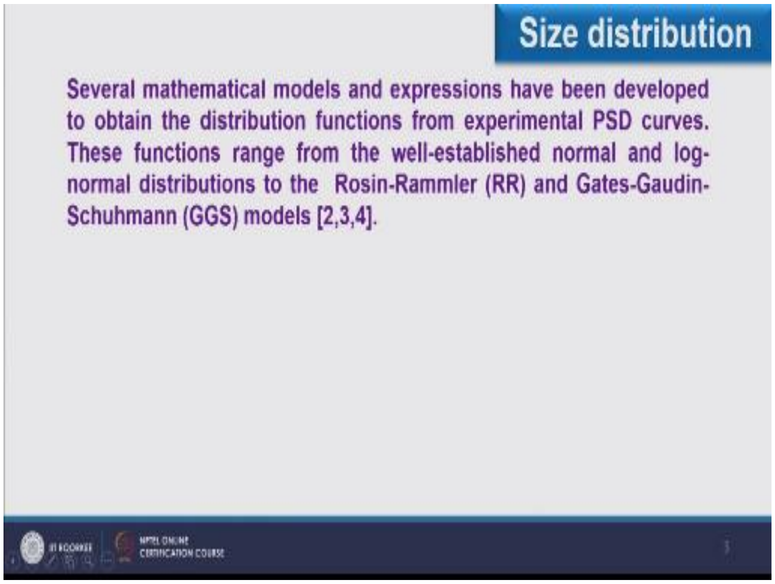

Any other method is not able to distribute, to give the distribution of particle properly there we can utilize the mathematical model and its functions and these mathematical models usually use the experimental PSD curves, so these functions which are mathematical range from well established.

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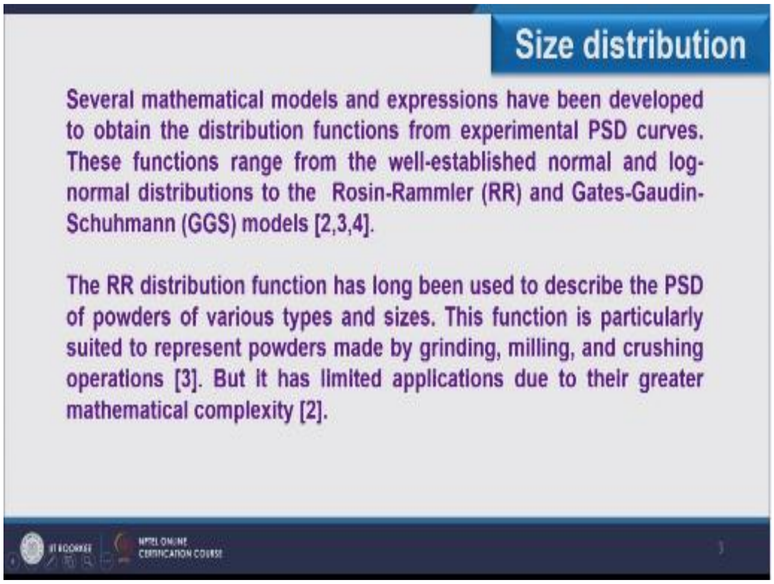

Normal and log normal distribution to Rosin- Rammler and Gates- Gaudin- Schuhmann models, so here we are having two models Rosin- Rammler model and Gates- Gaudin- Schuhmann model. The RR model that is Rosin- Rammler model or Rosin- Rammler distribution function has long been used to describe the PSD of powders of various types and sizes.

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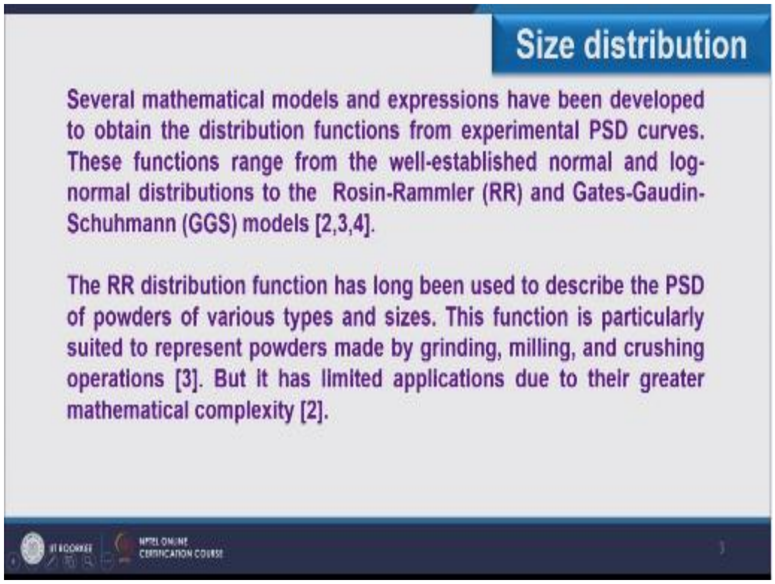

This function is particularly suited to represent powders made by grinding, milling, and crushing operations but it has limited applications due to their greater mathematical complexities. On the other hands Gates Gaudin- Schuhmann distribution is simpler to use so in the present lecture.

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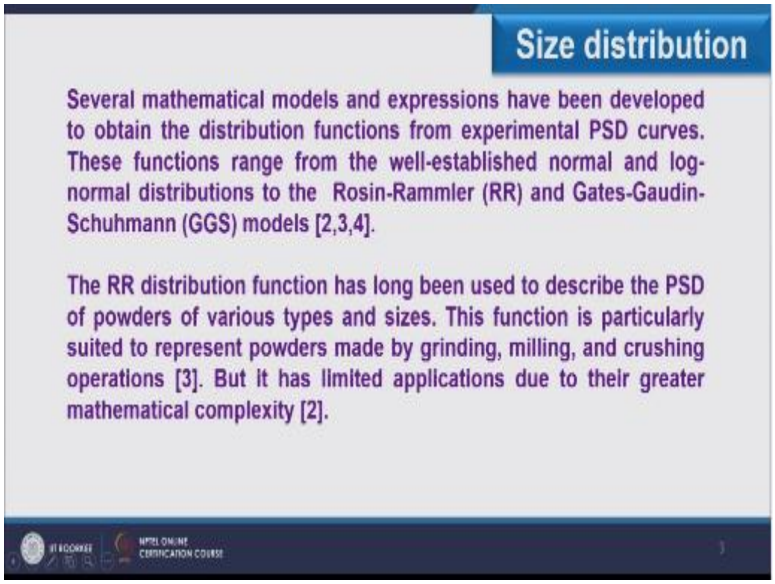

We are demonstrating Gates Gaudin- Schuhmann that we call GGS model for size distribution. Now in this slide if you see here I have shown.

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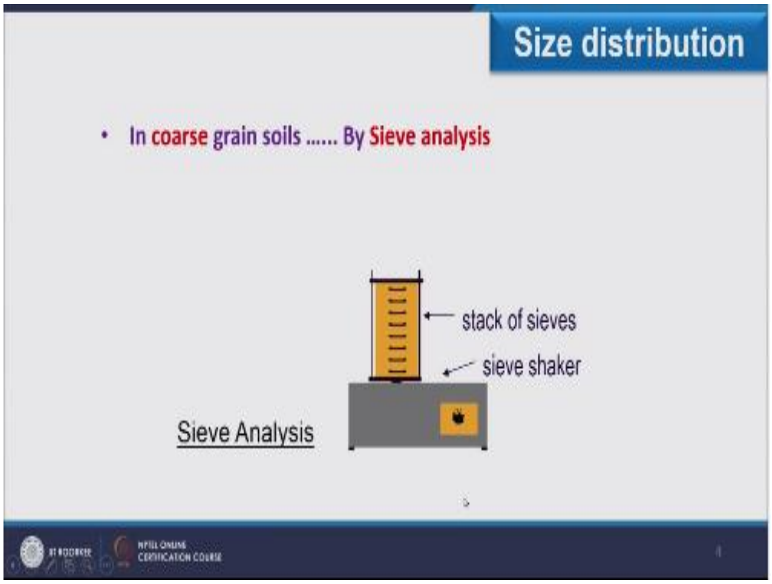

In coarse grain soils by sieve analysis, what is the meaning of this, that coarse grain size distribution we carry out using sieve analysis. However if you see the data or see mesh chart it gives the value up to 40, up to 40 μm only so sieve analysis does not give the size distribution below 40 μm so when we have to compute the distribution below this.

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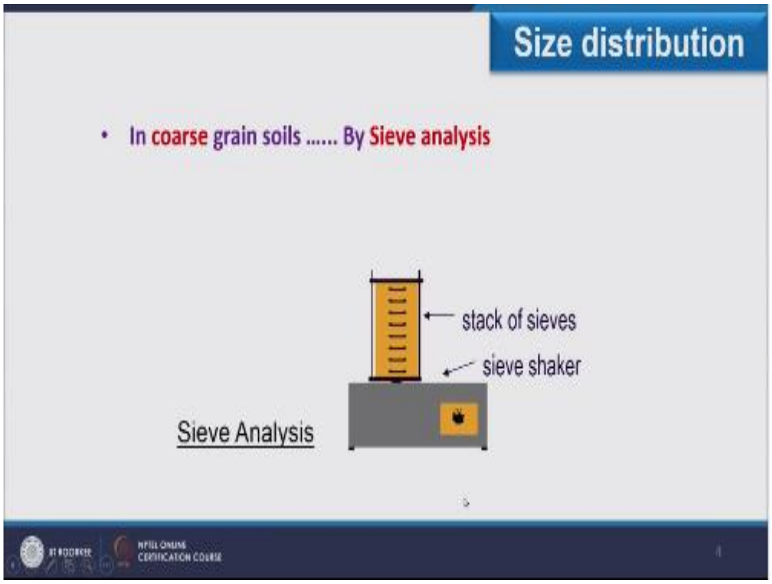

Then we go for Gates Gaudin- Schuhmann distribution function which is very much suitable for fine grain size particles. So what is the use of Gates Gaudin- Schuhmann distribution function, it calculates or it gives the particle size distribution when I am handling with very fine size particles where sieve analysis is not suitable, so Gates Gaudin- Schuhmann distribution function is widely used function.

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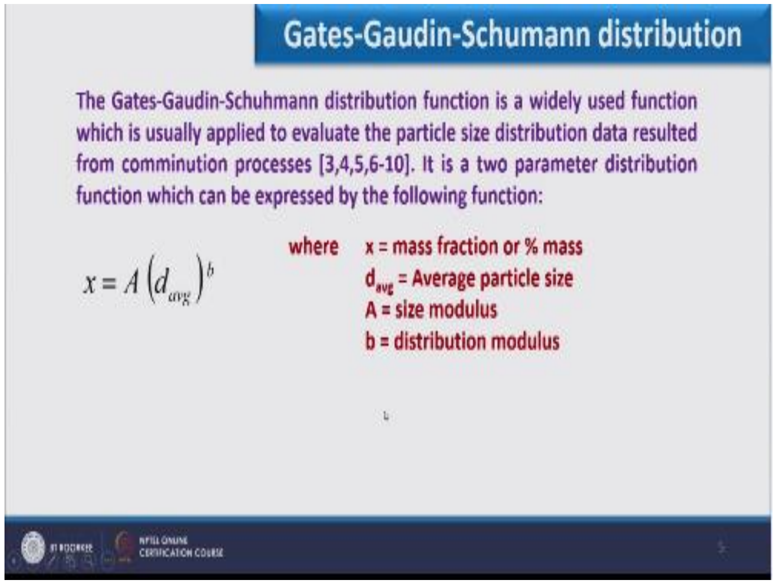

Which is usually applied to evaluate the particle size distribution data resulted from combination processes. It is a two parameter distribution function which can be expressed by this expression where it goes as x=A d_{avg} raise to power b, the parameters over here x is the mass fraction or percentage mass d_{avg} is average particle size, A is sized modulus and b is the distribution modulus where A and b we obtain from the experimental data analysis we are having. So while taking log of this two we can write it.

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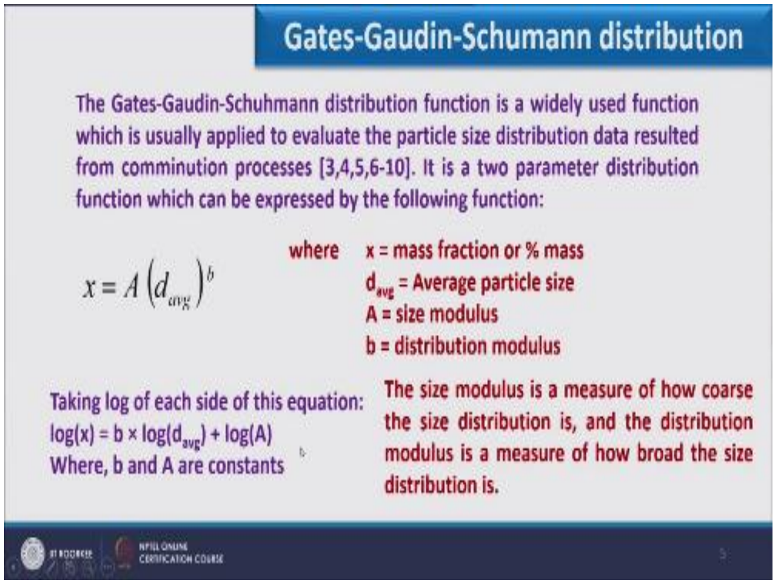

Log x=b x log (d_{avg}) + log(A) where b and A are constants so size modulus is a measure of how coarse size distribution is and distribution modulus is a measure of how broad the size distribution is, so A and b are representing these values which we can obtain from the experimental data.

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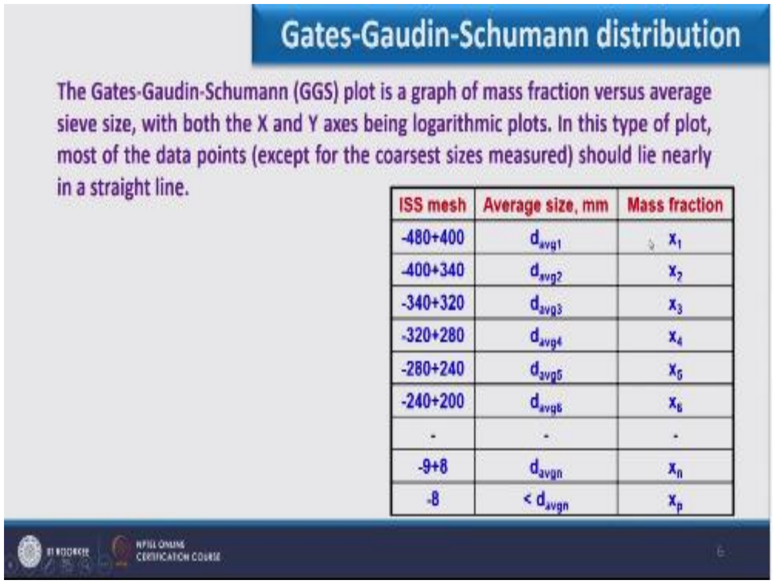

The Gates Gaudin- Schuhmann plot is the graph of mass fraction versus average sieve size with both the x and y axes being logarithmic plots. In this type of plot most of the data points except for the coarsest sizes measured should be nearly in a straight line so what happens? Here you are aware with this table where I have shown the Indian standard screen mesh number - , + I guess you remember it – shows under size + shows over size and here I am having the average size of particle d_{avg1} and here I am showing the average size of particle which can be obtained by arithmetic mean.

Of opening for 480 mesh screen and opening of 400 mesh screen and x_1 is the mass fraction which is available on 400 mesh screen / total mass which we have fed for the screen analysis, so you are very well of this data. Now we are using this data for computation of fine grain size distribution, how we will do this, using Gates Gaudin- Schuhmann plot. Now what is that plot, this is the plot.

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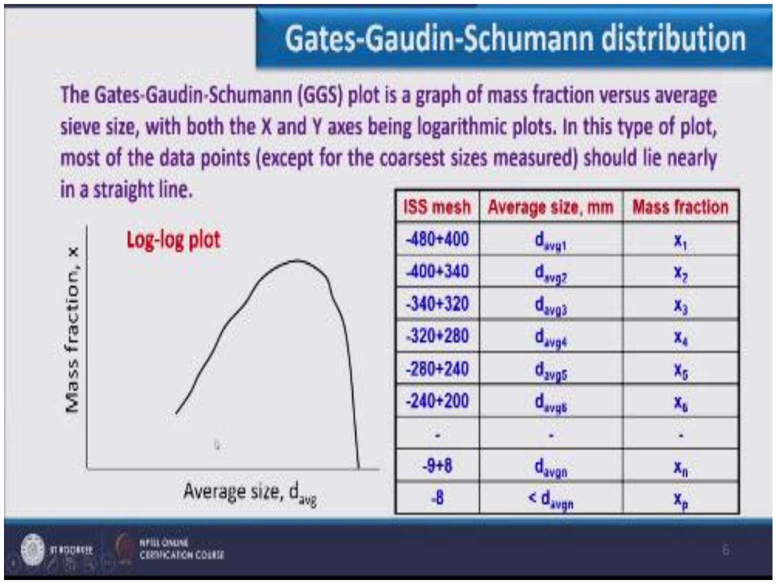

Which we call Gates Gaudin- Schuhmann graph, here the plot is between mass fraction versus average size that is d_{avg} it is a log- log plot and this mass fraction as well as this average size d_{avg} is taking from this table only. So if you see this figure what it shows that when I, I am concentrating on this part which is basically dealing with the fine particles because here d_{avg} keeps on decreasing so here I am having the fine particles so if I am considering this particular section and usually it gives the straight line.

Apart from the coarsest section the rest of the section or where the fine particle lie it gives the straight line section. Now what is my purpose over here? To plot this, my purpose is to compute the fine grain size distribution, now how I will obtain this? If you consider this – 8 mesh screen what is the meaning of this, that the material which is passed through 8 mesh screen and it is retained on the pan so what is the distribution of particles which are available on pan that we can obtain using this curve.

That is the purpose of this Gates Gaudin- Schuhmann plot, so this is the Gates Gaudin- Schuhmann plot which I have just shown.

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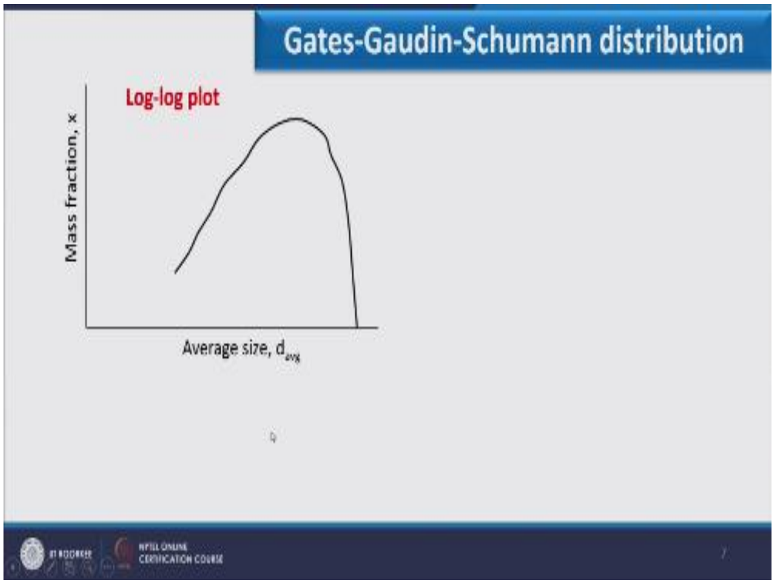

Now my area of work in this graph is this section only where I am getting fine particles.

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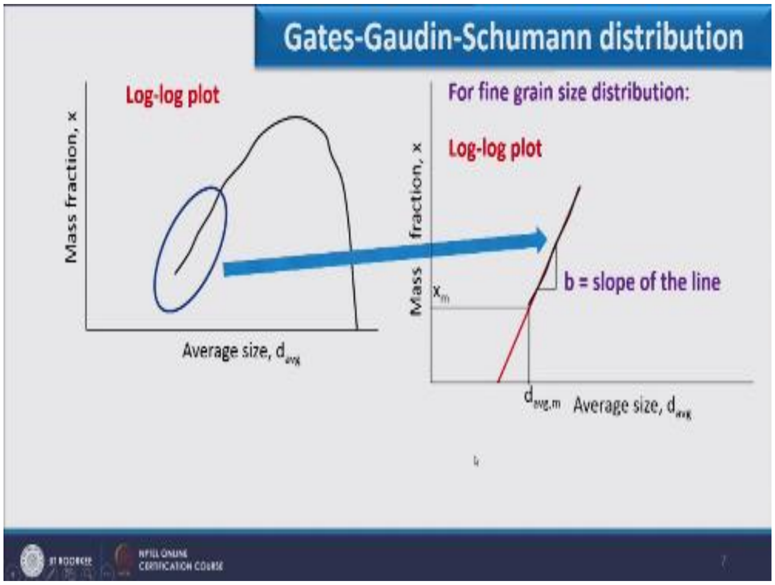

And which is slightly straight as far as its nature is concerned, so to understand this properly I will extra pull at this in another graph where I have re plotted this particular section as you can see over here so this is again the same plot but only a section I have shown over here. Now what I have to do, I have to extra pull at the straight line by passing these points till it will reach to the end okay.

So here you see this red line I have shown which is basically passing through the data points falling at below section or below screens or bottom screens, so for this line we have to compute the slope of it. For this line I have to compute the slope to know the value of b. If you remember b in Gates-Gaudin-Schumann distribution functions can be obtained by slope of a straight line, if I plot the graph of log law plot. So finding the b from this graph is easier, once I know the value of b, $d_{avg\ m}$ and x_m what is $d_{avg\ m}$? If you see the value at the end what is the value of d_{avg} as well as what is the value of x_m.

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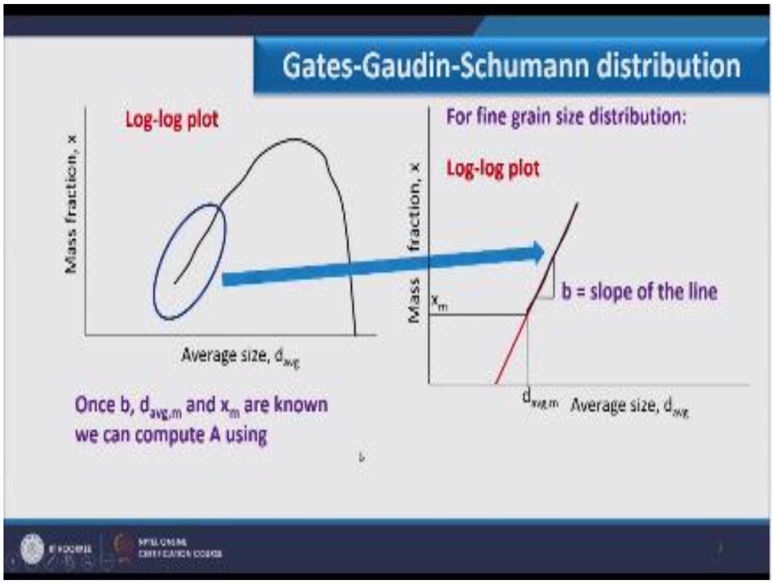

What is the last value of a mass fraction as well as d $_{avg}$ available to me that I can see from the table or I can see from this chart also. So once I have the value of b, d $_{avg\ m}$ and x_m I can calculate 'a' using this expression.

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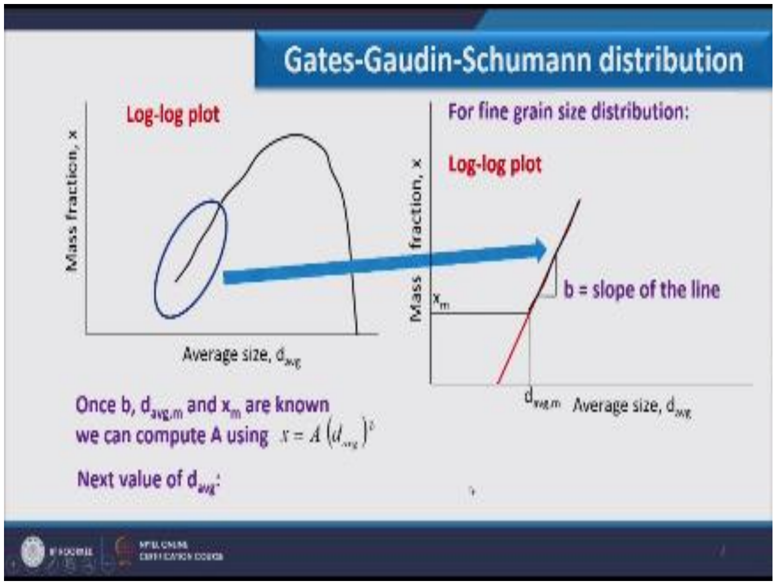

This is the Gates-Gaudin-Schumann distribution function, here I know the value of x, I know the value of $d_{avg,}$ I know the value of b while seeing the slope of a straight line which is shown in red color and 'a' I can found from this. So once I know the value of a and b I can have the expression of x as a function of $d_{avg.}$ Further if I want to calculate distribution in this particular region what I have to find is the d_{avg} below to this.

I know the lower most d_{avg} from the particle size distribution, what is the next lower value of $d_{avg,}$ how I can find it by using the factor by which the two consecutive screens are defined. For example if you remember lecture 4 of week 1 there we have discussed that between two successive screen there is a gap of, there is a difference of $2^{1/4}$ in the opening, in the similar line the same statement we will use over here that d_{avg} just below.

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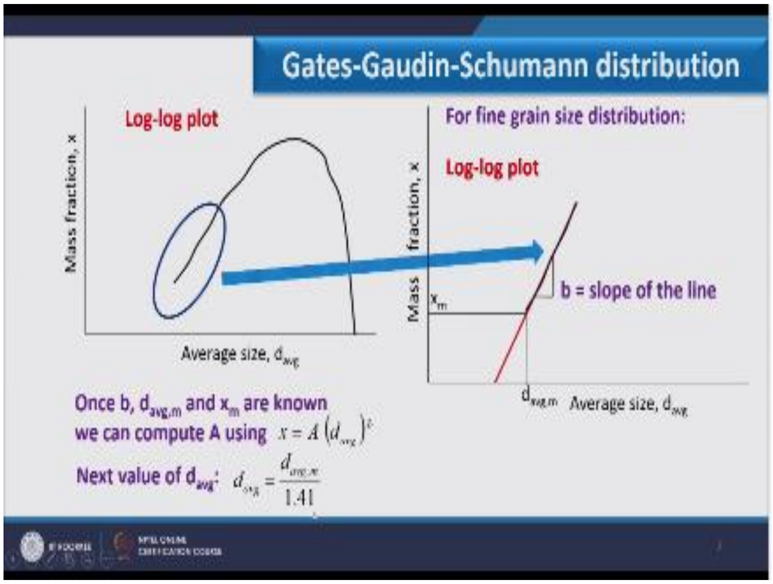

2 $d_{avg\ m}$ should be calculated as $d_{avg\ m}/1.41$, now why this 1.41 comes? Because instead of taking value $2^{1/4}$ we have taken over here $2^{0.5}$ so that value may vary.

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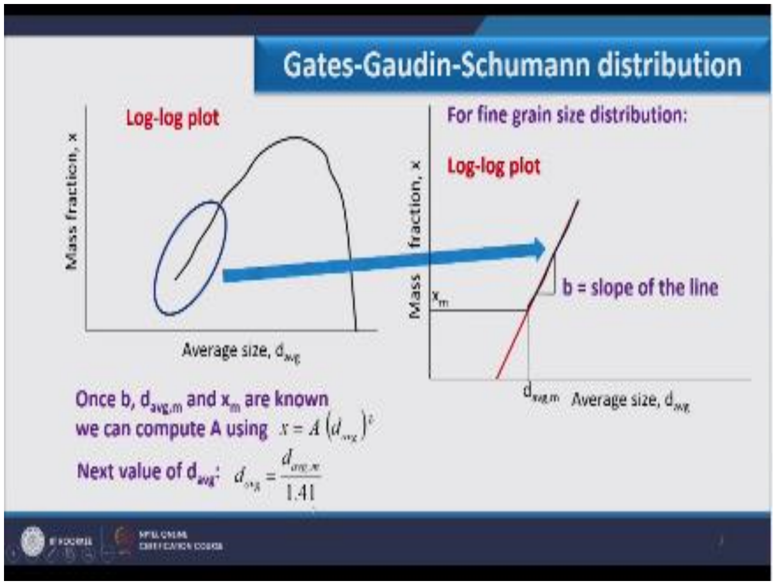

But the successive difference between opening of a screen can be defined by these vectors only, here I have taken that vector as 1.41 so once I am having the lower value of d_{avg}.

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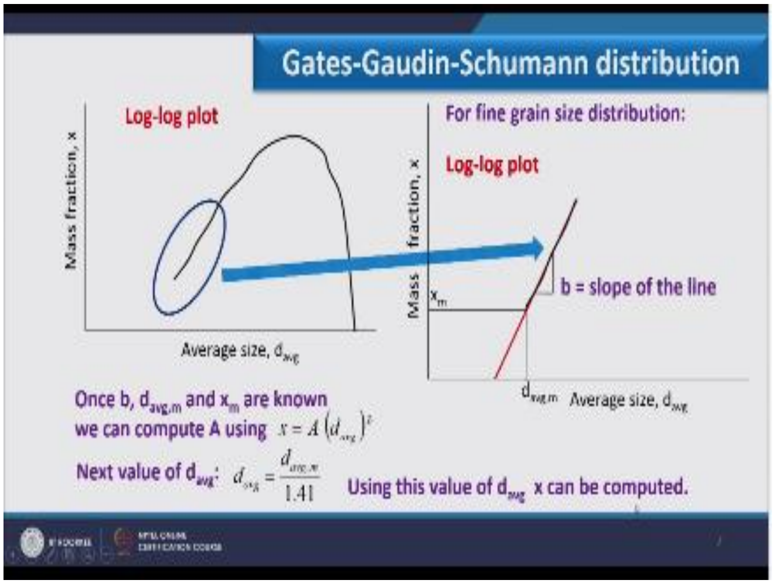

I can put that value of d $_{avg}$ over here, I know a and b value so I can find next value of $x_{m.}$ So using this values of d $_{avg}$ x can be computed so further we will find the next lower value of d_{avg} by using the same expression and then I can find next value of x.

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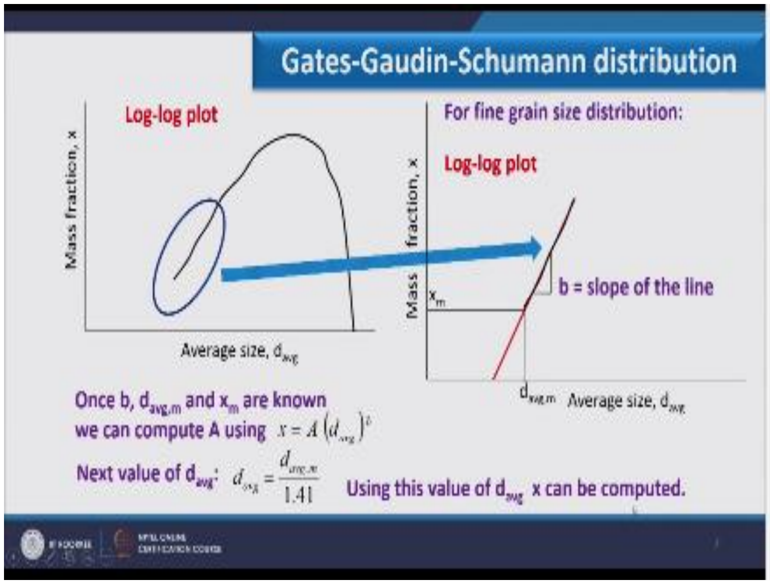

In a similar line we keep on calculating the x values till all the values of x would be equal to x_p.

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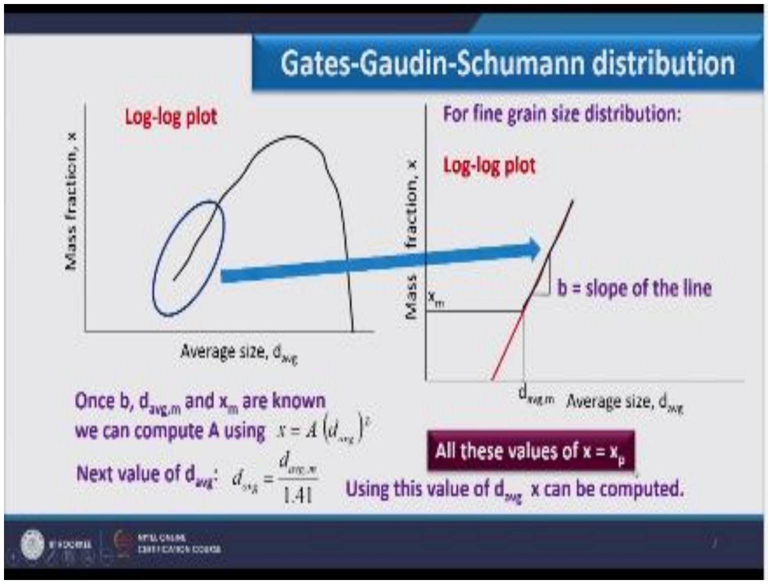

What is x_p? Is the mass of total feed available in the pan. So if x= x_p it means I am having the distribution of material.

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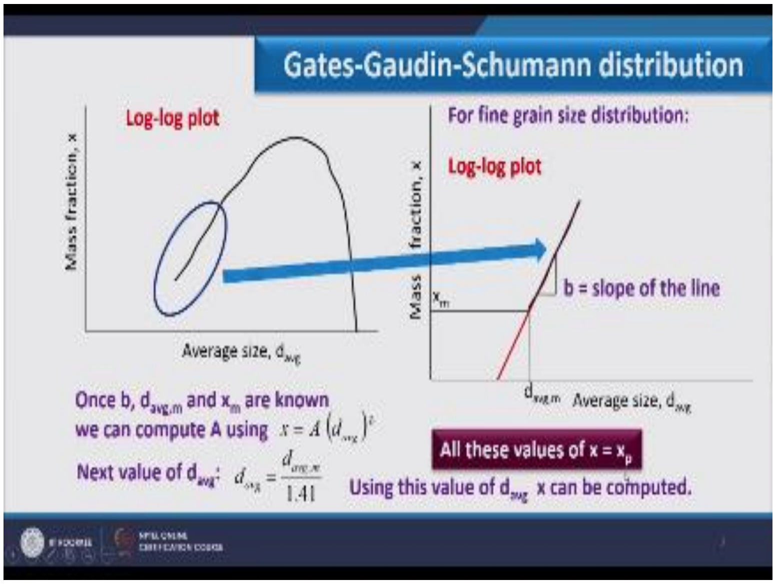

Which is available in the pan. If the size distribution of particles from a crushing or grinding operation does not approximate a straight line it suggests that there may have been a problem with a data collection and there is something unusual happening in the combination process, so again you have to repeat the process till we are getting the straight line because usually the data should be like that.

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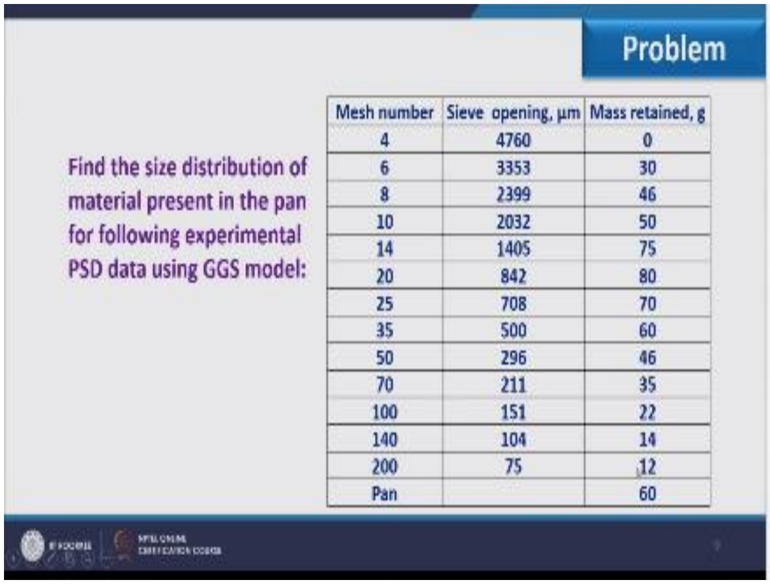

Problem

Find the size distribution of material present in the pan for following experimental PSD data using GGS model:

Mesh number	Sieve opening, μm	Mass retained, g
4	4760	0
6	3353	30
8	2399	46
10	2032	50
14	1405	75
20	842	80
25	708	70
35	500	60
50	296	46
70	211	35
100	151	22
140	104	14
200	75	12
Pan		60

When I am going to lower particle size it will follow the straight line. So to illustrate the computation, to illustrate how the GGS calculates the particle size distribution I have taken this example. Here if you see this in this table I am having the mesh number from 4 to 200 and below 200 I am having the pan, here we have the sieve opening and mass retain on each screen is shown over here.

So you can see in pan I am having 60 gram. So what is the purpose of this problem is to find the size distribution of material present in the pan for following experimental PSD data using GGS model. So let us start the computation of this, here this is the same table which just I have shown.

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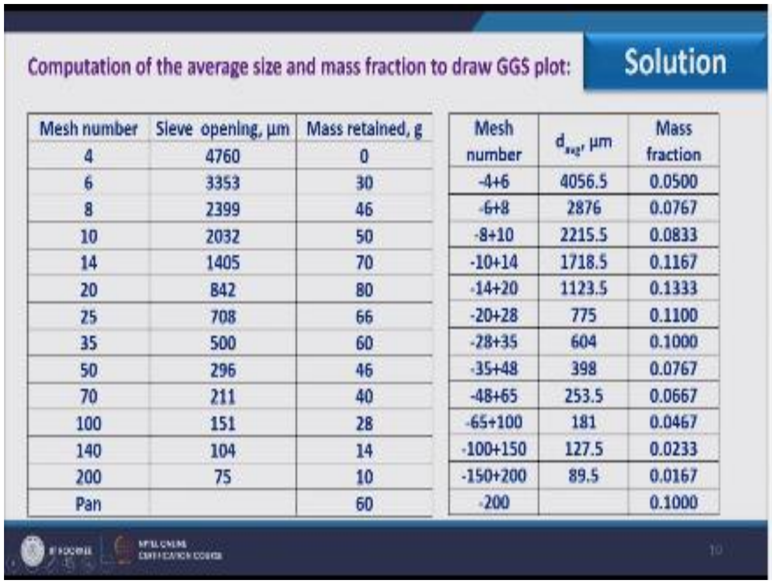

Computation of the average size and mass fraction to draw GGS plot: **Solution**

Mesh number	Sieve opening, µm	Mass retained, g
4	4760	0
6	3353	30
8	2399	46
10	2032	50
14	1405	70
20	842	80
25	708	66
35	500	60
50	296	46
70	211	40
100	151	28
140	104	14
200	75	10
Pan		60

Mesh number	d_{avg}, µm	Mass fraction
-4+6	4056.5	0.0500
-6+8	2876	0.0767
-8+10	2215.5	0.0833
-10+14	1718.5	0.1167
-14+20	1123.5	0.1333
-20+28	775	0.1100
-28+35	604	0.1000
-35+48	398	0.0767
-48+65	253.5	0.0667
-65+100	181	0.0467
-100+150	127.5	0.0233
-150+200	89.5	0.0167
-200		0.1000

Which is the problem table and here I have to calculate the average size and mass fraction to draw GGS plot. So how I can compute d_{avg} ? Because if you see the value of mesh number 4 over here correspond to this no mass is retained on this, it means all mass is passed through 4 mesh screen and here if I consider 6 mesh screen it has 30 gram.

So how I can write this -4 + 6 and d_{avg} I can calculate by doing the arithmetic mean of these two value, that is 4760 + 3353/2. So it gives me the value 4056.5 µm. Mass fraction how can obtain? By joining all this, by adding all these value and then 30 would be divided by that added value it gives the mass fraction of these particular fraction. In a similar line I can calculate the value, so here you see in the pan.

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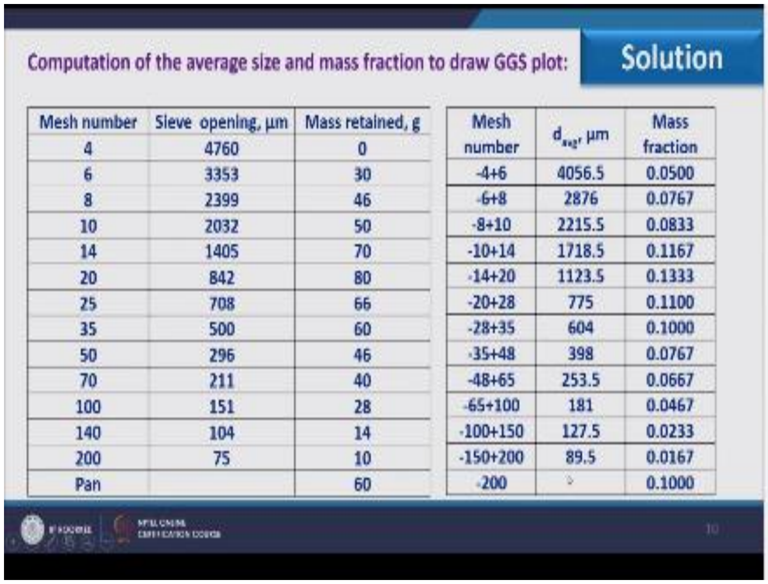

Computation of the average size and mass fraction to draw GGS plot:

Solution

Mesh number	Sieve opening, µm	Mass retained, g
4	4760	0
6	3353	30
8	2399	46
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-48+65	253.5	0.0667
-65+100	181	0.0467
-100+150	127.5	0.0233
-150+200	89.5	0.0167
-200		0.1000

I have written -200 instead of pan because the material which is passed through 200 mesh screen is collected on the pan. So -200 corresponding to this I am having the value 0.1, so I have to find the distribution of this particular section using GGS plot, so next step is to draw the GGS plot, so here we have the GGS plot.

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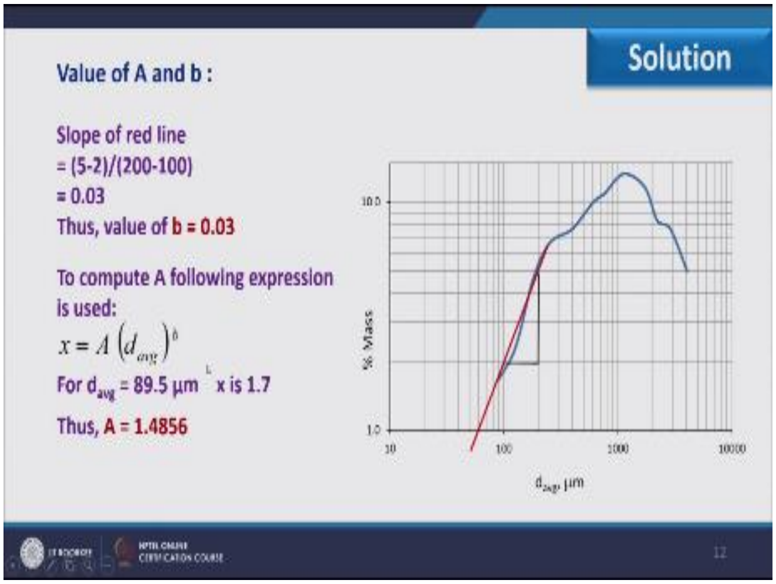

How I have obtained this, using this d_{avg} as well as mass fraction. So this mass fraction will give the negative value on logarithmic axis that is why I have considered its percentage. So here you see this is d_{avg} in µm and here I am having percentage of mass and both these axis are logarithmic axis as you can identify while seeing the grids of the diagram so this is the GGS plot. Now to find the value of A and V what we have to do, we have to extrapolate the data which is available at the end of this graph.

Where the fine size is available, N is also here but here I am having the cosset size but here I have to find fine grain size distribution, so I am concentrating on this particular end. So here I have taken the straight line which is not very much suited to this, so if I consider a straight line like this which is shown with red color the slope of this straight line you can find very well that is 5 if I am having 1 over here, then 2,3,4,5 5-2/200-100, so it gives me the value 0.03.

Therefore the value of b is 0.03. For computation of A I will use $d_{avg.}$

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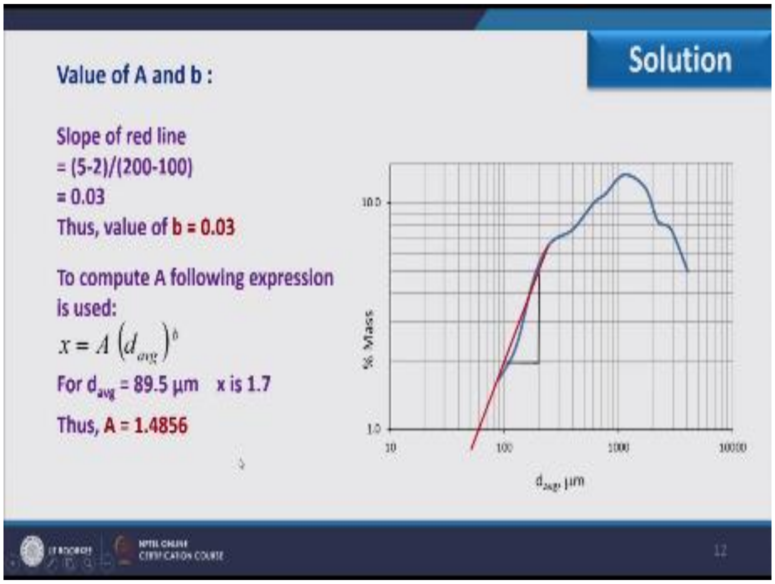

And x of last screen which is available at this point, so it is you can take this value from the table only, it is having d_{avg} as 89.5µm and x as 1.7 percent. So here x is basically mass fraction as well as percent mass if you remember the definition of it. So here I can write the x and d_{avg} value as well as b value and find the value of A which comes out as this much, so here to compute the size distribution of mass present in pan.

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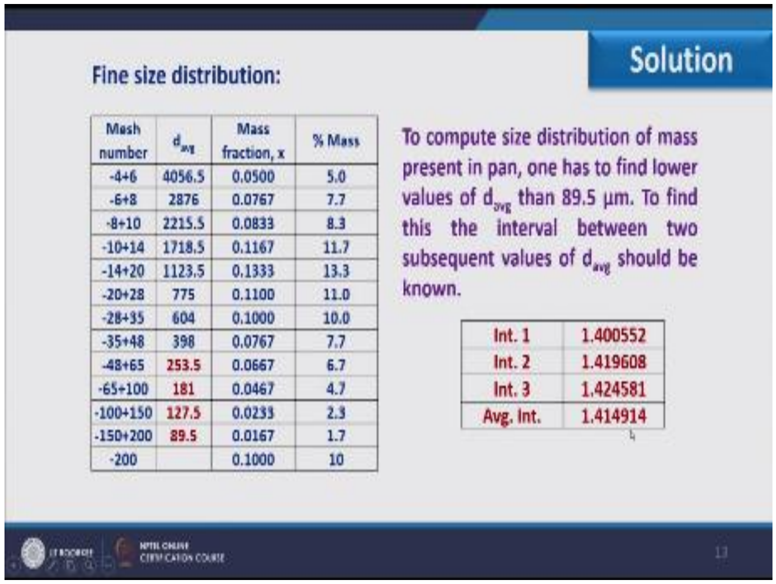

One has to find lower values of d_{avg} then 89.5 μm, to find this the interval between two subsequent values of d_{avg} should be known. Now what I have done over here if you see the value using these value I have plotted the, I have considered the end section of the graph. Now what happens if I consider these two value, the ratio of this two is coming 1.42458, the ratio of these two is 1.419, the ratio of these two 1.4005, so if I consider the interval between these the average interval I am finding 1.4149 so this value I will use to find the value of d_{avg} below to the 89.5 μm value.

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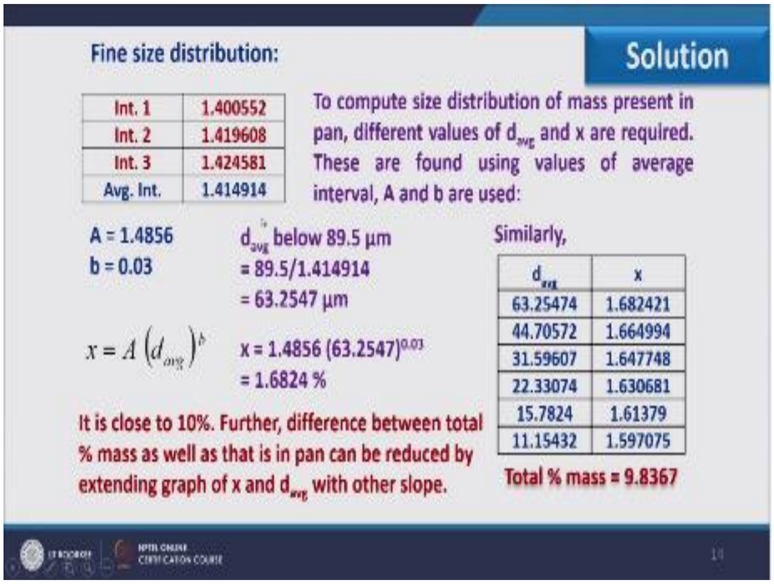

And in this particular slide if you see here to compute the size distribution of mass present in pan different values of d_{avg} and x are required. These are found using values of average interval A and b, so if you see.

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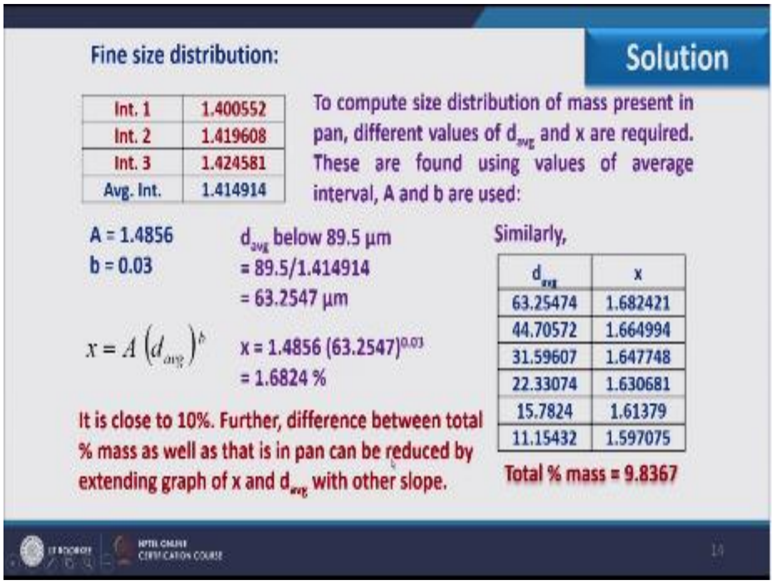

The average interval it is coming as 1.41495 A value and b value we have just seen how we have computed this. So the d_{avg} below 89.5 µm is 89.5/1.414914 that is this value and it is coming as 63.2547. Once I am having this value I can use this value along with value of A and b in this expression to calculate the value of x, so x is coming like this. So next value of d_{avg} I can find like 63.2547/1.414914 and further I will use that d_{avg} value along with A and b value in this expression to calculate x. So x I am finding as 1.664994, so here if you see here I am having different d_{avg} values and here corresponding x values are given.

So if you add all these x it is coming as 9.8367 which is close to 10% value which we are having at the pan. So it is close to 10%, now why this difference is there, I have to achieve 10 and I have achieved only 9.8367 because of this slope and slope value.

As well as value of A, so further difference between total percent mass as well as that is in pan can be reduced by extending graph of x and d_{avg} with other slope. So once I am changing the slope I can find new value of b and A.

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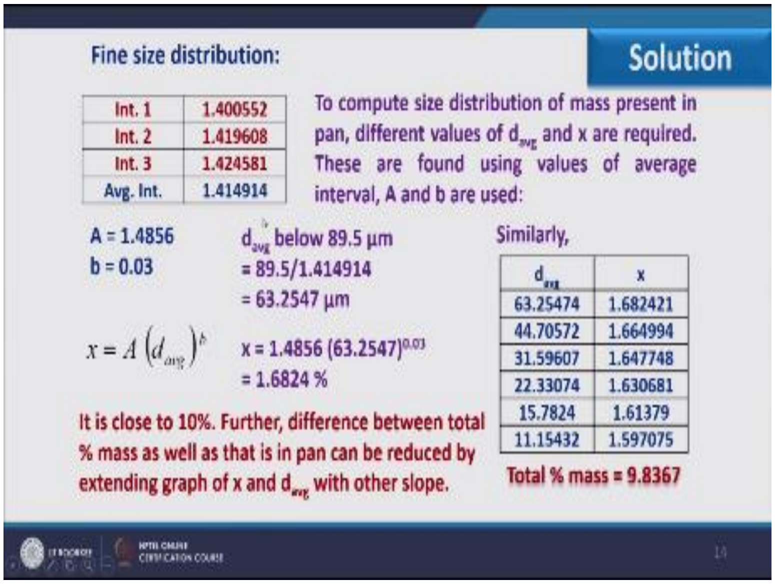

And similarly I am finding more suitable values of A and b which gives the total mass equal to 10%.

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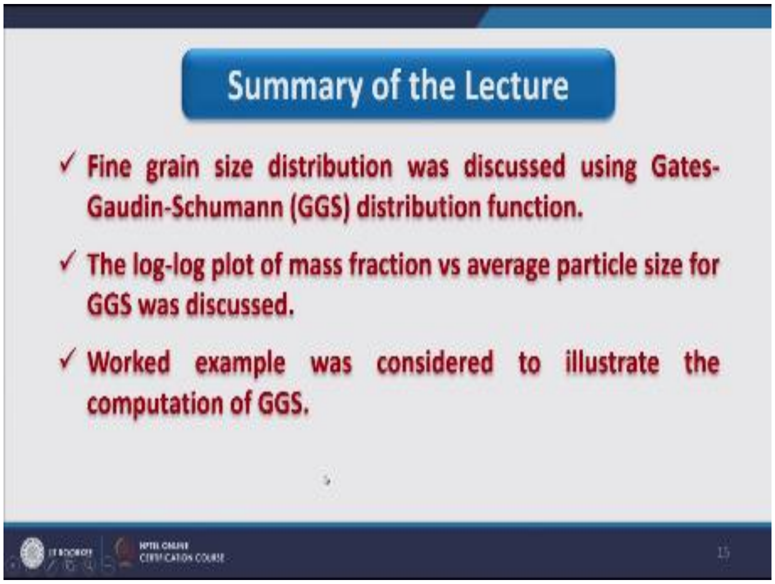

So the summary of this lecture is fine grain size distribution was discussed using Gates-Gaudin-Schumann distribution function. The log-log plot of mass fraction versus average particle size for GGS was discussed. Worked example was considered to illustrate the computation of GGS. So these are the three summaries, three main points of the present lecture.

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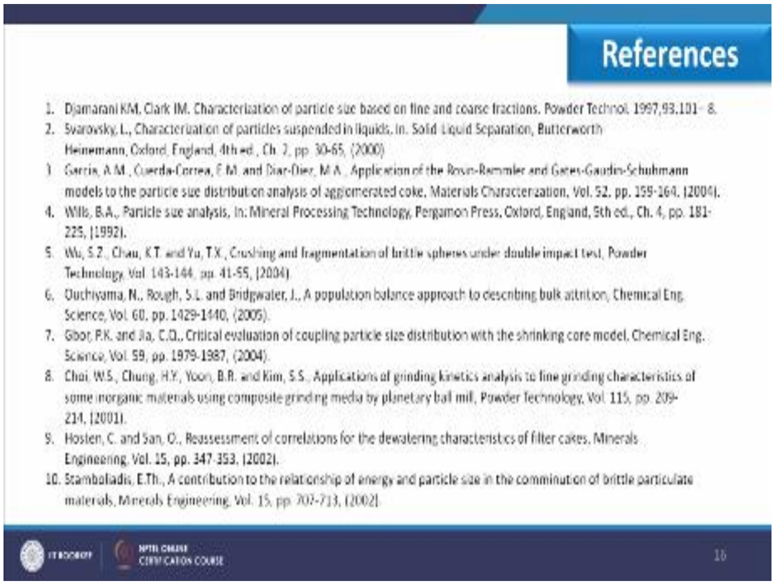

These are the references and that is all for now. Thank you.

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