Geotechnical Engineering I
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Lecture-10
Classification of Soils and Sieve Analysis

Until now, we have discussed a lot of things the learning the fundamental behavior of soils and particularly, you know the classification system, different types of weathering processes, how the soils are form, how do they get deposited and how do they get, what are the transporting agencies and so on. Now, today I will be discussing about the classification scheme number 2 for soils. And this is what is known as the mechanical characterization of soils.

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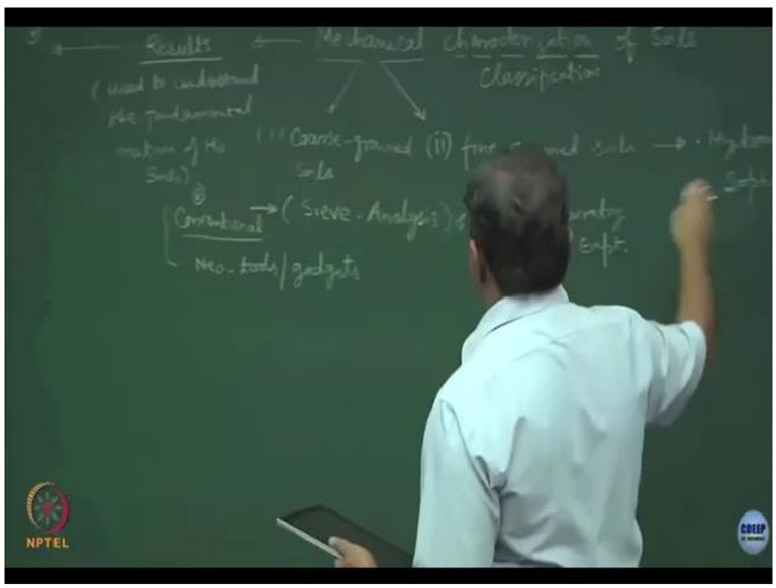

Sometimes we can also call this as the classification. So, this could be either mechanical characterization or classification of soils. Now, one thing you should realize there is that soils can be classified in different ways. We have talked about the geological classification scheme, residual and whether we have talked about the characterization or classification of soils based on the transporting agencies.

And we have also talked about the classification of soils based on their constituents. Now, we will be talking about how the mechanical attributes can be utilized to characterize or classify the soils. So, as far as the mechanical characterization of classification is concerned, we classify soils in 2 forms. The first one is a coarse grain material, coarse grain and the second one is the fine coarse grain soils.

As the name suggests, the particle size happens to be the most important thing to differentiate between the class of the soils. Mostly, when we talk about the coarse grained soils, we perform sieve analysis which you must have done in the lab. This is conventional. This is the conventional way of classifying the soils of the cross grain material. There are different gadgets which I will be talking about in today's lecture which are say neo.

So, neo tools or you may say gadgets, these are sophisticated instruments which are used for classification of the soils. Now, fine grain soils are normally classified based on something which is known as hydrometer analysis which you might have performed in the laboratory or we have again different type of sophisticated instruments which are used to characterize the soils. The process is simple, you take some over drain soil and pulverize it.

And dry it, so that the lumps are broken and then by using a series of sieves, you can find out what is the percentage of weight which is retained on the sieves. I hope this exercise you have done in the laboratory. You have done this classification. So, I am skipping this portion, you should be conversant with sieves analysis. So read about it and perform a laboratory experiment. Similarly hydrometer analysis also I am sure you must have performed in the laboratory.

I will be talking about the philosophy of how these tests are done. What is more interesting is in today's world, the results which I get from any of the mechanical characterization schemes. So, results are very precious. And these results are treated as the results which pathologic to the medical professional alright, so looking at these results, I can do a lot of diagnostics of these soils use to understand the fundamental behavior of the soils.

And this is an art to make out what type of soil you are dealing with. Now, one of the ways to interpret the results would be in most of the conventional schemes. When you talk about the neo tools or the sophisticated instrument, we may get the image and we can measure the particle there itself in situ. But when you talk about the conventional systems, where you are doing sieves analysis or hydrometer analysis.

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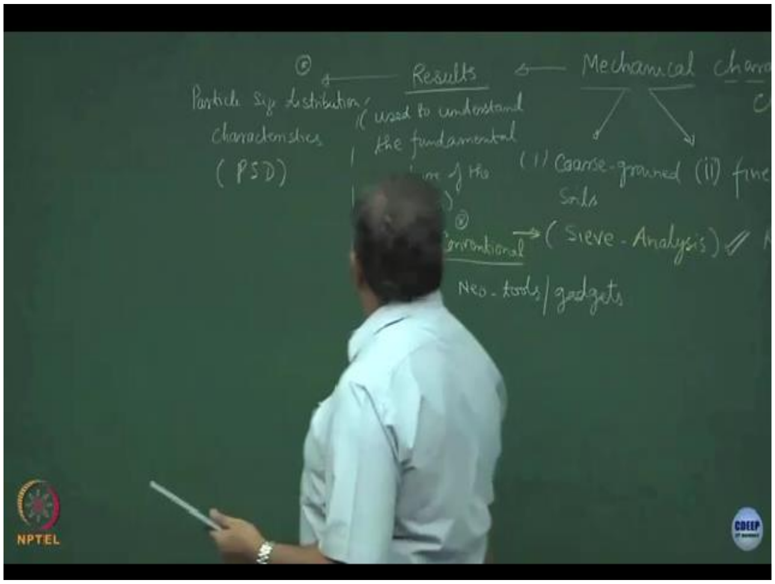

Normally we get what is known as particle size distribution curve. We do not use the word curve though is a curve rather we writing we will use the word characteristics alright. In short way we write it as PSD because a lot of information can be revealed or diagnosed from the particle size distribution graph or the curves, we normally use the word characteristics.

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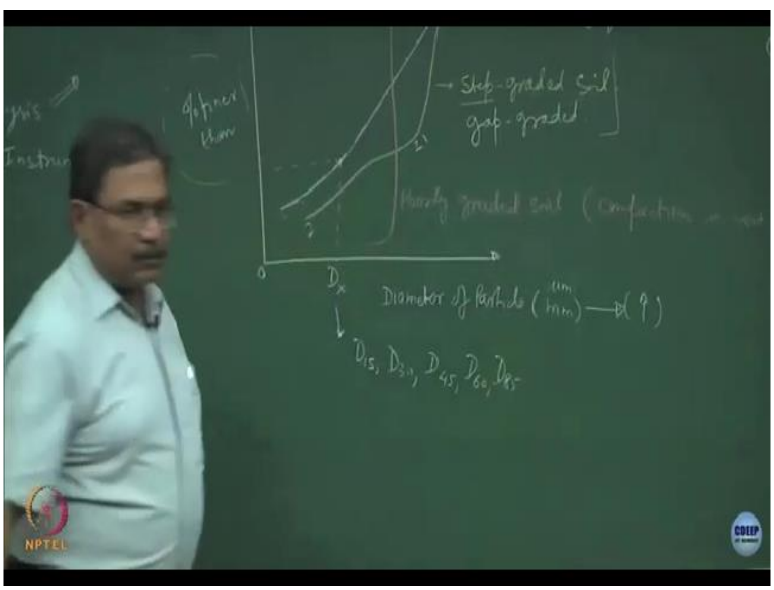

A typical particle size characteristic would look like there is a nomenclature, we plot as percentage finer, then is written in some of the books it is not a very good idea to use the word than because it is understood that if I am considering diameter of particle normally we write it in microns or mm micrometres. The way we define this term percentage finer than is corresponding to a diameter, we call it as dx.

So, suppose if I get a graph like this, alright, this a typical PSD the way you plot it is you do sieving, whatever is retained on a certain sieve soil you find out what is the weight fraction and then plot it over here for a given diameter of the sieve or the aperture of the sieve. So, this is how this is right, this becomes one point. This is how the external points are joined together to get a PSD characteristics.

Now, where is the technology part coming into the picture, this you will find any book, but our technologists will interpret the information from this graph is very, very important. So, this is a typical sieve analysis and looking at the nature of the curve alright of the characteristics, I can define a lot of behavior phenomena. This could be something like this also. I could define a curve like this also or I can get a soil where the characteristic curve would be let us say of this type alright.

The red one is defined as a poorly graded material alright. Why poorly graded, because most of the particles are falling in a certain range of particle size starting from let us say 0 to 100%. And this size, this side the diameter increases, the yellow one seems to be step graded material or let us use our soil, however the white one would be a uniformly graded soil.

So looking at the nature of the graph or the characteristic curve, I can understand what type of soil I am working with, what is the philosophy behind this. The philosophy behind this is at the most first of all, I can have 100% of the soil mass. And then the minimum would be let us say, in few microns. Poorly gated material cannot be compacted. So imagine you have all snooker balls and if you want to compress them together or bring them close to each other it is not possible why.

Because the sizes are so uniform that you cannot create a dense matrix out of it. So, absolutely difficult materials to compact, compaction is next to impossible is poor let us say alright. Size of the grains of the soils are uniform and hence you cannot compact them much. That means I cannot create a compact system out of it, most of the soils which are lying in the kinetic basin and which are prone to liquefaction.

I think we have discussed the word liquefaction earlier. Loss of strength because of shaking up quick would be mostly poorly graded soils alright. So they cannot be compact that, you cannot use them for designing a good foundation let us say foundation pack, how a step graded soils they look like as if they are the combination of 2 types of soils. So this is soil number 1 and this is for soil number 2.

So, this is the step graded or sometimes we also call this as gap graded alright, as if they are the combination of 2 types of soils, tricky materials to utilize. Now, where is the technology. The technology is tomorrow one of your customers is going to tell you give me a finished product where the particle size are going to be only in certain range and I want a certain gamma D. Now, this becomes an interesting problem where technologists have to work material scientist.

They are trying to pack the nanoparticles to a desired density. For making a chip let us say so, difficult task, this is absolutely impossible a poor, the best material to deal with as a civil engineering material would be a well written material. Now, this also known as sometimes well graded, the type of good book which you follow you will find these type of analogies, so, excellent materials to or soils material means soils to compact and create a structure of your requirement alright.

Now, I am sure you must realize until now everything is going very, very, you know, qualitative. We are saying poorly graded, well graded, step rated, gap graded everything is qualitative. There is no quantification of the phenomena which you have done until now. So, what we do is as far as the coarse graded materials are concerned, we try to quantify them by using the Dx which are D 15.

Now, how to read this, D15 is the diameter of the particle which is 15% finer than the entire particles is this part okay. So, D15 is the diameter of the particle which is 15% finer than the entire mass. So, in this type of a soil, you will have certain value of D15 we use another term as D30 30% finer than diameter. Then we use the term, D45 sometimes, we use the term D60, sometimes we use the term D 85 also. This is the nomenclature.

And remember D is the diameter in millimeters. So, one of the ways to read this graph is on x axis from left to right the particle diameter increases alright, if you never plotted reverse, then the whole philosophy will be changed. So, the nomenclature is you plot the diameter on the x axis which is increasing in size. So, normally from micron range to millimeter range and this is from 0 to 100% is this okay.

So, when you do the laboratory experiment, please try to plot these graphs and interpret. Now, the interpretation number 1 is about the particle sizes.

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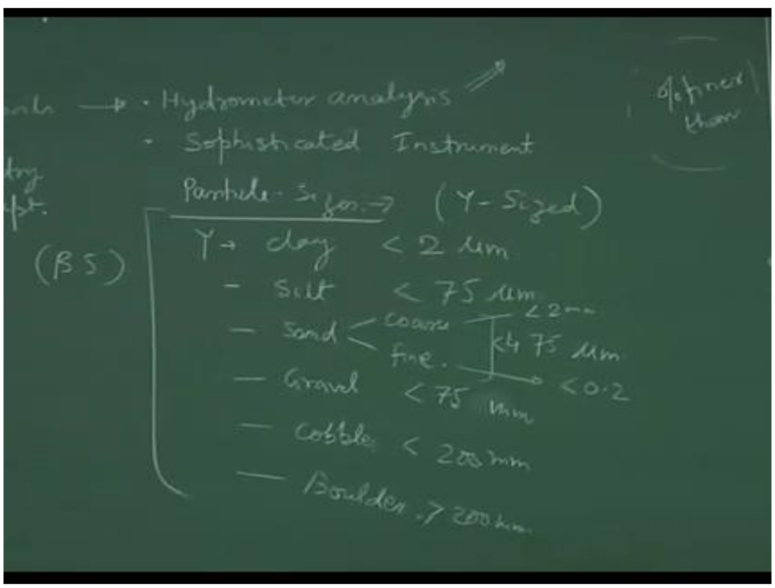

I hope you will realize we are talking about the mechanical characterization of soils. So, no chemical attributes or chemical picture, no mineralogical attributes or chemical picture is only the attributes size and based on size we define clay fraction, silt fraction, sand fraction, gravel fraction, cobble fraction, stone fraction gold fraction, is this funda clear.

So, we are not using her word the clay as the mineral we are using here the clay as clay sized, silt sized, alright gravel sized and so on, so these are all sized, we define this as y sized y could be clay, y could be silt, y could be sand, y could be what it could be see coarse sand, fine sand, then comes your gravels, then comes the cobbles, and then comes the boulders. So the way we read it is clay sized, silt sized, sand sized, in sand course fraction of the sand fine fraction of sand, gravel sized, cobble sized. I will remove s boulder size.

One of the guidelines says that clay size is less than 2 microns. silt is less than 75 micron. This you have to remember alright, this part you should remember. Sand is normally 4.75 micron first of all, less than 4.75 micron, gravel is less than 75 micron no 75 mm, cobbles are less than 200 mm, and boulders are greater than 200 mm. This is the classification system which is normally used as per Bs, British Standards alright.

There is a small deviation as compared to other classification schemes. I will not going to those details as far the fine sand is concerned the fine sand is normally less than 0.2 mm and coarse sand is less than 2 mm. This is as per the International Society for soils science. So, there is a standard yes please. This is 4.75 less than 4.7. Yeah so I understand your point. So this is less than that is what I said there is some discrepancy.

So the more and more which one 4.75 micro meter. Yes sands. No, no, this is micro meter. So sand is 4750, this is okay. Acha yeah. So 4.75 mm yes and then you have less than 2 mm 0.25 mm 75 yeah now it is alright. So, there could be a discrepancy in some of the particle sizes depending upon the type of course that you are following, but try to remember at least British Standards and this is what is going to help you.

So, when you analyze these graphs, you plot these numbers over here and read out what is a fraction which is finer than this is okay, this I am sure you must did in the laboratory. Now, one step ahead of this would be there are few numbers which we defined for coarse graded materials based on the sieve analysis utilizing this concept, where we define a term which is known as Cu.

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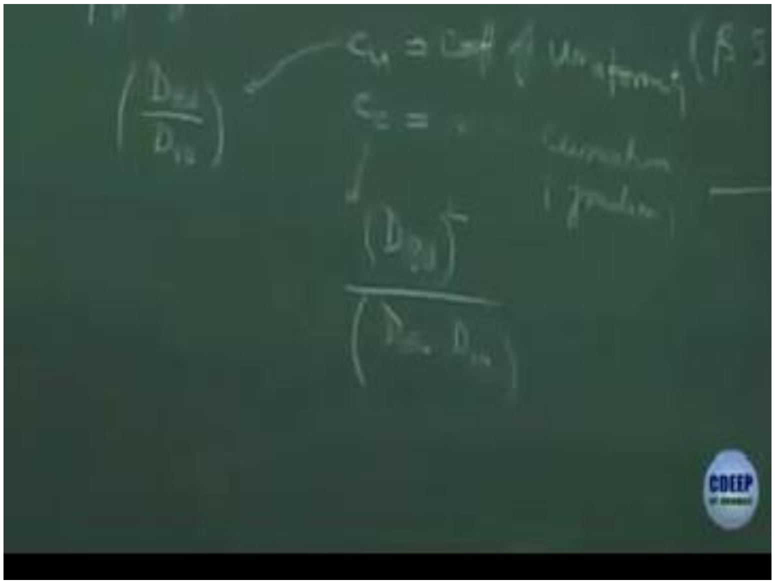

This is known as a coefficient of uniformity and there is something known as Cc. We define this as coefficient of curvature. Sometimes we also call it as gradation coefficient of gradation, alright now cu and ccs are, so see cu is D 60 by D 10 this is correct is it, and this is the D 30 square upon D 60 into D 10 is this part okay. As far as coarse grain materials are concerned, the classification is done. So you take coarse grain soils texture would be very sandy material, gravely sandy material, seemed them through a stack of sieves, find out the percentage which gets retained on the sieves.

Compute the percentage finer than that aperture and brought into the respective diameter, plot this graph from this graph get the DX values, classify the soil based on this nomenclature, compute cu and cc term alright, and there are some standard numbers which I was assigned to this we will talk about that. Now, what is the application of the whole process as a technologist, let us try to remember this series nothing more than that rest I think you understood.

Those of you will get a chance to work in the design of filters and this is our chemical engineering becomes very close to geotechnical engineering, soil mechanics alright, when you design different type of filters, different type of filter media or when I design different type of filter or sewage control, talking about the design of dams.

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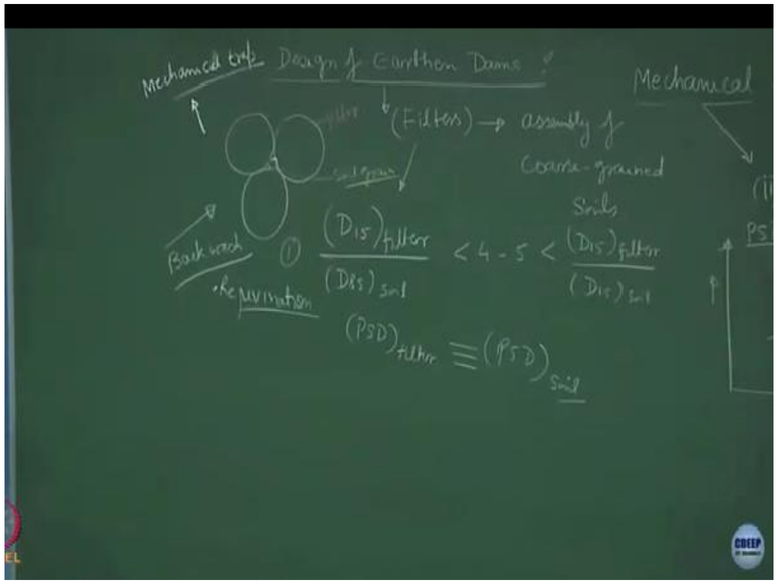

Dams are the ones which are most neglected objects in our society. And I hope you have realized that if you are not giving them due consideration, what is going to happen. Hope you are realizing last one month whatever has happened in the country. Is this correct, you must be reading newspapers and all. So, this is going to be an interesting subject to discuss, we will be discussing quite in details.

One of the components of the earthen dam is filters and filters are nothing but the assembly of course grained material alright. So when I say coarse grain soils you will be utilizing different components fractions in such a way that you can form a good filter media. Swimming pools have normally granular filter beds alright who with the water trickles. And these general material are quite prone to give shelter to the bacterial activity.

They get converted into biofilters and through which I can pass the swage and the sewage can be treated. So, those of you who are interested, learn this more and more. When you design filters the criteria is do not try to mug this up. It is all available in the course. As a designer, you will be getting course which you can use upon D 85, this is just to showcase to you what is the application of the particle size characteristic.

D 15 of filter divided by D 15 of soil. One of the guidelines to learn the filters, the second guideline is the particle size distribution curve of the filter soil or the filter material should resemble the particle size distribution of the soil. Let me ask you a question. Suppose, if I have you know PSD now, I will not be drawing x y x all the time. And suppose if I say this is the soil why do designing filters.

First application which I said that you want to allow the sewage or the wastewater to trickle through it and get purified. Apart from this the filter could be designed to stop erosion of the soil fine. So that the particles of the soil get trapped in the poor space which has been created because of the grains. So, a typical conceptual model for a coarse then filter material would be like this. This is the soil or the grains of the soil and the finer particles yes, this would not be the grains of the soil, this would be a filter media.

So, this would be a filter media and the soils would come and sit somewhere here, soil particles will come and get mechanically log over here. So, this would be a soil grain I hope you are understanding what I am trying to repeat. The filter particles are acting as the sea and they will not let the fine grain material to pass through the whites is this okay. So, this is what becomes a good filter media.

So now if I extend this analysis over here and if I asked you a question where the filter media should be sitting, what would we answer. So this subject requires a lot of intuitive thinking and mugging is not going to help you, it requires dedicated understanding of the concepts. I am sure you must have realized in a lot of concepts, I keep on asking why, where, how. This is what I expect from you that you should be aware of this or this you have to go back.

Read some literature, apply some mind. Do I give a lot of hints over here. So anybody who can answer this question, if the soils are here, where the filter should be on the left hand side or right hand side, the soil particle have to be finer than the filter media. So this answer is wrong. Why, there is no funding providing a filter media which is finer than soils, agreed those soils are soils have to be protected. So, this is what we learn today correct, is interesting.

Applying logic, believe me you need not to do mug up anything. So, this is a filter media okay. This fulfills this condition now, remember this side the particle size is increasing, the size of 1%

extraction is increasing and this is a condition why I wanted to design filters so, that the fine particles of the soil get trapped and they do not come out of the matrix to stop erosion process alright.

This is one constraint. The second constraint is so, this is what the first condition would be, what are the second condition, soil is a very intelligent material. Remember, the moment you include something into it, it has a tendency to reject that inclusion unless the system is identical to it, among all the construction material that you come across in the history of mankind or evolution, you will realize that the soil is the most you know, intelligent material.

So, intentionally I have drawn both the curves quite similar to each other clear. So, another requirement is the PSD characteristic shape should be identical to the type of soil which you are trying to protect alright. They should be similar as it just slightly shifted on the right hand side. Now, if your material happens to be, let us say a poorly graded soil, which are the chances in the material sense you cannot have several sizes available in the system.

The question would be, I cannot achieve the density, because I have written there you can compact it you can create a compact bed out of it and if you really want to compact a material, this has to be a material where most of the particles of different sizes are available in it alright then only the materials can be compacted. What is the theory behind this, the theory behind this is uniformly graded soil, well graded material.

The first layer of the particles would be bigger. The second layer of the particles would not layer I should use, the second types of particles which are available in the soil mass would be this alright, the third types of soils would be finer than this and so on. So larger the variety of the particles that you have in the soil system, the chances of compacting it would be better and this we will prove that wrong with the help of theory of compaction is this okay.

Those of you who will be working in let us say interdisciplinary areas like growing grass on the pictures of the sporting fields whatever, pictures or coarse of different type of sports, what is expected, it is expected that you create this matrix first number 2 grow the vegetation. So, the rules of the vegetation should pass through the pores which are available in the system and they should go on hold the bottom layers of the pitch or the court agreed.

And then comes the microbial unit. So, microbes will harp on these available spaces, they will grow over there and they will form a strong system of soil, root, bacteria, environment, water interaction. Now, this is a hard subject on which people are working, is this part clear, diameter of the particle increases the percentage of it finer should decrease, very good question. Remember, this graph has been obtained by sieving.

You must have received an answer the lab. So, you must have seen apertures on the sieve clear. So, the top most sieve is a big aperture or the smaller aperture you see bigger. How to read this is good that you asked this question. So, the biggest particle everything is part finer than this. Everything passes through this agreed. The second sieve size is less than the first one, less particle size 80% finer than this agree.

And so on, so it is good that you asked this question for the sake of everybody. Percentage finer, finer is also same as the percentage passing, anything which is finer than that particular aperture is going to pass through that sieve and hence it is finer passing also it depends upon what you are using, anything else. Yes, the filter which we use for water purification if once the dust or the darkness is trapped in the filter.

So is any process to remove the dirt or just it with the filter is got wasted. Very good. So, excellent question when I am teaching sewage analysis if I do backwash alright, so what I am going to do, if I apply backwash, if I pump let us say some fluid inside the filter and if I force these finer particles come out of the matrix, this is sort of a washing clear. So by applying back pressures or by applying back washing, I can clean up the filters.

So you can rejuvenate them, read more on the net about this, so in most of the environmental engineering related problems, the biggest issue is designed to filter and the filter stops working after it has lived its life agreed. So what I am supposed to do and supposed to point and the moment I throw it, this becomes a secondary source of contamination and imagine a matrix which has lot of concentration of chemicals.

So where you going to throw it, big question, how you lifted another question. So better what we should do is keep on cleaning frequently alright okay. Now coming back to your other question regarding the cleaning up of the water which you are using in the candles of water purification system. Their pores are going to be extremely small. So, they are made up of geolytic material, I can create a mechanical sieve read more about this.

This is a mechanical trapping I have created alright, based on the particle size I am trapping the small particle clear, I can design a system of filters which could be a molecular filter. So, what is going to happen now, all these sieves, all these systems which are going to be in a matrix will trap cations and the molecules plasma treatment of different types, different types of silica transplantation.

Different types of chemical processes which are taking place in the industry and he making particularly vegetable oils, different type of medicines which you are doing are all based on sieves blood transfusion is another good example of how you would filter out the bad blood from the good blood, good example of molecular would be kidney of the human body. So read about all this okay, is the concept clear.

So here we have gone from mechanical to molecular system is a different aspect altogether. So, in the candles that you are designing, all the cations will get held up and then the water gets purified. Currently there is not any technology for RO purifier to clean it filter, we are just going all the filter of RO purifier, I think you know that RO is the obsolete idea and people are again coming back to the point that RO should not be used of your seasons.

All your calcium, sodium, magnesium has gone out of water and that is what you are drinking and people are saying that you have vitamin deficiency because of RO water and cane water, bottled water you read a lot of discussions going on. So what they are doing again after doing RO, they are doing mineralization of water stupidity. Let us move on to now yeah I show you what is the state of the art in classification or characterization of coarse grained material. Remember, we are still talking about the coarse grain materials.

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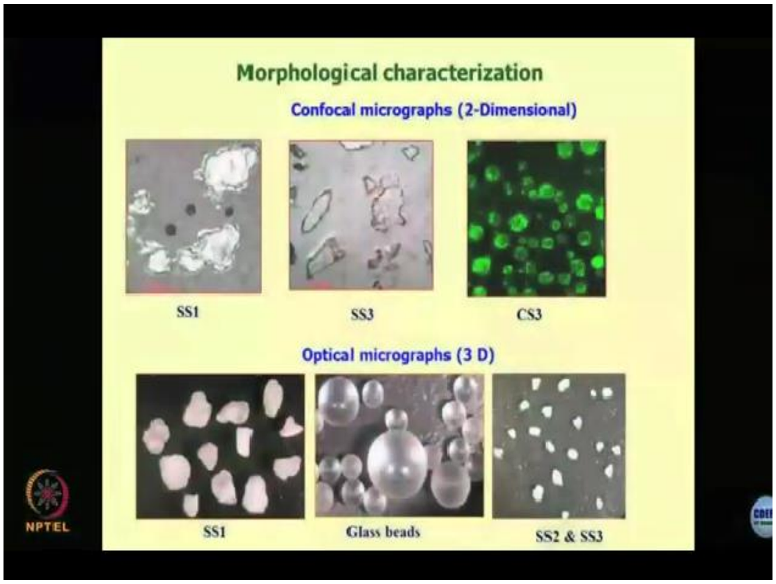

So, when we deal with the coarse grain materials, all this is conventional, which has been done since 1930 40. You know, not much of fun here. But these 2 concepts confocal micrographic and optical micrography, you know people are using to study the particles in a better way. So, those of you who might have heard about neoprene bearings clear. So, bearing bear in like you have ball bearings, so neopin bearings, you know, people try to those steel with some sort of additives.

It could be carbon, it could be carbon black, very high speed carbon they add into it. So, when you do doping of the steel, it becomes very high strength and you know, it resilience modelers and other models are extremely high. So, when you are doing this type of research or application and these type of studies become very important, I want to see the whole morphology of the particle. So, 2D and 3D types of analysis is done.

This is a peculiar standard sands which I was talking about that as per Indian standard, this is supposed to be a spherical system of sands which is not true. These are the thin sections which have we have taken and we have done the analysis. In 3D, the standard sand looks like this highly irregular shapes. These are the glass beads which are made up of glass manufactured by industries.

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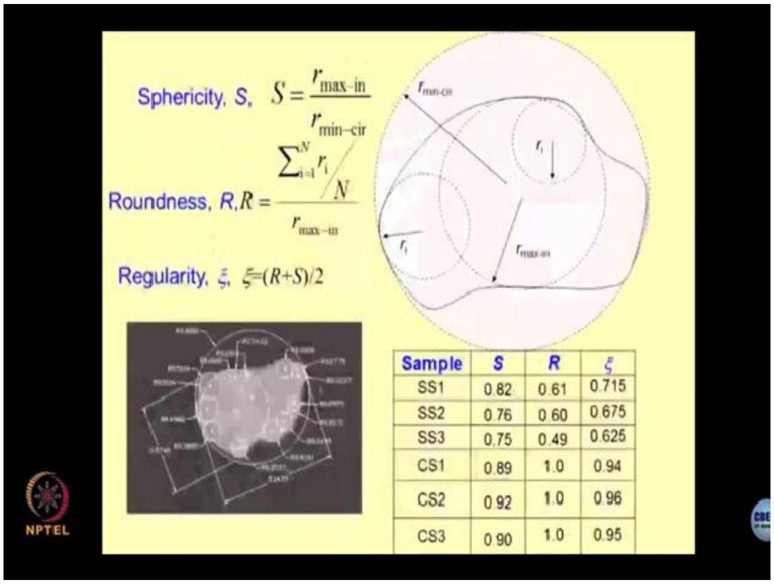

And this is how the complete modeling of grains is done in today's world. So, you take the photographs of the each grain sit down in your lab, maybe 3000 4000 grains, you take photographs, and then you try to inscribe as scribe as many circles as you can. So this is the grain of the sand, one of the grains and then try to fit in as many circles as you can fit in inside the grain boundary and one which is you know, subscribing the entire thing.

And then you take their ratios to define the sphericity roundness and regularity, those of you who might get a chance to work in earthquake engineering, soil dynamics particularly for them this becomes very, very important. So, how spherical system and how rounded a material is, how regular a material is and then by defining these indices we can go ahead with this. Those of you who are interested in reading much about it, read the papers which have been published by Prashant Barde and myself long, long back.

And then we have correlated the particle morphology with the sheer velocities which are required to cause liquefaction of the soils.

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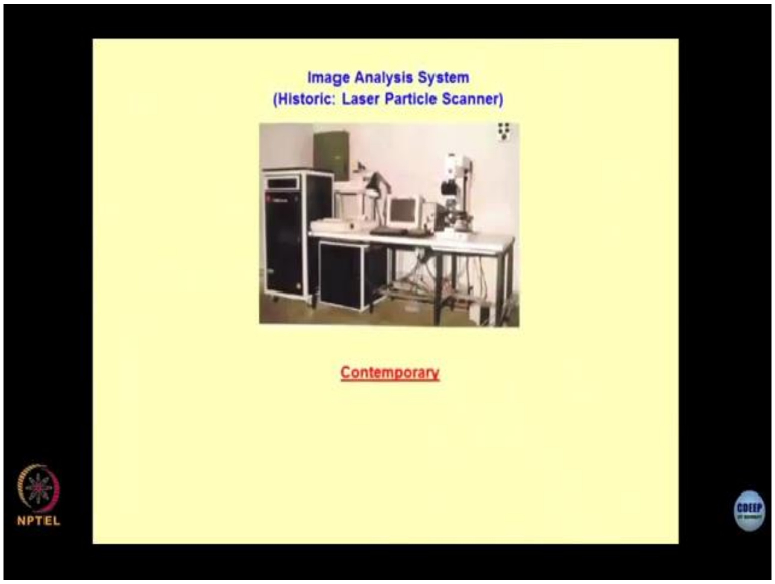

Another interesting thing is what is known as image analysis system. This is the pristine, historic, you know laser part in the scanner on which we used to work with 15 20 years back, but now the world has become quite technologically advanced. So just to avoid any copyright and unnecessary canvassing in the classroom. I have not included any particular website but what you can whenever you get time please go through all these websites where are different vendors have come out with very sophisticated particle analyzers.

So, gone are the days when people used to do all these things manually or sieve analysis becoming obsolete. The reason is simple if I am dealing with the sands which have a lot of cabinet on them, or if I am having sands which might be having some sort of a alteration of the properties by any chemical process, just know I was talking about a chemical alteration of the sand into you know, mineralogical alteration, which I discussed long back.

So, people like to see the real life situation other than breaking the bond and breaking the you know carbonate adjacent between the grains and so on. So one of the systems is known as image analyzer, which we have in IIT I think most of our departments will be having Melbourne and just go and check out the video which give you enough idea about how this particle size analysis is done for the coarse grain materials. And everything is computerized for that matter and you can get results quickly fine.

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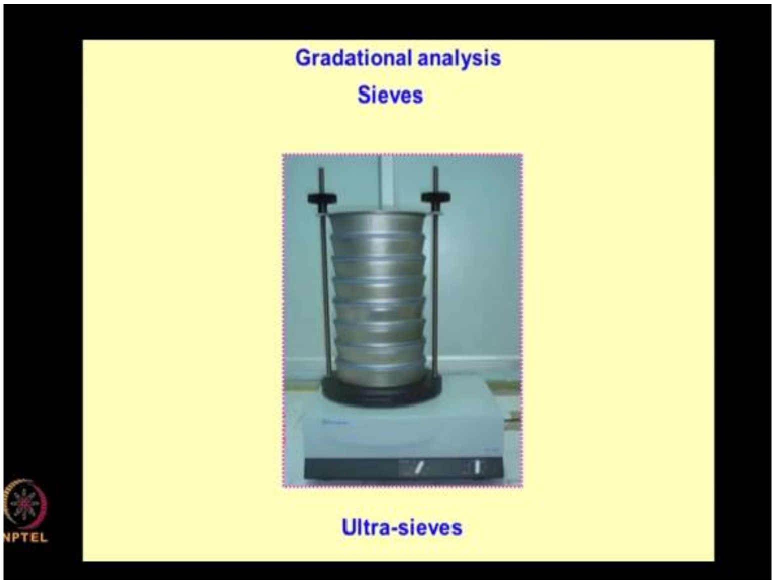

Then sieves which you might be using in the laboratory. But these are slightly sophisticated sieves which we have in our laboratory and these are laser cut sieves and we can go up to 2 micron dry. But this is an art and there is a paper which we have written in ASC American Society of Salinas where we have shown that why all this should not be studied anymore. But coming back to the 3rd year classroom I have to talk about all these things.

So this advanced research and there I am trying to show that none of this works. If you have time, if you have talent and idea go through this alright, this work was done by Santha Kumar and myself in 2013 14 I do not know. S. Santha Kumar So, these are the sieves which are used for dry sieving up to **2** 20 microns, when 2 microns 20 microns. And these are known as utra sieves.

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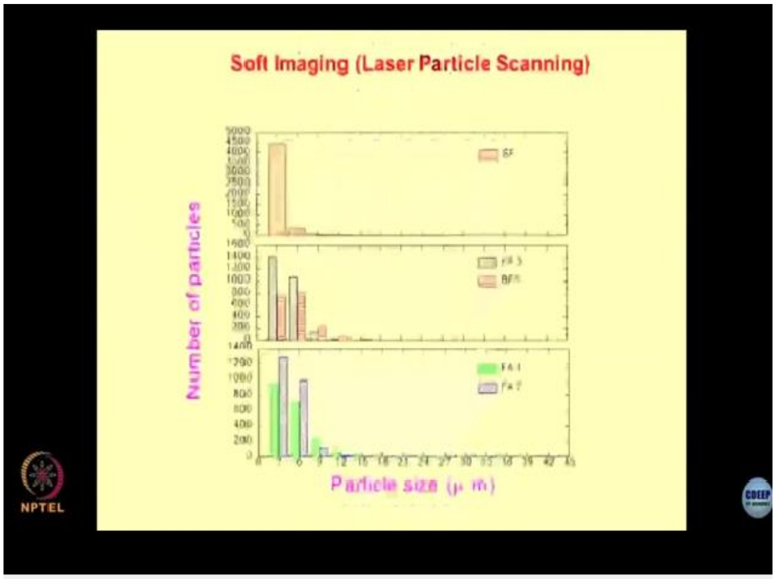

The results of soft imaging are this earlier days my students used to work on this type of histograms you know 4500 particles have been counted, you not believe, this is what has been done, and then we used to draw a particle size distribution.

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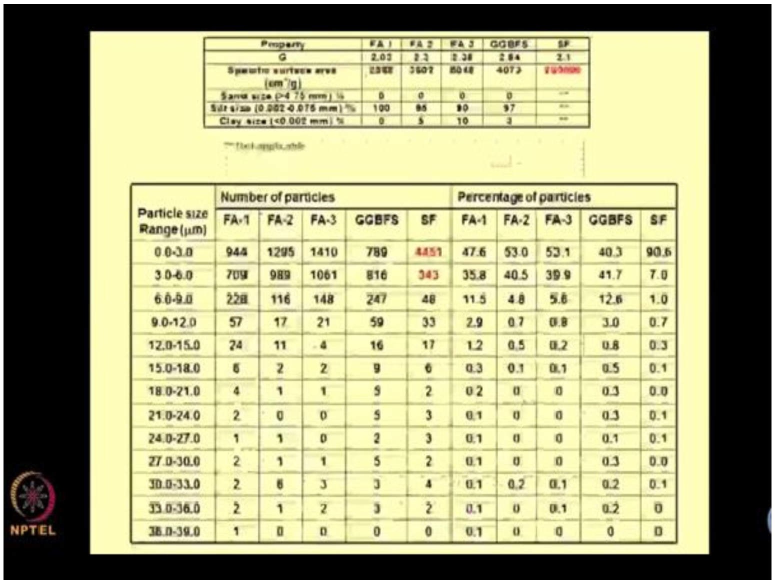

Property	FA 1	FA 2	FA 3	GGBFS	SF
G	2.03	[illegible]	[illegible]	2.84	2.1
Specific surface area (cm^2/g)	[illegible]	[illegible]	[illegible]	4073	[illegible]
Sand size (>4.75 mm) %	0	0	0	0	**
Silt size (0.002-0.075 mm) %	100	95	90	97	**
Clay size (<0.002 mm) %	0	5	10	3	**

Particle size Range (µm)	Number of particles					Percentage of particles				
	FA-1	FA-2	FA-3	GGBFS	SF	FA-1	FA-2	FA-3	GGBFS	SF
0.0-3.0	944	1295	1410	789	4451	47.6	53.0	53.1	40.3	90.6
3.0-6.0	709	989	1061	816	343	35.8	40.5	39.9	41.7	7.0
6.0-9.0	228	116	148	247	48	11.5	4.8	5.8	12.6	1.0
9.0-12.0	57	17	21	59	33	2.9	0.7	0.8	3.0	0.7
12.0-15.0	24	11	4	16	17	1.2	0.5	0.2	0.8	0.3
15.0-18.0	6	2	2	9	6	0.3	0.1	0.1	0.5	0.1
18.0-21.0	4	1	1	5	2	0.2	0	0	0.3	0.0
21.0-24.0	2	0	0	5	3	0.1	0	0	0.3	0.1
24.0-27.0	1	1	0	2	3	0.1	0	0	0.1	0.1
27.0-30.0	2	1	1	5	2	0.1	0	0	0.3	0.0
30.0-33.0	2	6	3	3	4	0.1	0.2	0.1	0.2	0.1
33.0-36.0	2	1	2	3	2	0.1	0	0.1	0.2	0
36.0-39.0	1	0	0	0	0	0.1	0	0	0	0

Now life has become simple we have different type of gadgets where you can do analysis quickly. Now, just to show you something interesting, different type of materials and a specific surface area and this is silica fume. You know, we have been talking about 20 meters per per gram is the surface area of the silica fumes and this is how the statistics used to be done. Number of particles they are falling in which range and based on that, you see the predominance of the particles.

But there are many research papers which are available where people would like to withdraw certain part of the particle size distribution and that becomes a synthetic soil. So, somebody orders for a specific purpose I need this type of a soil clear how to create it. So, this becomes an art. So, from this I would like to take out few fractions by sieving them and then this becomes my synthetic soil and then how to manipulate this is an interesting idea.

Now, let me start discussing about now the fine grained soils, I am sure you must have dealt with finding materials like silty, clay, sandy soils in your laboratory experiments it becomes difficult if you are dealing with a fine grain materials. So one of the ways to find out their particle size distribution characteristics would be hydrometer analysis. This is also known as sedimentation analysis. How many of you remember stoke’s law, how many of you remember terminal velocity, critical velocity.

Remember, very good, when you are studying 10 +2 physics you never heard that where it will be utilized, the complete geo mechanics of fine grain soils is based on the stoke’s law which is nothing but the sedimentation analysis where we will be using the concept of terminal velocity. Sometimes this also known as critical velocity, but try not to use critical velocity terms, let it be terminal velocity.

A good example is drops of the rain alright when they fall and when they come on the when they hit the Earth, the normally hit at terminal velocity correct. As I said these are tricky materials to handle. And hence nowadays , people are taking use of laser particle scanning, laser defactometers they are using. Sometimes they use SCM though it is difficult, I think we have discussed about this and sometimes they use what CT scanning that will not give you a particle size fine grain materials SCM of different types okay.

So, let us go back to the conventional concept fine grain soils when you are dealing with the moment you put them in oven at high temperature their activity lost. So, you should not have done this mistake aired right. So, we will put a condition remember and coarse grain material inside take the soil, pulverize it and put it in the oven in the coarse grain material and fine grain material we should not do oven right.

We should do air dry, remove the claws, fine grain materials are very notorious. You know what happens because of the surface charged with you have talked about the double air theory and all those things. The moment hygroscopic moisture is available, they form clots. So, several particles will come together and they will form a clot, clot is a sort of a agglomeration of the particles, alright. So you can just break them by using a light time. Normally we use wooden mallet, we do not use heavy time also.

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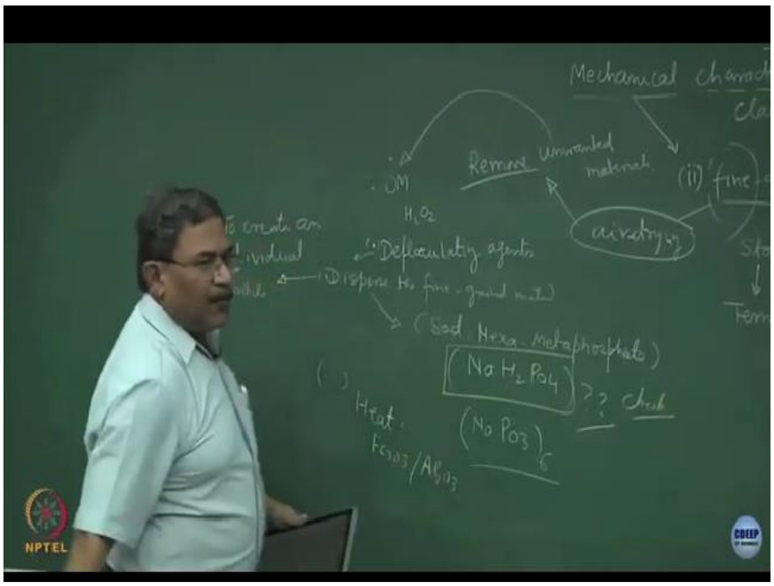

Having done this, try to get rid of all sorts of unwanted materials. What are these unwanted materials, number 1 organic matter. So, what do they do. They will allow the interaction of the soil with H2O hydrogen peroxide. It oxidizes the organic matter which is fine in the system fine, we use some deflocculating agent. What this deflocculating agent do, they disperse the fine grain material.

Sodium hexametaphosphate is a good example of this, yes it brakes the bonding particularly the hydrogen bond H2O and that is it. So, when you say is the water hygroscopic moisture which is binding all the particles forming the clot, when you add these type of system, they reduce surface tension number 1 and number 2, they break the hydrogen bonds between the different clay particles.

So, this is what is added to disperse the fine grain materials, so, that each particle becomes an individual entity, just check it out the give me the correct formula to create an individual particle which would fall in a column of water. Sometimes what we do is we heat it also to get rid of the components of Fe_2O_3 which are mostly present in the soil and Al_2O_3. I hope you can realize it is a sort of a manipulation that you are doing with the material to change the basic characteristics.

And then you are dealing with it. So there are a lot of limitations of the material. Normally, sodium hexametaphosphate is less than 4% by weight. Let us talk about the principle of sedimentation.

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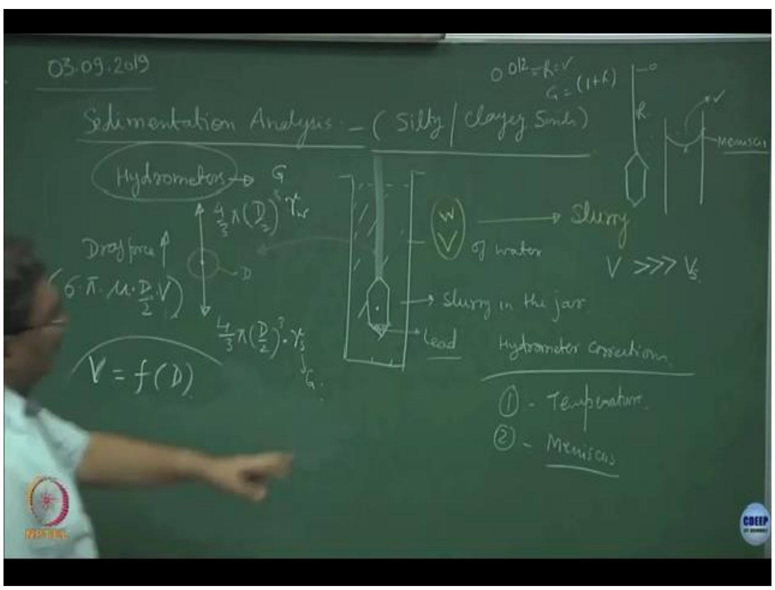

See those of you who are preparing for competitive exams you have to remember these things, because there is no other way is meant for mostly silty and clay soils, first the concepts of the analysis and then I will write down in a typical bookish manner which you have to mug up, normally we considered a jar or a volume which is quite big so this is the volume of water we fill it up with water.

The solution of the soil in which all this has been done, you have treated the soil with H2O organic matter is there you have added sodium hexametaphosphate to get rid of the flocculation making it deflocculated. You have heated it with Fe2O3, Al2O3 to get rid of alright, take W of this side and dissolve it in V volume of the fluid water. So, this is the V of water in which you have dissolved this and then mix it thoroughly.

I hope you must have done this alright. So, once they become a slurry of good consistency I hope you can realize why we are not using sieve analysis sorry we are not using segmentation analysis for coarse grain material, because if coarse grain materials are there in the process of making a slurry, half of the particles will settle now. So, this becomes a heterogeneous mix and hence we never use coarse grain materials we filter it out and from the soil after filtration of the fine grain that fraction only is used for this analysis.

So W is the weight of solids which you have taken, dissolve in V of water to make a slurry and this slurry is transferred into the jar, so this becomes your slurry in the jar, alright I am sure you must have used hydrometer. So hydrometers are used to measure the specific gravity of the solids in the slurry, a good example of hydrometer which is used for finding out the quality of the mild would be electrometer.

I can measure the specific gravity of the fluid and then I can know whether these are rotated or not. So, as far as the mechanics is concerned if I consider a particle of fine grain material which is falling freely in the system and if I zoom it this is how it will look like. A poor assumption is that even the fine grained soils are historical in nature is an assumption, the stoke’s law limitation is it is valid only for circular particles.

So, if these the diameter of this crane can you draw a freebody diagram, what is the 3rd source which has lacked, any idea, no you are doing fluid mechanics surface viscous force you are right. What is that viscous force known as drag very good. So, if this particle is dropping down in an in finite column of a fluid here, why infinite because this V is much, much, much larger than volume of the soil grain this is ok.

So, if it is going down, they will be a drag force. What is the magnitude of the force anybody remembers, very good, yes. yeah, you are right. So, this is 6 pi I defined as a mu eta is what your viscosity okay alright. So, you are convenient with eta. Eta is porosity, if you remember. So notations have to be carefully chosen. Otherwise chances are when you will be dealing with the problems later on in the porous media when the fluid is flowing you will move it up fine.

So, 6 pi mu R is the radius into very good. So, this is 6 pi mu V by 2 into V rest symbol. So, this is the gravity so 4 by 3 pi R cube into what would be this gravity component very good no no no no gamma d, gamma d is a the matrix, it cannot be only gamma. So when I said hydrometers measure what specific gravity clear. So, this is going to be the unit weight of the grain this is okay.

So, this becomes your volume into density mass multiplied by g will be taken care of clear, it is ok and then you have another force acting, what is that force, buoyancy very nice. So, this becomes 4 by 3 pi d by 2 cube into now, tell me what this would be gamma very good and that is your equilibrium, this gamma s has to be substituted in the form of s alright. First you understand this thing that your this has to be in the form of G it is okay.

Why, because you have to have hydrometer analysis. So, you should be loading hydrometer over here. This is how the hydrometer looks like, this is a CD of the automata those of you who have done this experiment, you have done very good. So, what type of corrections you apply those 3 corrections. The first one is temperature, why normally hydrometers are designed for 20 degrees centigrade.

So when you are working at room temperature 27 28 degree, you have to apply this expansion of the hydrometer. Normally, this is filled up with what you call it as lead. So, the first temperature correction has to be applied, number 2 meniscus mostly soils when they are in the slurry form, what happens, you know, the menisci is getting formed like this, this is a menisci. So, when you look at the materials which are not transparent you have to read at this surface.

And not at the bottom of the menisci. So, you have to add this much of the correction which is known as meniscus correction in the hydrometer reading. Sure, you must have observed that hydrometer reading would be increasing from top to bottom is it not. So, if I say that this is R value, it is understood that if R is known, G will be equal to 1 + R and normally R is up to third decimal place this is okay.

So, you apply the temperature correction, meniscus correction, number 3 is whatever additives you have added over here because of their addition what has happened the gamma s of the slurry has got changed. So, this is the additives mostly dispersive agents correct. So I will give you the correct answer of what these functions are write down these expressions and try to prove it of course, there is nothing much to improve D square upon 18 rho s minus O W upon mu into G.

Try to prove this, rho s into G is gamma s, which is the density of the slurry and rho W into G is gamma W which is the unit of the water. Now try to reverse this function and write D square as a function of V, and this is what is known as have to be careful this has to be a small v because capital V I am using for volume. So, please be careful, this is small v. So, this will become 18 into v into mu upon rho s - rho W into G.

In other words, D would be under root of D. So, what it indicates is D is the function of root of v I think this simple you can just sort it out, what are the interpretation of the whole thing. The first one is this is valid only for particle size less than 2 micron, which is a typical clay size fraction that is a big thing. Number 2 is particular is a spherical particle which assuming though clay particles are platelets, and they are not spherical.

Number 3, the volume of the jar in which the suspension is taking place much, much larger than the volume of the particle alright, Brownian motion. So less than 2 micron is for not considering the Brownian motion less than 2 micron, the Brownian motion will start and ends we cannot do that yes. turbulences not yeah so turbulences in a sense when you are dipping it in the soil, then we are disturbing it. That is not a limitation of the Stoke’s law.

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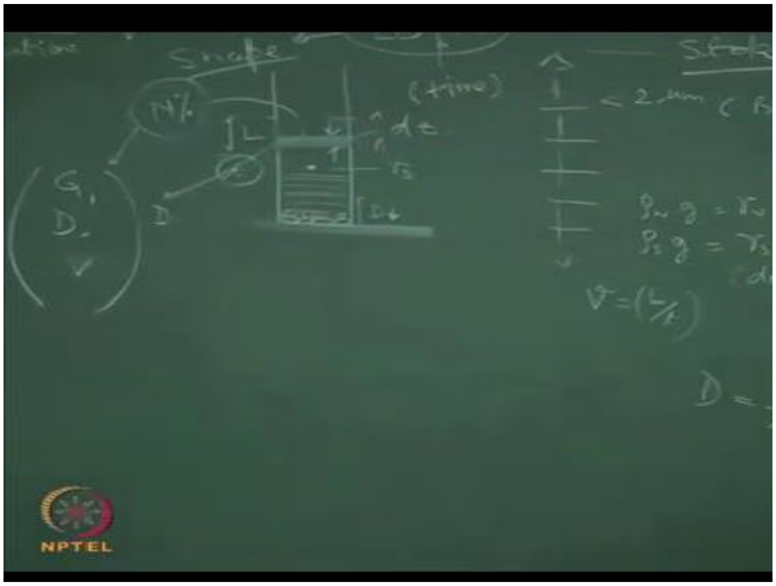

Let us consider this is the jar and at this point I am measuring the density of the soil unit of the soil alright and this point is matching with this point. The one of the questions is how do you get D value. One of the assumptions could be that velocity is equal to L by t, where L is the distance which the particle has traveled from one point to another point during sedimentation process, extremely difficult to obtain.

But the classical geomechnics talks about this. So, imagine if I have laser obscuration method, those of you who are interested read about this LOTM, in our department we have this machine. So, this is basically a sort of a laser obscuration transformation method obscuration time sorry, laser obscuration time method yes. So, what it does is when a particle is falling from a particular distance let us say point number A to point number B.

I can capture this by using a laser beam and hence I can obtain the L and I can notice the time, this type of devices used to understand how the rotation and the dynamics of the particle is taking place about its axis and so on. You can do the and shape analysis also. This is one concept, in conventional geomechanics, when we are dealing with hydrometer we are not going to use this concept much unless.

Somebody measures in how much time a particular particle during settling is falling from one place to another place, sometimes it might be visible you are dealing with a soil you must notice once you keep it on a flatbed the particles start settling down and the top most water becomes clear and you will be having sentiments getting deposited over here. Now, this logic tells me bigger the diameter the velocity is going to be more.

So, all the particles are going to sit here and as you go up the particle size would be decreasing is this okay. Is this part clear. Now, if I assume that there is a hypothetical plane at this point and the thickness of this plane is let us say Dz and n is the fraction of the particles which are available in the system which are finer than this diameter of particle D sedimentation column where the sedimentation is occurring.

I have taken a hypothetical plan the system of thickness z and I am assuming at a given time, all the particles which are greater than diameter D, I have settled down and whatever is remaining the system are N% finer than clear. This analysis will have to do later on related with G related with D, related with the velocity V yeah, you are right very good, say gammas s. So, if you see here this is the density of the suspension or the slurry.

So, this has to be greater than as gamma w correct, you are right, otherwise sedimentation will not occur. So the soils which might be having components lighter than water, this another limitation is forcing us to create now, in this series, if the soils are organic in nature, they cannot be used and hence you get rid of them because they will be floating only on the water surface. And they will not settle and hence this analysis cannot be done, there is another limitation.