Soil Mechanics/Geotechnical Engineering I
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Lecture – 03
Soil Classification

Once again, welcome to this soil mechanics course. This, as I have mentioned that the last lecture, that we have to understand certain characteristics that is permeability characteristics, compressibility characteristics and shear strength characteristics. So, that will come of course, much later and before that we have to understand the composition actually. So, like we have mentioned rock formation and then soil formation, now, the soil in what form? As I have mentioned that by different agencies different types of soil can be formed and again sometime we understand this sand is one type of soil that is based on size, clay is another type of soil based on it is size; silt is another type of soil based on it is size.

But, now in many condition or situation they will be mixed together. If I take a soil mass from any site always we will find that consist of all 3 particles mostly. Most of the time it will have all 3 particles; that means, it may have sand, it may have silt, it may have clay or sometime it may have silt and clay it sometime may have sand and silt like that.

So, that means, you have to understand now the composition. If you understand and if you know the composition of soil many things will understand actually. You may not be able to quantify that how strong it is or how permeable it is or how compressible it is, but at least if I know it is a sand it is comparatively less compressible, it will be compressibally stronger and it is comparatively more permeable whereas, if it is a clay soil then; obviously, and clay silt together then we will understand it will be compressible, highly compressible and it is actually strength is comparatively less and it is comparatively less permeable.

So, these are qualitative information; that means, if I know size this or composition then we can get those qualitative information. So, because of that we need to if I get a soil from a site and then what I have to do first I have to see the grain size then what size of particles and what quantity it present in a mass and if I get that I will be able to tell qualitatively many things about its behavior.

So, because of that soil classification is the first step perhaps in soil mechanics course whatever we have got those are introductory actually. The classification perhaps is the first step; that means, if I want to develop a site or develop a certain things in a particular area first of all you do feasibility etcetera and see whether it is a rocky soil or sandy soil or clayey soil or all those thing we will find out select the site and after selecting the site then next step is the sampling, then testing; testing means what test is first is the classification; that means, what particles at what composition what proportion is present. So, that to be first determined.

So, for this actually, in fact, we have to for classification purpose we need to do some test and there are different test in the laboratory you can do it, but suppose you are in a site and you do not have any equipment or instrument or accessories with you, but you have to keep some qualitative idea what type of soil it is. So, in the field itself sometime we may able to do some sort of test and this qualitative actually; obviously.

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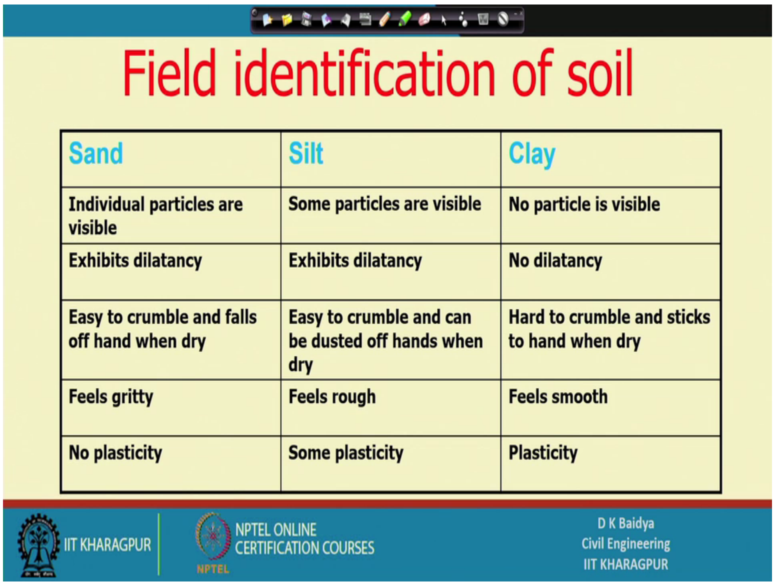

And then I have kept in this table that sand silt and clay in 3 column and you can see that and site by site what I will look at and if it is a sand then individual particles are visible; that means, sand particles sand; obviously, we can very easily can differentiate because those particles were taken hand and if I this like that then it will be flowing from my hand and silt also some particles are visible generally not visible, but it is finer. So, it is particles are not visible generally, but some particles may be visible; whereas, in clay no particles will be visible. So, this first step if particles are visible then definitely sand and particles not visible it can be silt or sand something sand silt or clay this much one test physical test we do.

Then exhibit dilatancy this is another thing between your sand, silt and clay there will be distinct difference we can say we can make a soil take some amount of soil mix with water and you make a soil pad on your hand and then if you shake like this and then finally, if the water comes out from the surface and becomes shining then that is called exhibiting dilatancy that was sand and silt both cases actually we will see that; that means, now and whereas, in the clay no dilatancy will be visible. So that means, now if you see individual particles visible then you can find out this is sand and exhibit dilatancy and sand can have that dilatancy, silt also can have dilatancy, but silt particles are not visible. Then, in that case again we can differentiate between sand, silt and clay. Clay does not have any dilatancy.

So, the first 2 step by a large we will be able to differentiate for what is sand, what is silt and what is clay. So, physical examination or checking is visible is individual particle visible, sand is almost identified. Now if the silt, particles are not visible it can be either silt and sand, silt and clay then if you do dilatancy test then silt will show dilatancy whereas, clay will not show dilatancy; that means, whether its silt or clay that can be differentiated.

Now, further still if you have doubt then that sand will be easy to crumble and falls of hand like if I do like this from my hand easily it will go out of my hand. So, is easily easy to crumble and falls off hand when dry like in wet condition of course, few particles may stick take to my hand or otherwise if it is dry condition if I do like this sand will go out from my hand.

Silt also same easy to crumble and can be dust off; that means, silt if I want to clean from my hand I have to do like this until unless do that silt sometime some of them will be stick to my hand and it is easy to crumble and it can be dusted off my hand the silt or whatever dust would stick to my hand then if I do like this it will be dusted off whereas, if it is a clay hard to crumble; that means, if I take a piece of clay then it will be dry it will be difficult to break and if it is a wet condition then it will stick to your hand. So, it will not be easy to dust off also, whether it is so fine particles it will be sometime stick to your hand.

And then these are the three, then fourth one is feels gritty; when the sand particles you rub between your finger like this you will gritty that very rough and if it is silt also will feel rough and gritty and feel rough this difference actually only through experience one can develop that what is gritty and what is rough? The sand what is very rough feeling will be there whereas, silt will have some feeling, but it is not rough as it is in the sand and whereas, if it is a clay particles like you would take a some amount of kaolinite or illite or montmorillonite and put between the fingers and like that in very smooth like talc and all similar to that feel smooth feeling will be there.

And last is another is sand will not have any plasticity; that means, sand mixed with water you will try to make ball you will not be able to do that if you cannot do that that is definitely it is a sand you cannot make a ball or it cannot role and in a thread like you cannot rolled into a thread.

And silt whereas, may have some plasticity, so, we can mix with water we can make a ball, but it is very easy to break it cannot make big ball or something some plasticity is there because of that we will be able to do we will not be able to make a very thin thread, you may make a very thick thread we can make; whereas if it is a clay, then if we mix with water then you can make any ball any shape like our some clay modeling etcetera for you can do we are able to do because it has plasticity because of this plasticity we can give this in different shape.

So, the in the field if you are there; that means, field I do this I field identification that I am talking about; that means, at a site actually suppose is engineer that site what type of soil is present if you want to identify then these are the few checklist you do, why you can whether particles are visible or not then you make mix with water and make some pad on our hands shake it like that if water comes out then either it will be silt or sand if it is not there then it is a clay, then if it is take a some small mass it is easy to crumble then it is a sand. It can be silt also, but silt sometime some soil will be stick to your hand whereas, sand nothing will be there in your hand.

Sand easily will fall off and when it is sand you have to dust off and when it is a clay it will be stick to your hand and when it is sand if you rub between your fingers, you will feel gritty; when it is silt when you rub off between finger it will be your rough feeling little and whereas, it when it is clay it will be smooth feeling and sand does not plasticity and silt will have little plasticity and clay, obviously, having high plasticity will be there and because of this plasticity property you can make any ball any shape and you can make thread also 3 inch thread.

So, these are the small things if you do at site then we will be able to do identify whether that sites sand is present, silt is present or clay is present. So this is actually as I have told that the physical identification, but that identification no one will accept, until unless when I will someone I have taken a job of classification job and though I know by that physical test that it is a sand or it is a silt or it is a clay, but you might give that information to the client they may not accept that, they want some data, they want some chart, plot and on based on that I have to conclude that this is a sand silt or silt sand something like that.

So, for that actually to give do some analysis that is actually inspection physical inspection and if you want to do some analysis there are mechanical analysis this called or sieve analysis or it is called dry analysis; that means, soil will be there, you collect from the site and then if it is a granular soil suppose then this analysis can be done through a sieve analysis.

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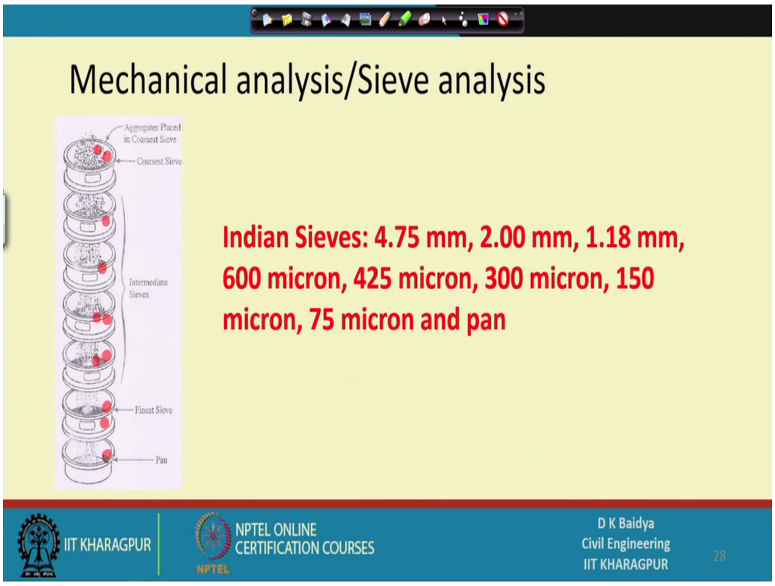

And this sieve actually different countries will have different types of the different size of the sieves and India also will have a set of sieves which we will use in the soil mechanics and there are generally 4.75 millimeter size opening is the top most sieve and 2 millimeter size is the intermediate, 1.18 millimeter next, then 600 micron, 425 micron, 300 micron 150 micron, 75 micron and the bottom most is the 1 pan will be there. So, this is the number of them are here. So, this is some of top most is 4.75 and in between suppose it is 2.2 millimeter this maybe 1.18 millimeter, this is 600, then 425 and then maybe 75 in between there maybe 1 or 2 and this is the supposed pan.

So, a definite amount of soil to be taken from the site or whatever sample collected from the site around 300 to 400 gram sample can be taken and can be kept on the top most sieve and after putting on that sieve and then it has to be put all sieve will be kept one above another and then finally, this can be shaken by hand like this or nowadays it is there is a motorized shaker, we can put the shaker entire assembly in the shaker and then you can give a certain amount of fix the time that how long it has to be shaken. When it will be shaken by vibration then that opening whatever we have mentioned this 4.752 millimeter etcetera they are actually the opening size, so, if the soil particle is bigger than 4.75 millimeter it will retain on this and if it is smaller than that then it will pass through this.

So, like that each sieve, some amount will be retained and some amount will be passed through. And finally, each and every sieve the certain amount will be retained and finally, bottommost sieve that is 75 micron sieve some amount will be passed through and some amount will be retained. So, this passed through material will be collected in a pan that means there is no opening. So, it will be collection only and if it is a sandy soil the passing through 75 micron will be very nominal amount. So, that is collected here and if it is 300 gram of soil you have to finally, collect it from each sieve.

The amount of soil retain and their individual weight will be taken and finally, what is collected in the pan has to be taken at finally, all to be added and you have to see that the total amount is about same, maybe very fraction loss can be there because of many things one grain can be lost here and there, but it is too much loss then this has to be repeated. Otherwise, whatever amount you have taken originally and finally, soil retained in each sieve including the pan has to be the same.

So, this is the way actually mechanical analysis will do; that means, we will take a amount certain amount of soil put it in the topmost sieve, put it in the shaker and then after a definite amount of time shaking the soil or particles retained in individual sieve to be collected and weighed and that has to be tabulated.

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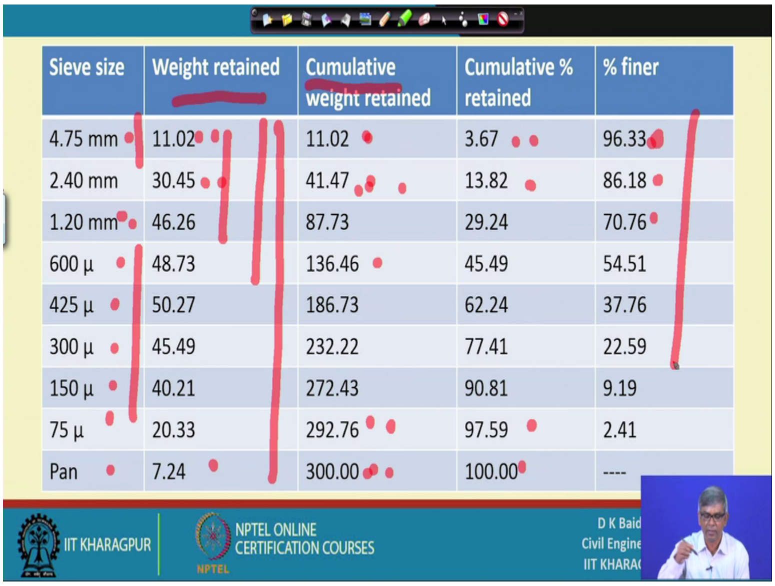

Sieve size	Weight retained	Cumulative weight retained	Cumulative % retained	% finer
4.75 mm	11.02	11.02	3.67	96.33
2.40 mm	30.45	41.47	13.82	86.18
1.20 mm	46.26	87.73	29.24	70.76
600 µ	48.73	136.46	45.49	54.51
425 µ	50.27	186.73	62.24	37.76
300 µ	45.49	232.22	77.41	22.59
150 µ	40.21	272.43	90.81	9.19
75 µ	20.33	292.76	97.59	2.41
Pan	7.24	300.00	100.00	----

This is the tabulation will be done like this, sieve size I have written here you can see again 4.75, 2.4, 1.2, 600, 425, 300, 150, 75 and pan and you can see around 300 gram of soil is taken and you can see retained on 475 millimeter 4.75 millimeter sieve is 11.02, then retained on 2.4 millimeter is 30.45 like that finally, on the pan retained is 7.24 and if you add them you will see it is coming 300.

So, for calculation purpose or classification purpose what we do? First column is the sieve size and all sieve size is nothing, but equivalent to particle size. Soil particle size is if the sieve size is 4.75 and if it passed through the 4.75 then particle size is smaller than 4.75 or the particle retained on 4.75 millimeter that mean the soil particles is bigger than 4.75 millimeter. So, that is what a first column. Second column will be weight retained all individual pan.

And then third column to be prepared, that is, cumulative weight retained. So, that means, here cumulative retained will be same as the previous retained on 4.7, but when I will go to the next stage cumulative weight retained will be the weight retained by 4.75 millimeter weight retained by 2.4 millimeter. So, these 2 together this 2 will be added and this will be there.

Now, if it is cumulative retained for 1.2 millimeter, so, these 3 to be added, then cumulative retained in 600 micron then this 4 will be added. So, like that finally, cumulative. So, when I will go to the pan that added all amount then it has to be 300 gram because we have taken 300 gram sometime minor fraction will be less.

Now, after getting cumulative weight retained, we have to find out cumulative percent retained. So, we can see initially was 300 gram cumulative retained 11.2. So, percent if you calculate it comes 3.67 and cumulative retained is 41. 47 and total was 300, this by this percent retained will be this 13 percent. 41 out of 300 is 13 percent.

Similarly, 292.76 at this level cumulative weight retained then percent cumulative retained will be this by this, 97 percent and when it will go it become 70, 100 percent. Now, percent finer is or percent passing percent finer nothing, but percent passing. So, through 4.75 micron how much percentage is passing 100 minus this. So, this is the percent passing through 4.7; that means, 96 percent 96.33 percent of soil taken out of 300 gram is finer than 4.75 millimeter soil particles. Similarly, here if I see the 86.18 percent is finer than 2.4 millimeter soil particles. Similarly, 70.76 percent is finer than 1.2 millimeter; that means, through this sieve 70 percent will be passed.

So, like that finally, size and percent finer, in between we have done some tabulation. Finally, we will be using this column versus this column; that means, this column versus this column; that means, sieve size versus percent fine or particle size versus percent fine and particle size will be plotted in a log scale and percent fine be in the normal scale because by this only people started studying and streamlined some behavior or classification process this will be same we are using.

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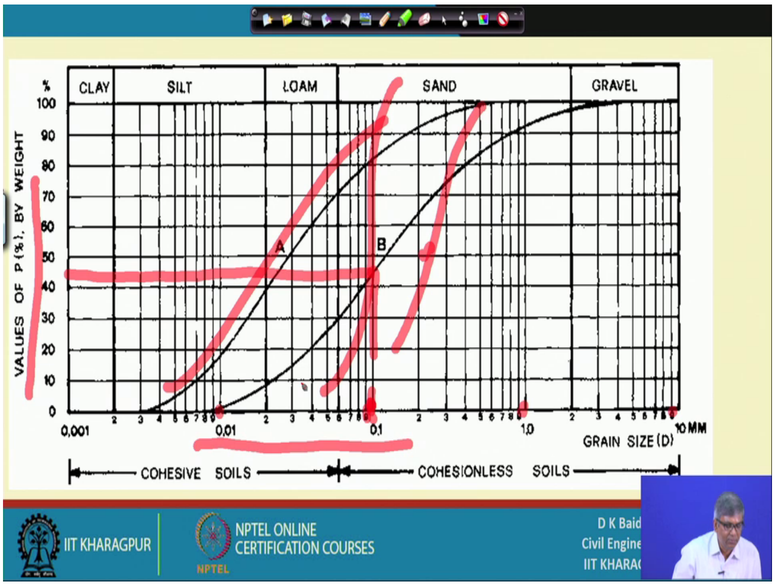

So, typically now, as I have mentioned that if I one side as I have told you that we have to use percent fine by weight and this site is the particle size and log scale you can see 0.01, 0.1 this is the log say one cycle, this is another cycle 0.1 to 1 and 1 to 10. So, like then whatever we have got that the previous table whatever we have got that is sieve size versus percent finer if you plot this is not the corresponding plot, this is a arbitrary plot I have taken, that is only to show how to do the calculation and here I have shown the plot how plot looks like.

So, if you would collect soil from different site, the plot will be different and based on that shape of the soil the shape of the graph one can actually tell many things about the soil grain composition and you can see this if it is typical S shape of curve you get it is typically it looks like a S shaped curve if we get then; that means, actually all particles almost present almost uniformly similar way and because of that that is called well graded; that means, all particles are same quantity is present. So, that because of that we can say that is a well graded and whereas, if a curves if we find only this portion like this the curve is like this; that means, only a particular size is present in this one soil.

So, if the curve is like this or curve is like this, then that means, a narrow range only a particular size of the particle present in the soil mass. So, because of that if this type of curve if you get that is called uniform soil or poorly graded soil whereas, if you get this type of curve that is proper S shape; that means, you get that mean all size particle is present then that is called well graded soil.

In fact, in the civil engineering purposes, in real life in fact, if we say we feel that uniform means good everywhere you expect uniformity whereas, in the soil mechanics soil is uniform means it is not at all good sign. Uniform soil is a bad soil because only one particular size of the particles are present, that is why it is called uniform and when all particles are same sized then voids will be more; like if it is same size of sphere if you would stack in a particular space then amount of voids present in that instead of that if I take a different size of the sphere and put it in a particular place then voids will be reduced significantly because between the bigger particles smaller particles will enter and number of voids amount of voids will be reduced.

So, like that if it is a uniform soil; that means, same particles are present mostly then voids will be large and because of that the soil is not good that is a uniform soil here no good and if it is a well grade soil; that means, all size is present equally that is well graded that is actually good.

So, that means, once you do a test from a sample and get this gradation curve and from these you can get whether soil is good, bad and what soil present at what percentage all those things we can find out. And in fact, from this curve if I want to find out we have certain number of sieve size, but still I want to find out; suppose, what is the percent soil is finer than 0.1 millimeter size. So, this is 0.1 millimeter I have marked here I go to this curve and from here I can see the percentage is more than 40 percent; that means, it for this curve the particular soil; that means, near about 45 percent is finer than 0.1 millimeter. So, from this graph like these many other things also you can find out.

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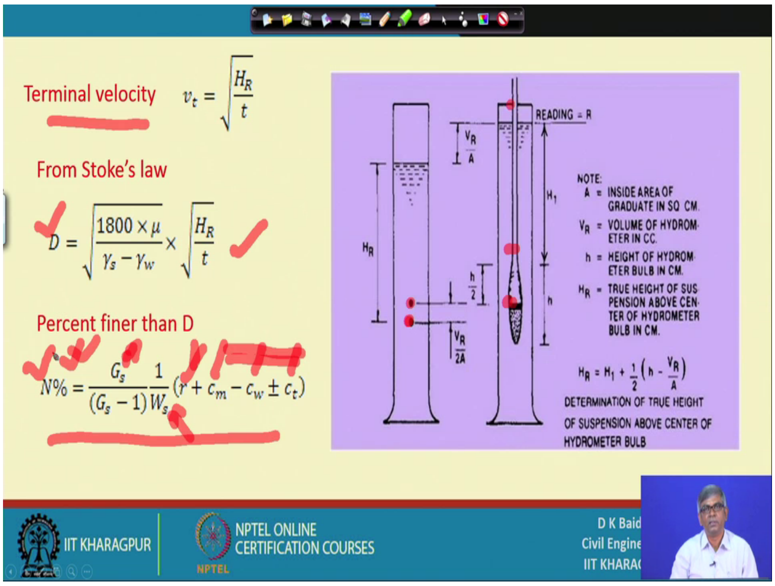

And this is actually the when is a coarse particle then we can do that way, but if it is some soil as I have mentioned that in the pan which is passed through 75 micron if it is a soil particles is smaller than 75 micron we will not be able to sieve it and those particles actually if you want to sieve then some amount will fly and value will be lowest and sum amount will be lost we will not be able to get the proper weight and because of that those fine amount of the soil content both coarse and fine particles, then the classification will be combination of the sieve analysis and then another analysis that is called hydrometer analysis.

Hydrometer analysis in that actually, generally we take the principle of Stoke's law and in this there will be a hydrometer. This is the hydrometer actually, this there will be a bulb in it and the total volume of the bulb is only based on this bulb from a neck to this to this and remaining portion volume is small it can be ignored and this is designed in such a way that if I put the hydrometer in a in a 1000 CC jar calibrated jar and these if I immerse in that soil, this will indicate the it will indicate the density of that water.

So, if we mix with some soil in it then density will change and automatically this hydrometer will give different reading. So, that actually will be taken and whatever characteristics were giving that at the centre of the hydrometer whatever characteristics actually giving, actually here and initially it was here and when I immerse this hydrometer it will be lifted by some amount and then this will be lifted by here and that amount can be calculated by this.

So, by Stoke's law that equation for terminal velocity v t can be obtained like this and diameter from the Stoke's law, you can obtain from this and again based on those calculation I can find out the percent finer in terms of this that is G s by G s minus 1 by 1 by 1 minus W s, r plus c m minus c w plus minus c t. So, what are those? This is actually I will take a certain amount of fine particles mix in a water, make a uniform sediment and that soil sediment I will put the hydrometer and I will take the hydrometer reading and from that hydrometer doing some more calibration I can do this calculation.

The soil we are taking that soil actually specific gravity to be determined suppose G s and amount of soil taken that is W s and hydrometer reading is suppose r and c m is suppose we discussed correct term correction and c w is actually if I put it in the distilled water and put it in a that sodium hexametaphosphate, sodium metahexa hexameta phosphate something some chemical we use actually. Sodium hexametaphosphate we use actually as a agent; that is actually this is based on the principle of Stoke's law and Stoke's law actually applicable for a spherical particles, small spherical particles and if it is a sometimes I put it in a suspension the spherical particle will have tendency to clock together and make a bigger particles and in that case Stoke's law will not be valid.

So, because of that we sometime add the chemical sodium metahexaphosphate that one actually as a deep flocculating agent and because of that addition there will be some correction. So, after, distilled water reading you have to take and temperature correction all those. This is the original reading and these are the 3 corrections after applying this correction this value to be done then we can find out the percent finer and diameter can be calculated from this and percent finer can be calculated from here.

So that means, I am getting a portion of the curve from hydrometer analysis and portion of the curve from the grain size analysis and these 2 to be connected and then if I connect them and then I will get entire distribution from silt say clay to sand gravel and then it will give you the complete against the grain size distribution in the sample.

So, this is the way actually of course, this hydrometer analysis lot of calculation and lot of calibration work etceteras is there. This thing can be discussed more in detail in the laboratory. Only thing I have just mentioned that is a part of classification combining sieve and hydrometer these 2 together that is hydrometer will be used for the particles which is finer than 75 microns and which is greater than 75 micron, that is, sand and gravel will be done sieve analysis and then both parts will be plotted in a single curve and then we will get the complete curve for the sample. And the then after plotting the curve, the plotting is same percent finer versus particle size and after doing that after examining the curve,, one can find out whether the soil is uniform or well graded or any other, so that classification can be finally decided. I think we can stop here.