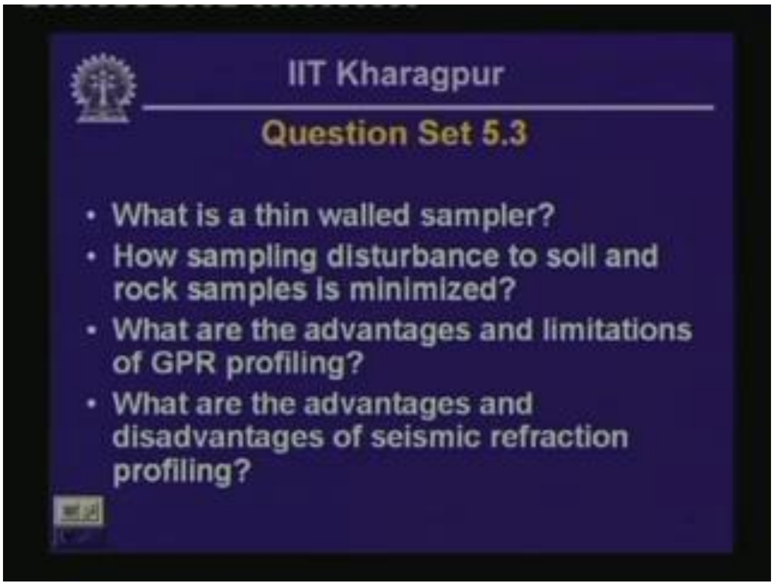
Engineering Geology
Prof. Debasis Roy
Department of Civil Engineering
Indian Institute of Technology, Kharagpur

Lecture - 18
Index Properties and Classifications of Soils

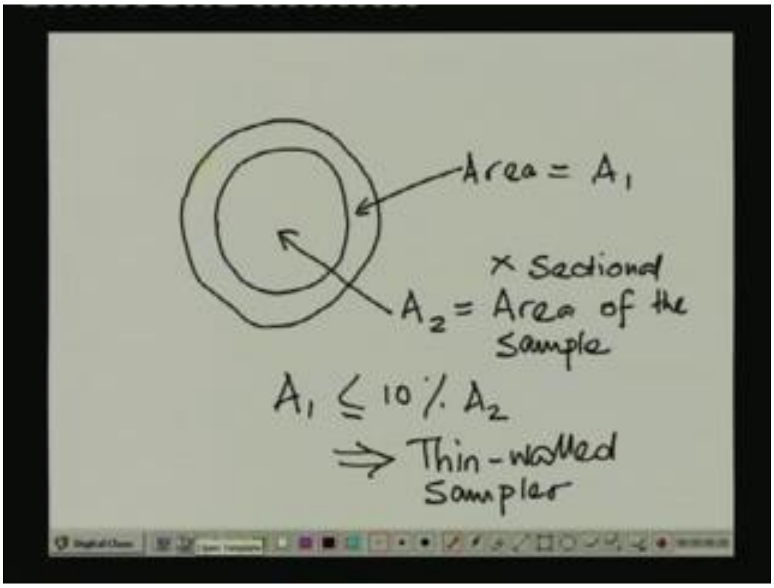
Hello everyone and welcome back. Today we are going to talk about index properties and classification of soils. But before we discuss or we take up today's topic, let us discuss the questions set of the previous lesson.

(Refer Slide Time: 01:09)



The questions are like this; the first one was what is a thin walled sampler? As I discussed in the previous lesson, thin walled sampler is a sampler which is basically a cylindrical tube with a wall, with a wall thickness of equal to or less than 10% of the sample cross sectional area. So, what is meant by that is say, we have got or here we are looking at the cross section of the sampler.

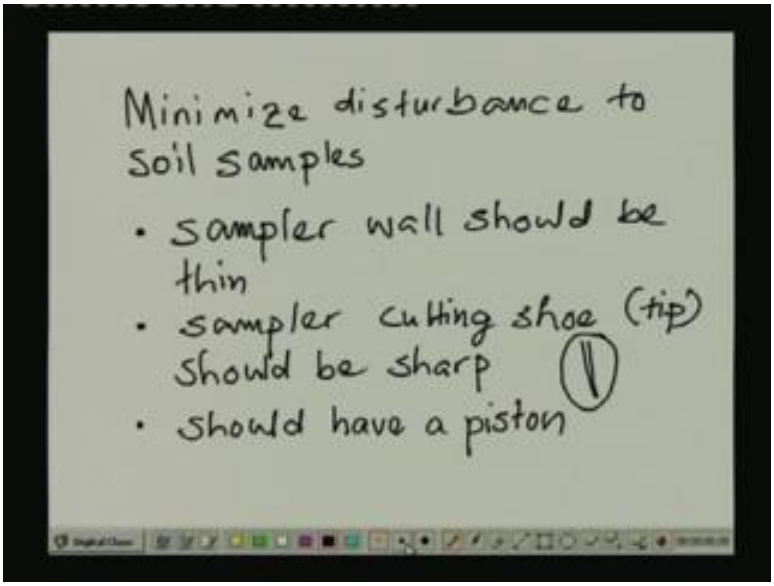
(Refer Slide Time: 01:42)



So let say, the outer diameter of the sampler is like this and the inner wall of the tube is like this; so this area, this is the cross sectional area, let say that is A_1 and this area here is let say that is A_2, A_2 is the area of the sample, actually cross sectional area of the sample. So, A_1 should be less than 10% of A_2; then the sampler will be called a thin walled sampler. So, that is the definition of thin walled sampler.

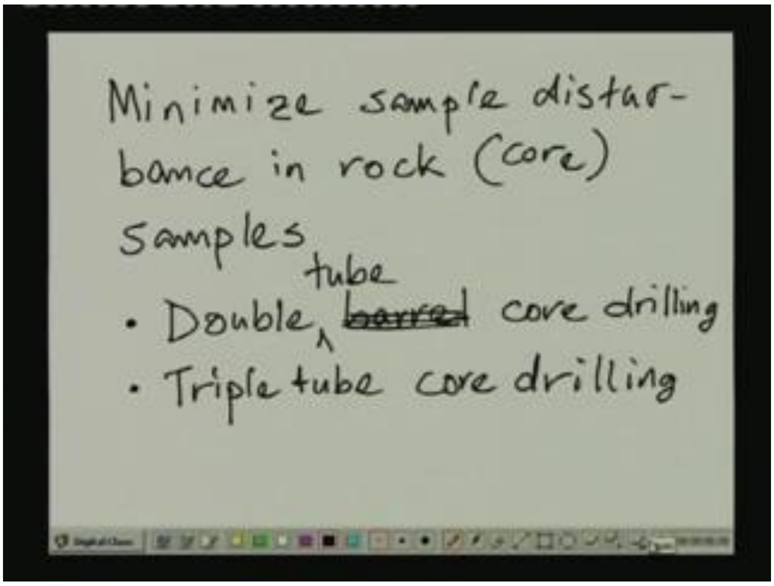
Getting back; second question was, how sampling disturbance to soil and rock samples is minimized? We discussed at length about the procedures for minimization of disturbance of soil and rock samples.

(Refer Slide Time: 3:19)



In order to minimize soils or in order to or the measures that minimize the disturbance to a soil sample, to minimize disturbance to soil samples, typical measures are like this - sampler should be thin walled sampler, wall should be thin, then cutting shoe or tip of the sampler should be sharp or it should be of this shape really, very thin knife like shape, then you could have a piston to preclude unnecessary entry of soil from outside of the outer diameter of the sampler. So, these are typical measures that can minimize sample disturbance. And now, let us consider the sample disturbance of rock samples.

(Refer Slide Time: 05:01)



To minimize sample disturbance in rock samples, let say core samples of rock; so what we do we can either go with a double barrel core drilling or we could even go with a triple, actually a double tube, let us call it double tube core drilling, triple tube core drilling is even better. So, these are the possibilities and the procedures of, each one of these procedures were discussed in the previous day's lesson. So, these are the options that we have in order to minimize disturbance.

Now, getting back to the third question; the third question was what are the advantages and limitations of GPR profiling? So, advantages are that you do not have to intrude upon the subsurface formations. So, that actually solves a lot of other problem such as introducing contamination to the instruments, to the investigation instruments.

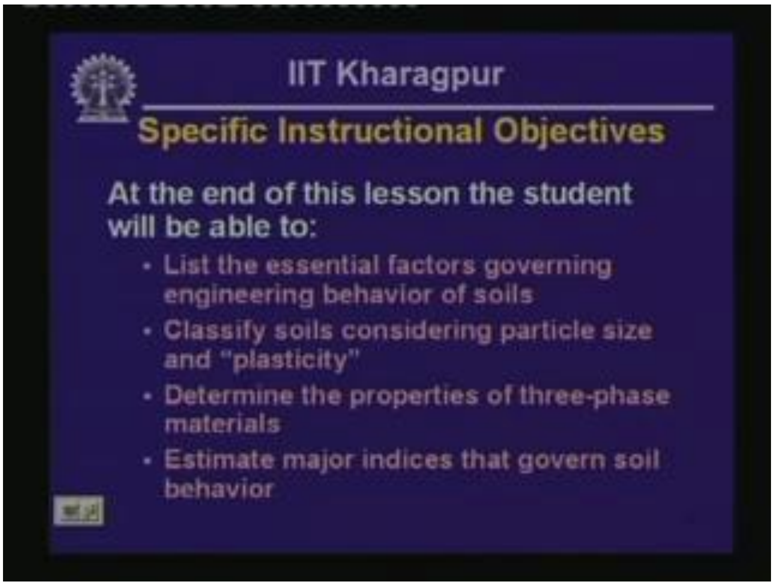
The disadvantage is really is that GPR is a procedure for shallow surface profiling. The typical depth of penetration is less than or equal to about 10 meters and the second thing is there are many types of geologic material that absorb energy used in GPR investigations.

And, to give you an example of such absorbent material, one such material is clay. So, these materials absorb the radar energy that is used in GPR profiling and as a result, GPR cannot see the details through these types of absorbent layers and the third limitation of GPR profiling is that it has got a very poor resolution. So, let us say, you want to detect 2 pipes that are placed within the same trench. In that case, GPR will not be able to resolve that there are 2 pipes; it will show that there are some inclusions within that trench but it will not be able to resolve 2 individual pipes in that case. So, these are the limitations of a GPR profiling.

The fourth question that was given to you was what are the advantages and disadvantages of seismic refraction profiling? So, the advantages in this case are typical of those of nonintrusive methods. In that, we do not have to actually get into the subsurface formation. So, that solves a lot of problem such as giving a path way for ground water percolation or getting the contamination if any in the subsurface layers into the instrument that is used in the investigation process. So, those kinds of problems do not arise if you go with nonintrusive methods such as seismic refraction profiling.

The disadvantage, the major disadvantage of seismic refraction profiling is that it requires that the velocity of the P wave or the S wave as the case may be increases continuously with depth or increases in discreet steps as the depth increases. If it is otherwise that means if you have got a layer, you have got a low velocity layer underlying high velocity layer, in that case seismic refraction profiling will not be able to detect the deeper low velocity layer. So, that actually takes care of the problem set and now we get on with the subject matter of this particular lesson.

(Refer Slide Time: 09:53)

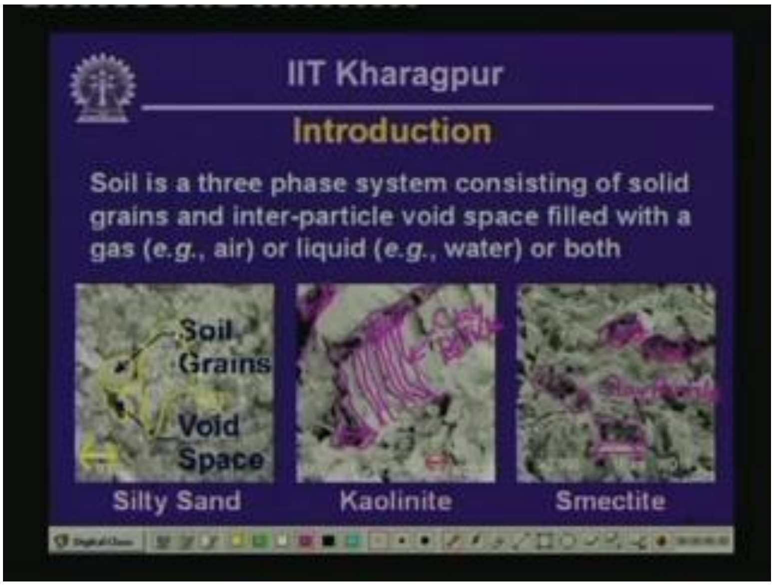


What are the objectives here? We want to learn the essential factors that govern the engineering behaviour of soil, then we want to classify soils considering particle size and plasticity, what we mean by these things we are going to come to those or we are going to come to that later.

Then we want to determine, we want to learn the procedures for, in order to or procedures used for determination of the properties of three phase materials and we are going to introduce major indices that are used in order to assess what kind of engineering behaviour is going to be expected of a given type of soil. So, those are the objectives of this particular lesson.

First of all, see we are talking about soil in this particular lesson; so first question that comes to mind is what we mean in engineering sense as a material that could be called a soil. Soil is essentially a three phase system consisting of solid grains, inter-particle void space and this particular void space could be either filled with gas such as air or it could be filled by liquid such as water or there could be a situation in which the inter particulate void space is partially filled with gas and partially filled with liquid.

(Refer Slide Time: 10:43)



So, some of the concepts are shown with three photographs at the bottom of your of the slide here. The photograph on the left shows a photo of Silty Sand. Now here, let me draw the scale of this particular photograph, let me highlight the scale of this particular photo. Now here, this much of length, this much of length of this particular photo represents one millimetre. So, you can say that this particular grain of sand, it has got an approximate dimension of one millimeter in this case. Now, you can see the grain of this matrix is clearly visible.

For instance, there is another grain here and also you can see the void spaces that are there in between the grains. So, this one here is the void space in between sand grains. You can see some finer grains out in this area; you cannot easily distinguish individual grains within that, within those, within the matrix of finer grains. So, these grains are Silt grains and the Coarser grains in this case are sand grains. So, this is a photograph of a Silty sand soil.

Then we move on to the middle photograph. In this case, this photograph was obtained using scanning electron microscope and the scale of this photograph is much finer, the line that I have drawn their on the photograph, this one, that represents 1 micrometre. So, you can see that this is a much enlarged view of the soil structure.

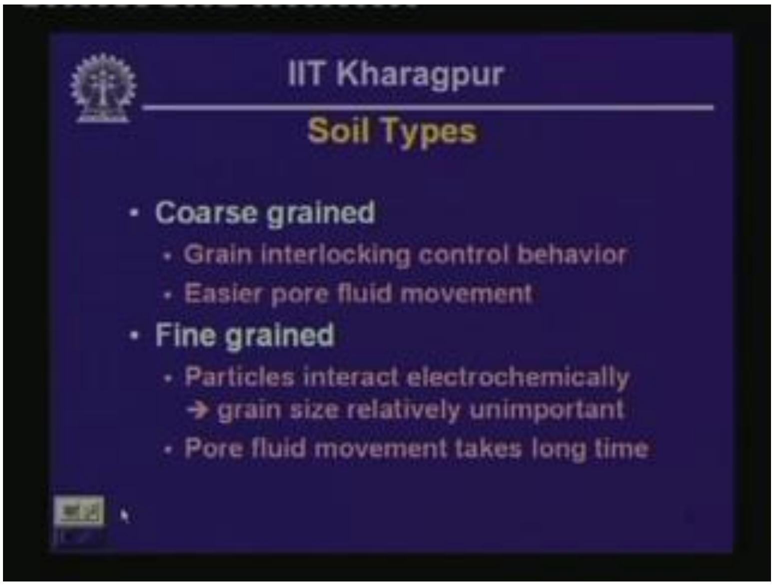
Now here, this one here is a photograph of Kaolinite clay; we talked about the chemical nature of Kaolinite clay. Now, what I want is to draw your attention to the fact that what you see here is essentially a stack of plate like particles and again as earlier, in between these particles, there are void spaces such as this one here or there is another one here. So, these are void spaces, there is another void space out here. So, these are all void spaces and these are clay particles, plate like particles.

Now, on the right is another scanning electron photograph and in this case what we got is again a much enlarged view even in comparison with the photograph at the middle, scanning electron photograph of the middle. Here, the scale shown by the arrow there that I have drawn on the photograph, this particular arrow represents a length of approximately 10 micrometer and this is a photograph of Smectite clay and here again you can see that there are void spaces; so these are void spaces.

Again, there is another void space here and in between or these voids are actually in between again, once again plate like clay particles. So, these are clay particles and these clay particles are much smaller than the clay particles of Kaolinite clay. So, that actually gives you some idea about what is to consider, what kind of material we are talking about when we are taking, we are considering a sample of clay.

So, clay then is composed basically of some solids and then it has got some void space in between and the void space could be partly occupied by some liquid and partly by some gaseous matter.

(Refer Slide Time: 16:09)



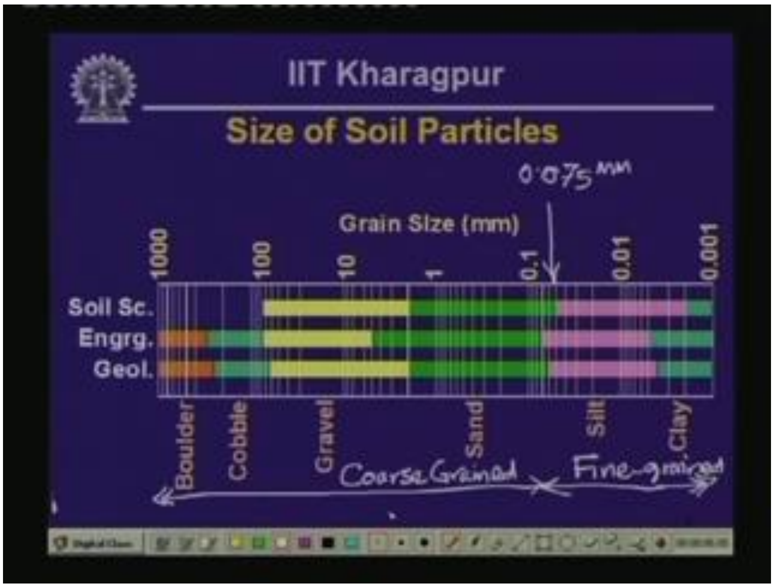
Now, what was also evident from what we discussed in the previous slide with the three photographs there is that there is an essential difference in the characteristic in the physical characteristics of the particles of coarse grain soils such as Sand and fine grain soil such as clay; whereas sands are composed of roundish particles or block like particles, whereas clays are typically composed plate like particles or in some cases they are composed of thread like material.

So, we have to distinguish actually because of this, this is not a, this is not a, this is not or this is very important actually, this distinction is very important and this actually gives rise to a remarkably different behaviour of fine grain particles and fine grain soils and coarse grain soils when they are subjected to elevated levels of stress and as a result, the way we describe or way we measure the properties of these different types of soils weather depending on grain sizes, it varies quite a bit.

So, there are two basic soil types then. One is coarse grain soil - here main aspect that control the soil behaviour is grain interlocking and because of the fact that the grain size is relatively coarse, the inter-granular void space, the dimension of the intergranular void space also is going to be relatively larger, the dimension of the void space is also expected to be larger. As a result, old fluid movement through this void space is going to be relatively easier.

And then, we could have fine grain soils. Here the particles as I mentioned are plate like or thread like and they interact electrochemically. As a result, grain size of this type of soil is relatively unimportant and here the behaviour is mainly controlled by the plasticity of the individual grains; we are going to look at later on what is meant by plasticity. And in this case because of the fact that the soil is finer grain, the pore space is much finer in comparison with those of coarse grain soils and as a result, fluid movement through this pore space is much more difficult. So, these soils, fine grain soils are much less permeable in comparison with coarse grain soils.

(Refer Slide Time: 19:07)



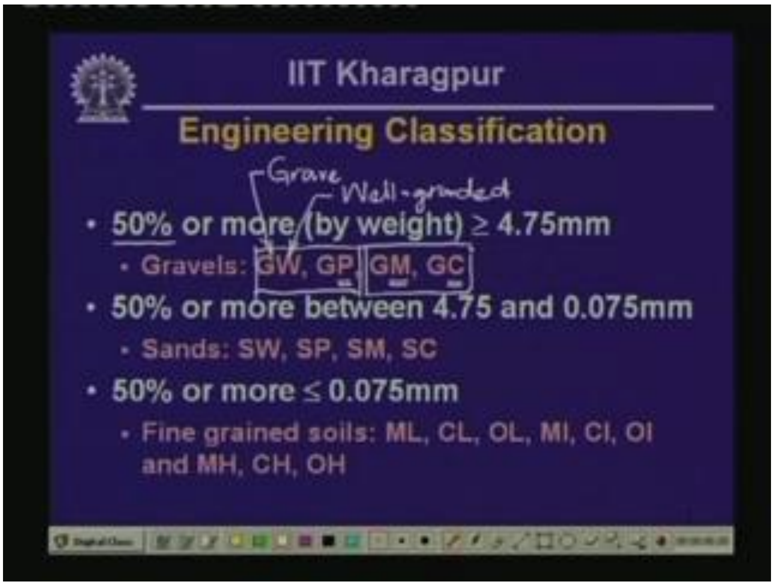
So here, we look at the grain sizes of different types of soils. Now, what we have seen is that up to here the soils coarser than approximately about let say 0.075 millimetre, they are called coarse grained soils, so they are called coarse grained soils and the soils that are finer than 0.075 millimetre, they are called fine grained soils.

So, types of coarse grain soils include boulder, boulders could be very large in dimension indeed, they could be say about a meter across. Then, if you go with a little bit smaller particle size, then could have cobbles; they are also several hundred millimetre in dimension. Then if u get finer still, then you would end up with the Gravel size particles, even more, even finer is sand size particles; so that actually begins from a particle size diameter of about, equivalent diameter about 75 micron to about a couple of millimeter in size and if you want to go even finer, then you are going to end up with silt or clay size particles as is shown on the plot there.

Another important fact that I want to, want you to see on this plot is that the correct, the classification of soils in terms of grain size will depend on who you ask that question. So, in soil science, the grain size classification is slightly different from the grain size classification used in engineering or the grain size classification used by geologist and all those different ranges used in soil science engineering or geology, they are shown using three stack bar charts on this particular plot.

So, carefully have a look at the range of the particle sizes that these different professions would categorise as boulder, cobble, gravel, sand, silt or clay; have a careful look at these charts.

(Refer Slide Time: 22:28)



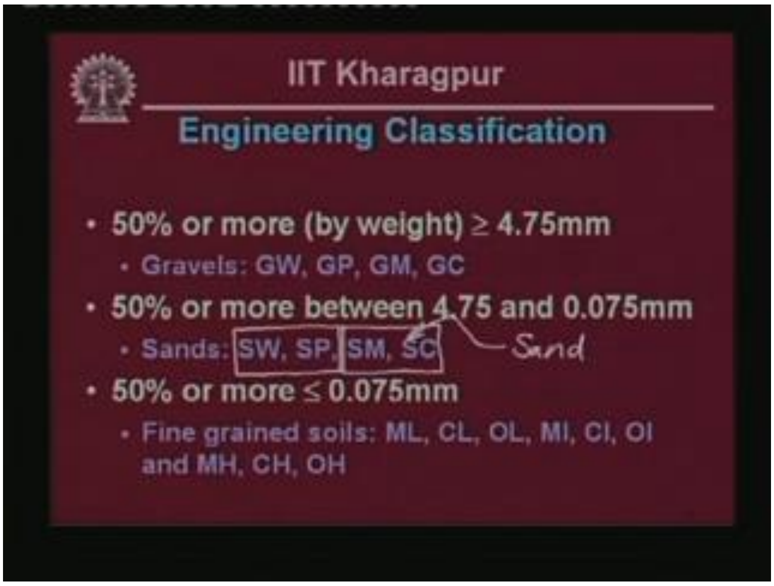
Now, we move on to engineering classification of soils. Now here, what we want to again look at for coarse grain soils; we want to classify the soils according to the grain sizes because coarse grain, the engineering behaviour of coarse grain soils as you have learned earlier, they are mainly governed by the interlocking, interparticle interlock and we are going to talk about or the fine grain soils on the other hand will be categorized based on their plasticity.

So, if you have got more than 50% by weight greater than or equal to 4.75 micron, 4.75 millimetre actually in this case, then the soil is going to be called a Gravel and the Gravel could be well graded Gravel. In that case, the symbol that is going to be used for that kind of soil is going to be GW. So, this one here, this particular letter represents Gravel whereas W in this case signify well graded that means within the matrix a large range of grain sizes, different size grains are included. You could also have poorly graded Gravel in which the grain size is primarily, the soil is composed primarily of single sized particles. So, P here indicates poorly graded.

So, poorly graded in other words, it has got the same significance as well sorted soil. Then you could have Silty Gravel and letter M is used to indicate silt in this case or you could have Clayey Gravel and letter C in this case indicates Clay. So, what may come to your mind in this case that what is the difference essentially between GW, between a soil classified as GW and a soil classified as GM because both of them include particles, a large range of particle size.

Now, the difference in this case is essentially, GW is used to denote a soil that is free from finer grain particles: so these two categories of soil - GW and GP, they contain little to know fines whereas GM and GC can be composed of a substantial proportion of fine grain soils although more than 50% of this type of soils as is indicated at the top, they should be composed of Gravel size particles that are those particles which has more than 4.75 millimetre in dimension.

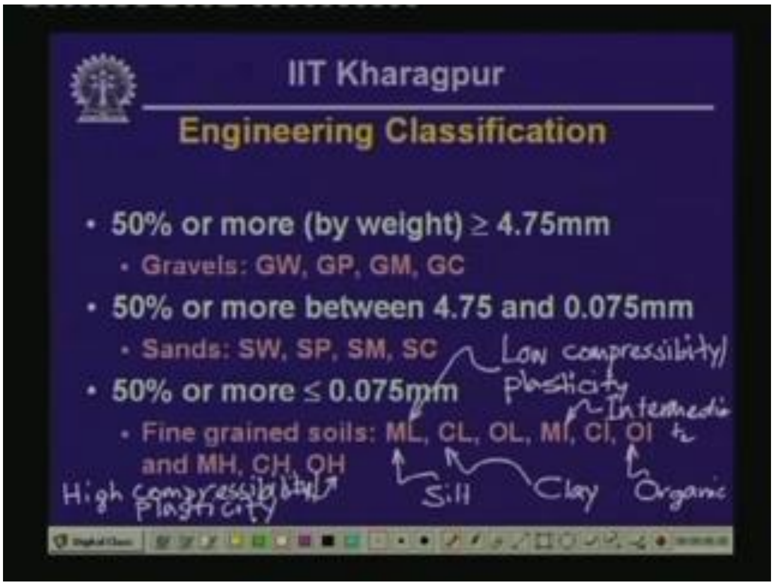
(Refer Slide Time: 26:42)



Then the second category in this case is if you have got more than 50% by weight again between grain sizes of 4.75 millimetre and 0.075 millimetres; in this case we are going to call the soil in engineering sense as sands, again you could have well graded sand, poorly graded sand, silty sand or clayey sand just like we had in case of Gravels. So here, symbol or the letter S is used to indicate sand and the significance of letters W, P, M and C are same as what we had in case of Gravels.

So here, once again SW and SP are symbols used to denote soils that have little to know fines whereas SM and SC are used to denote soils that have substantial amount of fine grain soils such as silt and clay size particles.

(Refer Slide Time: 28:00)

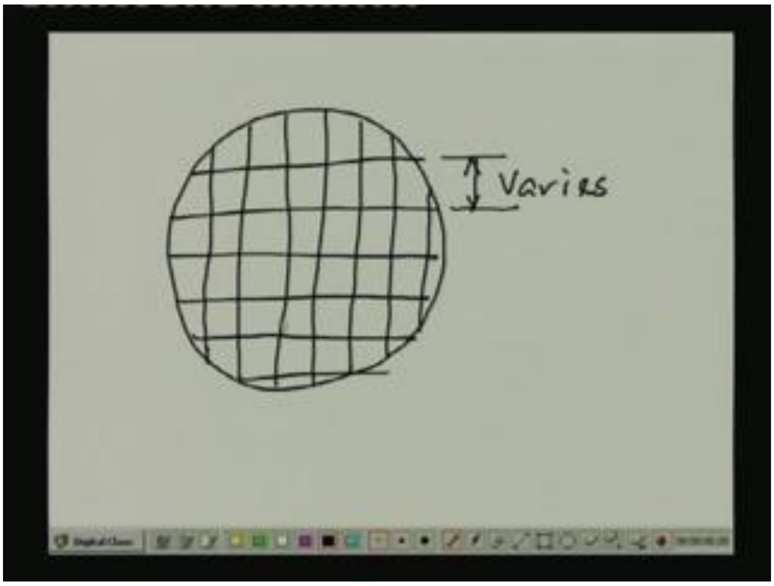


Now, the third category is going to be if the soil is composed of more than 50% by weight of fine grain particles that is particles which has got, which has got an equivalent diameter of less than 0.075 millimetres. So in this case, the soils are fine grain soils, several different symbols are used in this case; symbol M is used as I indicated earlier to denote silt, symbol L is used to denote low compressibility or low plasticity, then C is also explained before and is used to indicate clay, symbol O is used to indicate organic soil such as peat, I here is used to indicate intermediate intermediate compressibility or plasticity and H finally is used to indicate high compressibility or high plasticity.

So, you could have ML, CL or OL. So, those are low plasticity silts or organic soils or clays. Then you could have MI, CI or OI, they are silts or clays or organic soils of intermediate compressibility or plasticity or you could have MH, CH or OH, they are organic, they are silty soils or clay soils or organic soils which have high compressibility or plasticity.

Now, one thing comes to your mind, one question comes to your mind is; how do you find these different grain sizes, how do you determine the grain size in order to go through this kind of classification?

(Refer Slide Time: 30:36)



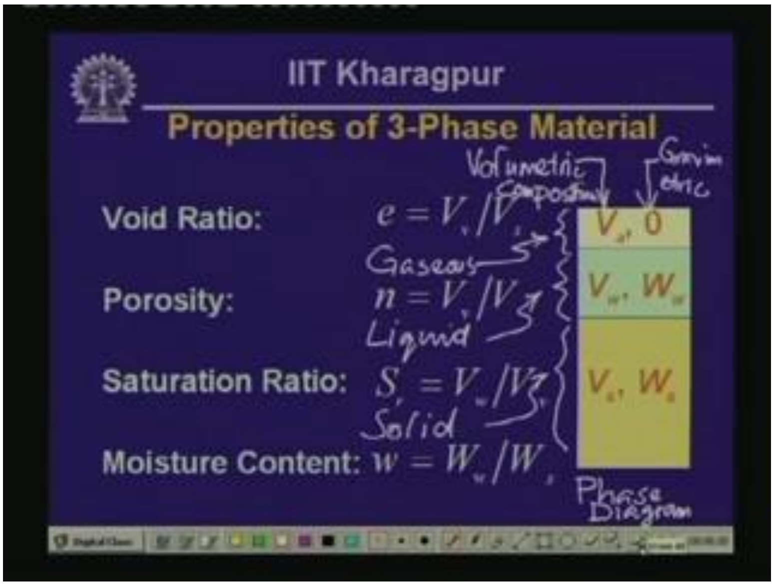
So basically, if we have got coarse grain soils, then the grain sizes are found by sieving the soil through a stack of screens of square mesh. So, these are screens used in order to determine the grain sizes of different soil types; they have got square mesh and this opening size, it varies. So, you could have, you could have a sieve that has got a very fine mesh and you could also have sieves that have got very coarse sized mesh.

So, what is done is that a soil is taken on top of a stack of these types of different screens, the screens are stacked one on top of another, they fit actually on top or one on top of another. With screens that have finer mesh, that are kept towards the bottom of that particular stack; whereas the sieves which are coarser, which have coarse opening size, they are kept towards the top of this particular stack, then on this particular stack, then the soil, a sample of soil is taken, a sample of dry soil is taken near the top or at the top this particular stack of sieves.

They are kept, they are placed on mechanical shaker, sieve shaker and after that, after shaking it for 10 minutes, after shaking the stack of sieves for 10 minutes, the soil retained on each one of the sieves are taken out and weighed and as a result you could find the proportion of representation of different sieve sizes from this particular analysis and the finest grains are retained at the bottom of this particular stack of sieve and typically the lowest, the finest sieve size used is 0.75 millimetre.

So, the soils that pass through this particular sieve size is going to be composed of fine grained soils. So, that is actually a simple way of finding out the grain size of different types of soils used in this kind of engineering classification.

(Refer Slide Time: 33:28)



Now, we get onto the properties of three phase material, how we can describe three phase materials. So, there are few definitions that we are going to introduce here. So, first of all, first definition that we are going to consider is that of void ratio. Void ratio, I want to draw your attention to the sketch before I introduce these different definitions.

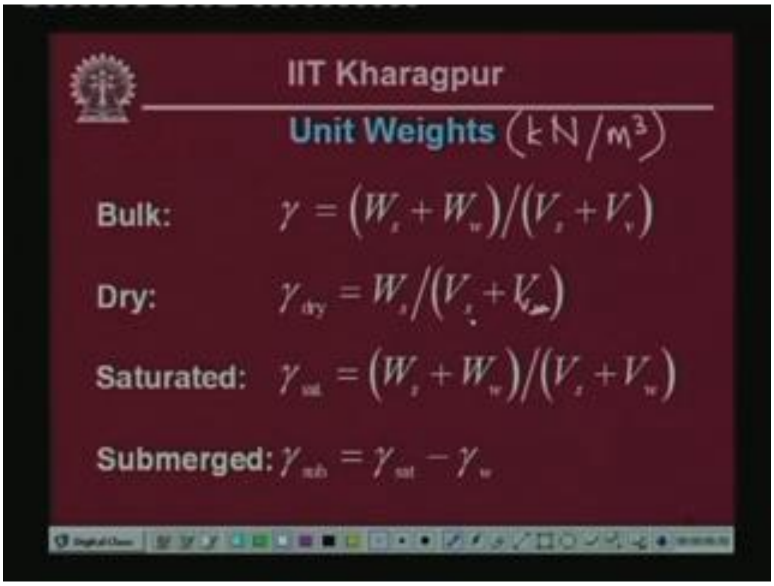
So, a phase diagram, a phase diagram of a three phase material such as soil is shown on the sketch to your right. So here, on the left are the volumetric measurements, composition of each individual phases; volumetric composition is on your left and Gravimetric composition or the weights of these phases are shown on the right of this particular phase diagram.

So, it is quite obvious from or what is, actually what is shown here includes a gaseous phase or air phase. So, the volume of the air phase, it has got a subscript a in it. Then the liquid phase is at the middle and the subscript w in this case indicates water because more often than not the liquid phase is composed mainly of water and then finally, we have got solid phase and here we are using subscript s in order to indicate that we are talking about the volume and the weight of the solid phase.

So, volume of the solid phase is going to be used, going to be indicated by the symbol V subscript s and weight of the solid phase is going to be expressed by using W subscript s, whereas the volume of the liquid phase is going to be V subscript w and weight of the liquid phase is going to be W subscript w, volume of the air phase is as I said earlier is V subscript a and the weight of the air phase is going to be negligible. So, we have used 0, we have used 0 in this case.

So, keeping these symbols in mind, void ratio is expressed as the volume of the void phase divided by the volume of the solid phase, then porosity is volume of the void phase divided by the total volume of the three phase soil, then saturation ratio is volume of the water phase divided by the volume of the void phase divided by the total volume of the voids, then moisture content is the weight of the water or the liquid phase divided by the weight of the soil solids. So, these are the four introductory definitions.

(Refer Slide Time: 37:27)



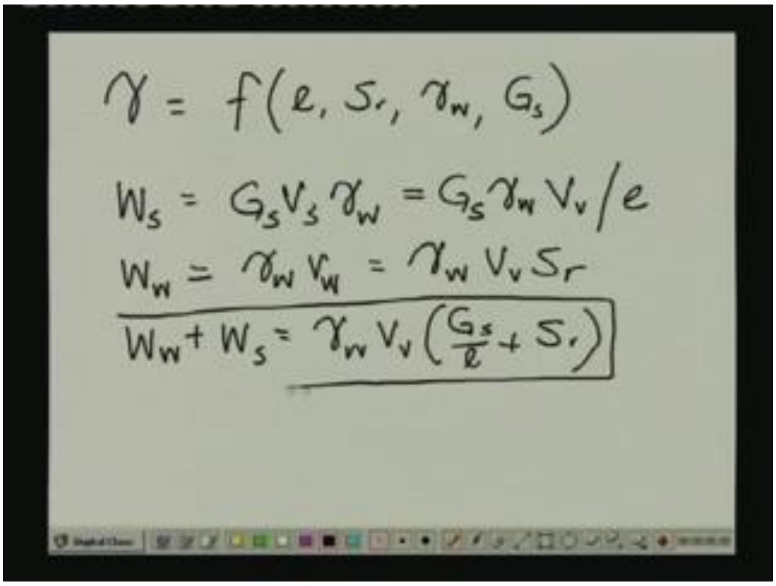
Then we could also talk about unit weights of three phase material, we could talk about bulk unit weight and you should notice that the unit of unit weights is in terms of SI unit is kilo Newton per cubic meter, bulk unit weight is defined as the weight of the entire three phase material divided by the volume of the entire amount of soil actually in this case. So, weight of the entire amount of soil divided by the volume of the entire amount of soil is going to be the bulk unit weight.

Then dry unit weight; in this case we only consider the weight of the solid phase and we divide it by the weight of the solid phase plus weight of the water and in this case or the volume of voids really. So, this one here should be volume of voids, not volume of the liquid phase.

Then saturated unit weight; in this case we consider the soil to be completely saturated that the void is totally filled with liquid. In this case, the weight is composed of the solid phase, weight of the solid phase plus weight of the liquid phase and that is divided by the weight of the solids plus weight of water and then we could also define submerged unit weight which is simply equal to the saturated unit weight minus the unit weight of the liquid phase or unit weight of water.

So, these are different unit weights that are considered quite often in order to find out the over bottom weights in soils. Now, it is worth while actually to take an example as to how we could find for instance bulk unit weight in terms of the, in terms of the void ratio, saturation ratio and the specific gravity of the solid particles. Let us take an example, so what we want to do, we want to actually express in this particular example gamma as a function of the void ratio, saturation ratio, unit weight of water and specific gravity of soil solids.

(Refer Slide Time: 39:57)

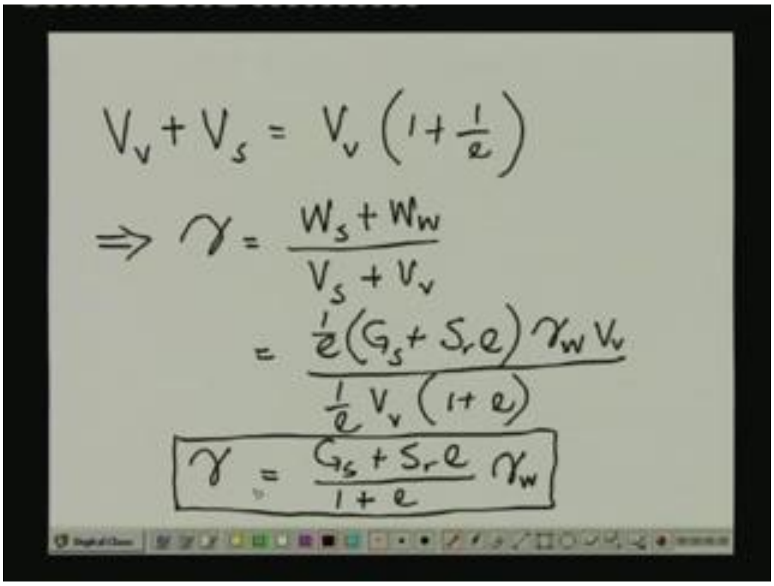


So, this is the objective. So, let us see how we proceed. So first of all, let us calculate the weight of the solid phase that is simply going to be given by G subscript s multiplied by volume of the solids and multiplied by the weight of water. So, that in turn is going to be G subscript s multiplied by gamma W multiplied by volume of voids, entire volume of voids divided by the void ratio.

Weight of the liquid phase or weight of water is going to be equal to unit weight of water multiplied by the volume of the liquid phase that is going to be equal to again gamma W multiplied by V_v multiplied by saturation ratio. So, I want you to recall what are the definitions of the saturation ratio and void ratio that we discussed in the previous two slides.

Now, we can say W_w plus W_s that is going to be equal to gamma w multiplied by volume of voids multiplied by specific gravity of soil solids plus the saturation ratio. So, I want you to recall, I want you to keep this particular result in mind and then we try to look at the volume phase or volume of the three different phases.

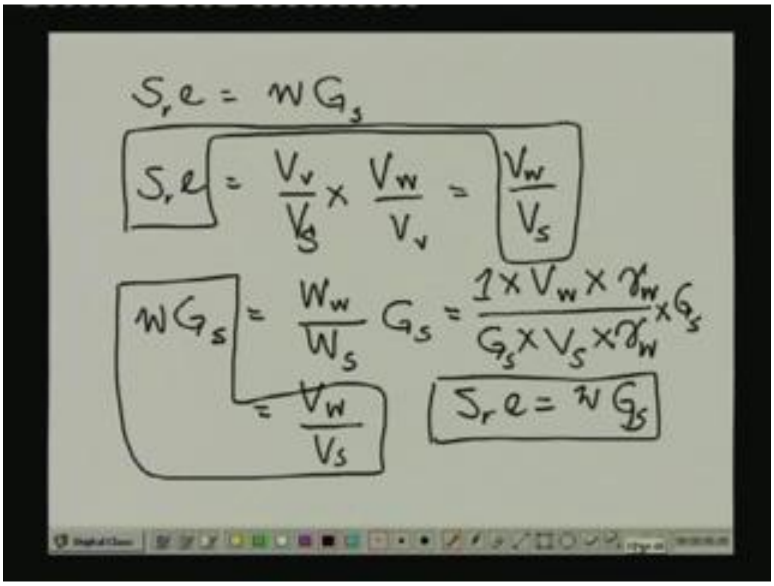
(Refer Slide Time: 41:55)



So here, we have to find out what is the volume of void? What is this quantity really? What is the volume of voids and what is the volume of solids; so that is going to be given by V_v multiplied by 1 plus 1 over the void ratio. So then, we can calculate the bulk unit rate as W_s plus W_w divided by V subscript s plus V subscript v. This is from the definition that we introduce earlier that is going to be given by 1 by E; using the results that we derived few seconds back, like this divided by 1 by E multiplied V subscript v plus multiplied by 1 plus E so that is going to be equal to G subscript s plus saturation ratio multiplied by the void ratio divided by 1 plus void ratio times gamma w.

So, this is your final result that bulk unit rate is given by G_s plus S_r e divided by 1 plus E multiplied by gamma w.

(Refer Slide Time: 43:34)

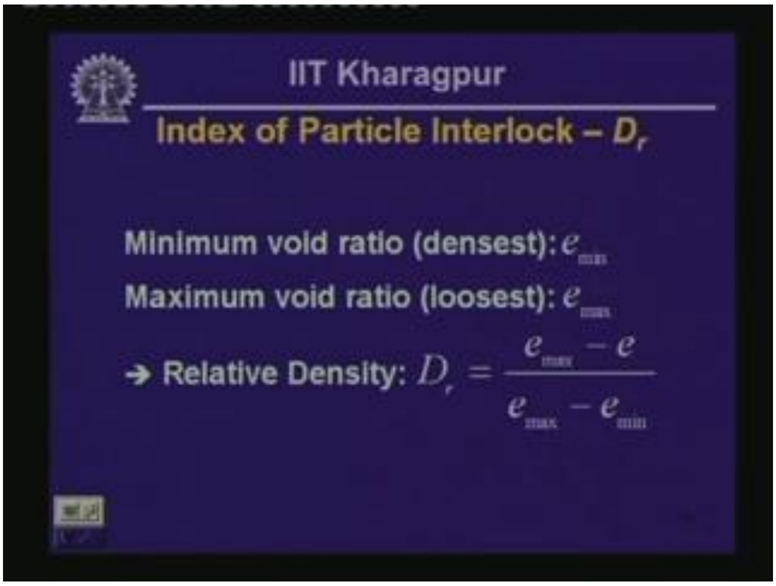


You could also show, you could also show actually there is another useful result in this case; saturation ratio multiplied by the void ratio that is given by water content multiplied by the specific gravity of soil solids. How do we do that? Using the definitions S_r multiplied by E will be equal to V subscript v divided by V subscript s multiplied by V subscript w divided by V subscript v that is going to be V subscript w divided by V subscript s.

Then W times G_s that is going to be given by W_w divided by W_s that is the definition of, that is the definition of water content multiplied by G subscript s. So, that is going to be again equal to 1 multiplied by V subscript W multiplied by gamma w divided by G subscript S; this one is used because, this one is used because the specific gravity of water is approximately equal to 1. So, in the denominator we have got G subscript s multiplied by V subscript s multiplied by gamma w and that in turn gets multiplied by G subscript s that is given or that is equal to V subscript w divided by V subscript s.

So, what you end up getting is S_r and WG_s, they are of the same, it has got the same right hand side so what we get then is S_r multiplied by E is equal to W times G_s. So, that is our final result in this case.

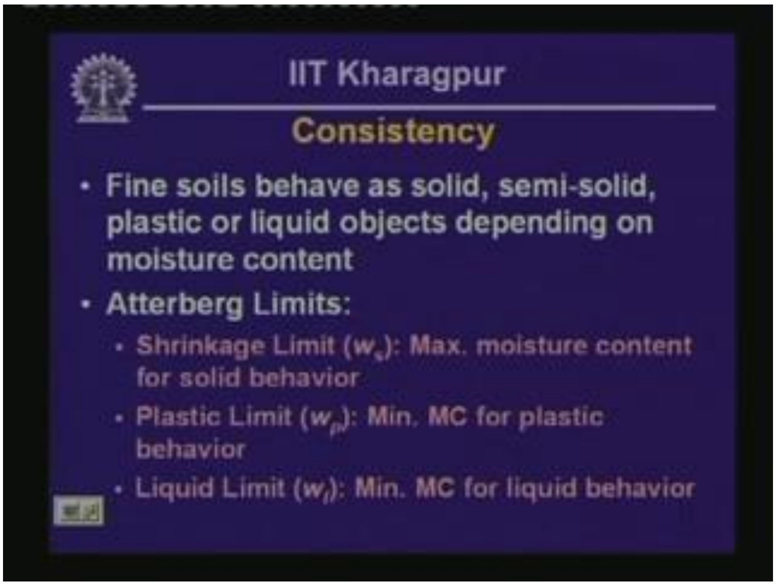
(Refer Slide Time: 45:34)



So, now we introduce an index of particle interlock. So, here what we say, what we introduce is the maximum and minimum void ratio - e_{max} and e_{min}. These are properties of a given type of soil. Now, relative density which is the measure of particle interlock is given by the expression at the bottom of the slide there which is e_{max} minus e divided by e_{max} minus e_{min}.

So, how to find e_{min}? e_{min} is found by taking a certain quantity of dry soil in a cylinder and shaking it according to specified procedures over a certain duration of time and finding out the void ratio of the resulting soil, densified soil and e_{max} is found by loosely depositing a certain amount of soil under water, a dry soil under water and finding out the void ratio of the resulting soil matrix. And D_r, the relative density you express using the symbol D_r can then be found by the expression which I have shown at the bottom of this particular slide.

(Refer Slide Time: 46:58)



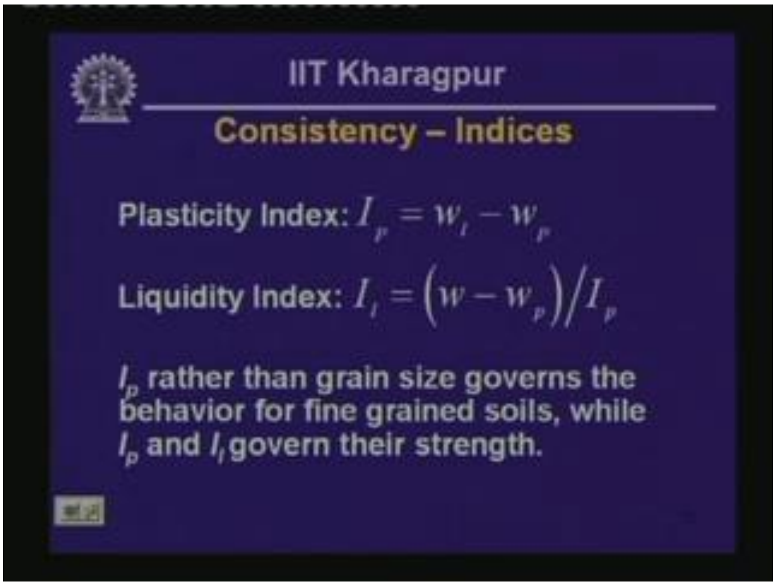
So, D_r is an index property relevant to coarse grain materials. But in case of fine grain materials, we have to talk about the plasticity of the soil and for that we have to introduce the concept of consistency. So, fine grain soils, they behave as solid or semi solid or plastic or liquid objects depending on the moisture content of the soil.

Now, then in order to quantify this particular behaviour, we introduce a few indices and they are called the Atterberg limits. First of all, we introduce shrinkage limit. So, in this, this is the moisture content; maximum moisture content for the soil to retain its solid behaviour. Then we could also define plastic limit; this is the minimum moisture content for plastic behaviour of the soil.

So, if natural moisture content of the soil sample exceeds plastic limit, then the soil is going to be, going to behave as a plastic material. In other words, it can be remoulded to give any shape to this particular, it can be remoulded to give a particular shape and that shape is going to be retained, the deformed shape is going to be retained by the soil.

Then we could introduce liquid limit and this is the minimum moisture content above which the soil is going to behave like a liquid material and with very low shear strength.

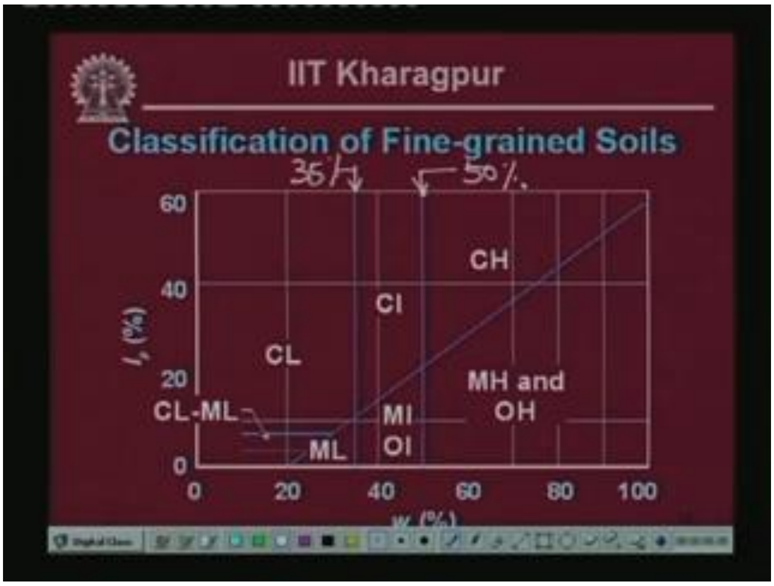
(Refer Slide Time: 48:55)



So, we have got 3 Atterberg limits then; shrinkage limit, plastic limit and liquid limit and based on this, we define another index. This is an index of consistency of the soil and that is called the plasticity index which is the difference of liquid limit and the plastic limit. You can easily realize that liquid limit will be a much larger number in comparison with the plastic limit or larger number actually in comparison with plastic limit, they could be equal. If you have got non plastic soil, W liquid limit is approximately equal to the plastic limit.

Then another index is called liquidity index. So in this case, we have got the natural moisture content W minus W_p - plastic limit in the numerator and that is divided by the plasticity index. So, plasticity index is controlled by the, it is controlled basically by the charge density because the clay particles are all negative, it has got negative surface charge because of isomorphic substitution of cations and because of this negative surface, the interaction as a result of it is measured by the plasticity index and plasticity index is a good indicator of the behaviour of fine grain soils, strength behaviour of fine grain soils and I_p - plasticity index and liquidity index both of them are also indicator of the strength behaviour of fine grained soils and the sensitivity of fine grained soils is measured by the liquidity index and what is meant by sensitivity, we are going to come to that in one of the future presentations.

(Refer Slide Time: 50:47)



Then we get into the classification of fine grained soils. So, we begin with the plot of the liquid limit verses the plasticity index and it has got, I want you to notice several different zones in that particular chart and depending on which zone your soil sample falls in, you are going to classify the soil according, soil sample according to that.

So first of all, we have got MH or OH at the lower right corner of this particular plot, then we have got MI or OI at bottom centre, then ML at bottom left, then CL or ML it is an intermediate soil type really within the small zone there, CL is if we are on the top left of the diagonal line within that particular chart there, this chart is also called Casagrande chart, then CI if you are within that zone and CH is if you are near the top right and finally the set of categories are as indicated on this particular chart here. So, this particular value or liquid limit is 35% and over here you have got 50%, the other line here is at 50%.

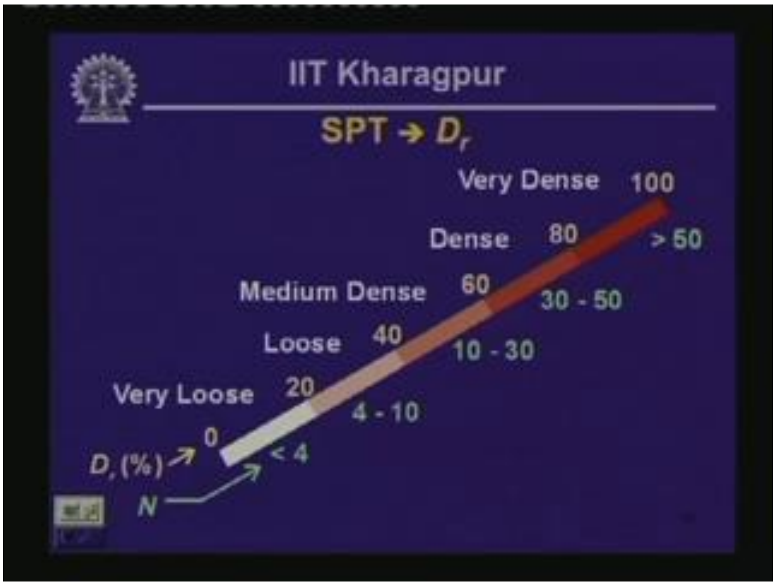
(Refer Slide Time: 52:30)

Now, how do you determine the relative density in the field? You conduct a test called this standard penetration test or SPT what is involved there, you drive the standard split spoon sampler which we already which we have already discussed in one of the previous presentations using a drop hammer, standard drop hammer that has got 65 kg of weight that fall and it falls through a height of 750 millimetre and this sampler is first placed near the bottom of the predrilled borehole and driving begins from there and what is done is 3 consecutive number of, actually number of blows required for 3 consecutive 150millimetre penetrations are recorded and the sum of the second and the third 150 millimetre penetration are summed up and they are reported as the raw SPT blow count or N, this is expressed using the symbol N and N relates to the relative density as we are going to see in the next little bit.

(Refer Slide Time: 53:38)

This shows the SPT test setup. Now here, what we are what we are seeing on the left is the SPT hammer at the top and the sampler is already down in the hole. So, the hole begins from here and the sampler is down in the hole and after the sampler is withdrawn, the picture of it is shown here. So this one, the picture on the top right of this particular slide is the picture of an SPT split spoon, standard SPT split spoon sampler and the schematic detail of this particular sampler is shown on bottom right and we have already seen the details of the construction of these type of sampler in one of the previous presentations; I am not going to get into details of this.

(Refer Slide Time: 54:42)



This is actually a stack bar that gives you the correlation between relative density and SPT blow count and it also gives the categories of different types of soils in terms of how dense or how loose they are. So, it goes from a scale of very lose to very dense depending on relative density going from 0 to 100% and SPT blow count going from less than 4 to greater than 50.

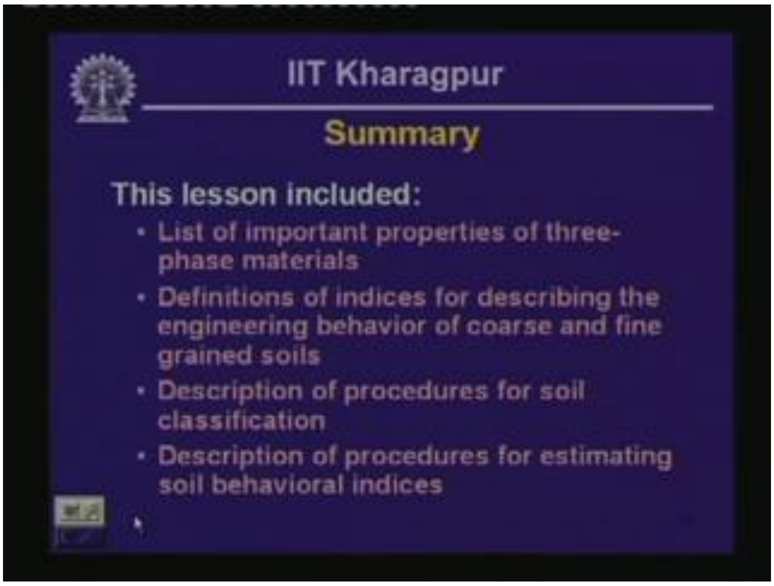
(Refer Slide Time: 55:15)

Then how do we determine the plasticity index? In order to find out the plastic limit, what we do? We remould a sample of fine grain soils and try to roll threads out of it as its shown on the left photograph there and if the thread breaks, when the diameter of the thread goes to 3 millimetre, then the moisture content at which this particular thing happens is called the plasticity index and in order to determine or the moisture content at which this thing happens is called the plastic limit and the liquid limit is found using an instrument called casagrande apparatus and the picture of it is shown on the right hand side of this particular slide.

Here you have got a brass bowl and you create a clay pat within the brass bowl, you itch an opening or itch a grove within the clay sample, cut a grove in the clay sample and then the sample, the bowl is bounced on a hard rubber on the hard rubber base. So, this one here is a hard rubber base; it is bounced up and down on the hard rubber base using a standard configuration and the number of blows, number of up down hits required for this particular clay, the grove open in this particular clay pat to close over a length of 15 millimeter is defined as the plastic limit. The moisture content at which the grove closes by 15 millimetres in 25 blows is called the plastic limit.

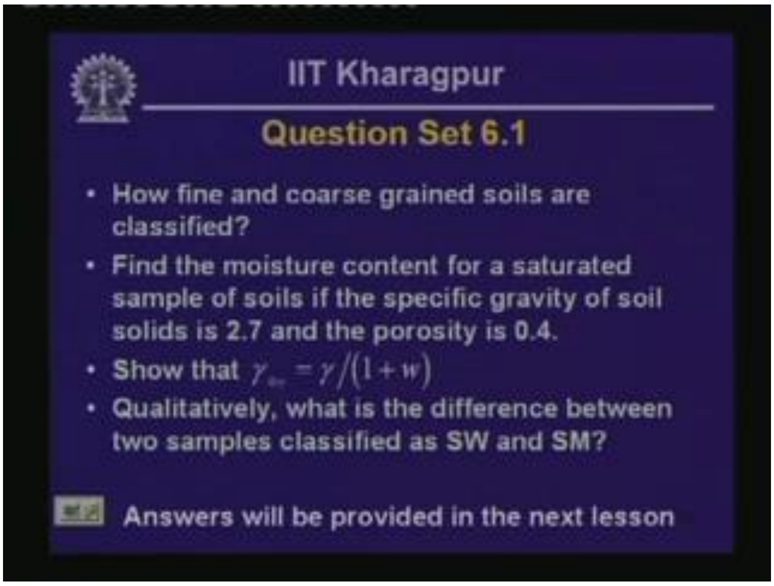
So, then you could find the plasticity index easily because you know the liquid limit and the plastic limit and plasticity index is simply the difference of the two.

(Refer Slide Time: 57:42)



Now, we summarize this particular lesson; what we learnt in this lesson is the list of important properties of three phase materials, we looked at the definitions of indices for describing the engineering behaviour of coarse and fine grained soils, looked at description procedure, we looked at the description of procedures for soil classification and we looked at indices, we looked at some of the indices for estimating engineering behaviour of different categories of soils.

(Refer Slide Time: 58:21)



Finally, we end this particular lesson with a question set. You try to answer these questions at your leisure. The first question is; how fine and coarse grained soils are classified? Second question is; find the moisture content for a saturated sample of soil if the specific gravity of soil solids is 2.7 and the porosity is 0.4.

Then I asked you to prove a relationship gamma dry is equal to gamma over (1 plus W), W is the moisture content and gamma is the bulk unit weight and gamma dry is the dry unit weight. Qualitative, and the fourth question is; qualitatively what is the difference between two samples classified as SW and SM?

Try to answer these question at you leisure, I will give you my answers when we meet again for the next lesson; until then, bye for now.

Thank you very much.