Expansive Soil
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Lecture 02
Index properties and classification of soil

Welcome, everyone, and today I will start the new lecture on the Expansive Soil and today's lecture will be the second lecture of the module one, which is entitled Introduction to soil mechanics. So, today topics will be on the index properties and classification of the soil. Here we will learn about some basic properties of the soil and how to classify the soil based on that.

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Initially, we will start with the index properties of the soil. As you know that index properties of the soil are the properties, which helps in its identification and engineering application. Generally, all these tests are done in the laboratory, and this gives us some idea about how the soil will behave in the field.

So, generally the index properties are consisting of two things, one it's derived from the soil grain properties, such as the specific gravity, grain size distribution and shape of the particles. The index properties derived from the soil grains properties do not depends on the way it formed, it only depends on the individual particle size, or individual particles.

Similarly, soil aggregate properties, which depends on how the soil forms and the way, or how it gets deposited, depending on the soil particle size, it can be coarse grained soil or a fine grained soil. So, if it is a fine grained soil, the aggregate properties will be like, Atterberg limits and unconfined compressive strength. Similarly, if it is a coarse grained soil, it will be the relative density. Basically, the index properties can be of two things, one from the soil grains, one from the soil aggregates.

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Then we will discuss about the phase diagram of the soil. When we take a soil, and when we see it carefully, we will find three things in it. First of all, it will be consisting of the solid particles, here you can see these are the solid particles, the second one will be the water, here you can see the water will be present in the void between the solid particles. The third one will be the air, you can see these are the air.

So, combinedly solid particles, water and air makes a soil. If we divide, or if we segregate all these particles into three different forms, then we will get this diagram. This is known a phase diagram. This phase diagram we will divide, or we will divide the soil into three parts, first the soil will be made up solid. So, since the soil solid is heavier, we will put it at the bottom. Second will be made up the water. Third, it will be made of air.

Since all this air water and solid are there, so this diagram is known as three phase diagram. If the air is if the soil is fully saturated, in that case what happened, the air part will not be there, or air will be replaced by water. So, only water and solid part will be there. So, for a fully saturated soil, it will be a two-phase diagram.

Similarly, if the soil is dry, in that case the water will be replaced by air, and this soil will be made of two things, one will be air and another will be the solid particles. Again it will be a two-phase system. So, if the soil is fully dry it will be a two-phase system, a soil is fully saturated, it will be a two-phase system, and if the soil is partially saturated, in that case it will be a three phase system.

Let the volume of the soil be capital V. Now, this volume is made up of three things. One the volume of solid, second the volume of water, third the volume of air. And then we take the weight of the soil. The weight of the soil is made of three things; weight of solid, weight of water, and weight of air.

Since the weight of air is 0, we can ignore that one. So, we can say the weight of the soil is made of weight of water and weight of solid. Here we have written,

$$\text{Total volume of soil} = V = V_a + V_w + V_s$$

Similarly, the total weight of soil is made up two things,

$$\text{Total weight of soil} = W = W_w + W_s$$

Now,

the volume of air plus water combinedly is known as the volume of void.

Volume of void will be designated as V_v,

Volume of void = $V_v = V_a + V_w$

So, using all these terms, we will be deriving some of the parameters of the soil, which will be helpful in developing some other relationship between the soil, water and air.

The first one is water content.

$$\text{Water content} = w = \frac{\text{Weight of water}}{\text{Weight of solid}} = \frac{W_w}{W_s}$$

It indicates how much water the soil is having. The value can be anything from 0 to any value, say when the soil is dry, though it will be 0 and soil is fully saturated, it can be of any value.

For example, for a highly expansive soil this can be up to 300, 400, for a sandy soil it can be up to 30, 40. So, depending on the soil and its condition, the water content can be of any value higher than 0.

Next is the void ratio.

$$\text{Void ratio} = e = \frac{\text{Volume of void}}{\text{Volume of solid}} = \frac{V_v}{V_s}$$

Generally, this value is more than 0.

And again, this value can be any value. Say for example, if we take a sand, it can be 0.3, 0.4. If we take a highly expansive soil like Sodium montmorillonite it can be up to 35, 30. So, depending on the soil type and how much water it is holding, the void ratio can be of different value, but it should be more than 0.

Next is the porosity.

$$\text{Porosity} = n = \frac{\text{Volume of void}}{\text{Total volume}} = \frac{V_v}{V}$$

Porosity again is a value which is more than 0.

Next is the degree of saturation. Degree of saturation tells us about how much of the void space is filled with water.

$$\text{Degree of saturation} = S_r = \frac{\text{Volume of water}}{\text{Volume of void}}$$

When the soil is fully dry that means, when there is no water in it, the degree of saturation will be 0. Similarly, when the soil is fully saturated, that means when the void is entirely filled with water, then degree of saturation will become 1. Generally, this degree of saturation is expressed in percentage. So, it can be of any value between 0 to 100 percent.

Next is the bulk unit weight.

$$\text{Bulk unit weight} = \gamma = \frac{\text{Total weight of soil}}{\text{Total volume of soil}} = \frac{W}{V}.$$

Generally, the unit is Kilo-Newton per meter cube, or gram per cc.

Similarly, another unit we use that is dry unit weight,

$$\text{Dry unit weight} = \gamma_d = \frac{\text{Weight of soilid}}{\text{Total volume}} = \frac{W_s}{V}$$

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Similarly, for a coarse-grained soil, there is another parameter which is used is relative density. Relative density generally indicates how densely soil is present in the field.

$$\text{Relative density} = \text{RD} = \frac{e_{max} - e}{e_{max} - e_{min}}$$

e_{max} = Void ratio of soil at loosest state

e_{min} = Void ratio of soil at densest state

e = In-situ void ratio

So, depending on the relative density, the soil can be termed as very loose, loose, medium, dense, and very dense. If it is in between 0 to 15 percentage, it will be like very loose. Similarly, 15 to 50 percentage it can be termed as loose, 50 to 70 percentage it can be termed as medium, 70 to 85 it can be termed dense, and similarly very dense condition. And relative density, as I told you earlier, is only applicable for a coarse-grained soil.

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There are the relationship exists between all these parameters. Say for example porosity.

$$\text{Porosity} = n = \frac{\text{Volume of void}}{\text{Total volume}} = \frac{V_v}{V} = \frac{V_v}{V_s + V_w + V_a} = \frac{V_v}{V_s + V_v} = \frac{e}{1+e}$$

So, porosity can relate with void ratio using this equation. Similarly, the bulk unit weight and the degree of saturation, void ratio, and the specific gravity of solid can be related with this equation.

$$\text{So, Bulk unit weight} = \gamma = \frac{(G_s + S_r e)\gamma_w}{1+e}$$

When the soil is fully dry, in that case, S_r will be 0. So, if we put S_r equals to 0, here we will get

$$\gamma_d = \frac{G_s \gamma_w}{1+e}$$

Similarly, when the soil is fully saturated, then saturated unit weight γ_s will be equals to

$$\gamma_s = \frac{(G_s + 1)\gamma_w}{1+e}$$

So, this will be your γ_s, or saturated unit weight.

There is a relationship between water content, specific gravity, degree of saturation and void ratio,

$$w.G_s = S_r.e$$

There is also another relationship between the dry unit weight, water content and the bulk unit weight.

$$\text{Dry unit weight } = \frac{\text{Bulk unit weight}}{1 + \text{water content}}$$

Here we have used the term Gs, Gs is a specific gravity of solid particles, which is present in the soil.

$$G_s = \frac{W_s}{V_s}.$$

Generally, the Gs of the soil varies from 2.4 to 2.8 and γ_w is the unit weight of water, which is equals to 9.81 Kilo Newton per meter cube.

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With this in some of the index properties, next we will go to soil particle size. The soil is made of various particles, for generally the soils are divided into different particles based on their sizes, average size. As far as Indian soil classification is concerned, the soil has been classified into two parts, one is known as coarse grained soil, the another one is known as fine grained soil.

Coarse grained soil consisting of boulder, cobble, gravel and sand. When the particle size is more than 300 millimeter, it will be known as boulder. When it is in between 300 mm to 800 millimeter, it will be known as cobble. When it is between 80 millimeter to 20 millimeter, it will be known as coarse gravel. When it is between 20 millimeter to 4.75 millimeter, it will be known as fine gravel. So, gravel is generally denoted by the term G in our soil classification.

Similarly, the sand also divided into three ways; coarse, medium, and fine sand. Coarse sand consisting of the particle size from 4.75 millimeter to 2 millimeter. Medium sand consisting of the particles from 2 millimeter to 425-micron, fine sand consisting of the particles from 425 micron to 75 micron. And sand is denoted by the term S in our soil classification.

Similarly, beyond the 75 microns, or particle size less than 75 micron are known as fine grained soil. So, for fine grained soil if the particle size is between 75 micron to 2 micron, then this is known as silt. If it is less than 2 microns, it will be known as clay. Silt is termed in M and clay in C. Since S term has already taken by the sand, silt has been denoted by M, which is known as mho in Latin word.

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If we look into all these individual particles, some of the particles we can see in our naked eyes, where whereas, for other particles we need some microscope or electron microscope. So, if you can look into this table, you can see the soil has been classified into two-way, fine grained soil, coarse grained soil. From sand onwards, the soil is known as coarse grained soil, which is divided as fine, medium, coarse; gravel divided as fine and coarse. Then comes cobble, then boulders. Similarly, fine grained soil classified as clay and silt. These are their particle size you can see.

Now, if we look into individual solid particles of this soil, for coarse grained soil we can see the individual particle in our naked eyes, we do not need any help. But on the other hand, if we go by this fine grain soil, we need some help of microscope, or electron microscope. For individual silt size we can see all the individual particles using a microscope, but to see individual clay particles we need an electron microscope. These clay particles are very, very small in size, less than two microns, so, it needs an electron microscope to see individual clay particles.

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Next will be how do you classify a soil based on the particle size? To do that we need to draw a particle size distribution curve. Particle size distribution curves, we will get a curve like this. So, generally this curve will obtain by doing some sieve analysis and hydrometer analysis. In particle size distribution curve, what we have to do is, we need to find out the particles of different sizes and the proportion by which it is present in a soil.

So, first for a coarse grained soil, we can do that for a set of sieves, you can see different set of sieve are there, with the number 4, 10, 20, 40. So, each number represents an opening size, so, from 9.53, to 0.075 mm. So, this is the lowest one. In this soil in this set of sieve, we will sieve the soil and then we will take out the sieve and find out how much soil has been detained in each sieve.

Then the remaining soil which is passing through 0.75 micron will be analyzed again with a hydrometer. Because this particle size is very less, so, we cannot use a sieve for this one, we have to go for a hydrometer analysis. So, once we know how much particle size are present of different sizes, then we have to plot a graph between the particle size in our log X, on the X-axis and percentage finer on the Y-axis. The curve which we will obtain will be known as the particle size distribution curve. Based on the shape of this curve we will determine whether this is a poorly graded soil, or well graded soil, or a gap graded soil.

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So, here we can see, this is a gradation of a soil. You can see there are three different curves over here. This is a particle size distribution curve. Generally, the soil can be divided into two way based on their particle size gradation curve, one is known as well graded, second one is known as poorly graded.

In well graded soil, particles of different sizes are present in a good proportion. In poorly graded, soil particles of mostly one size, or another size will be present. So, it will not give a uniform distribution of the particles. So, that is why this is known as poorly graded soil. You can see this graph is known as a well graded soil.

Generally, the shape of the well graded soil is a type of S like this one, where as a poorly graded soil is represented by this diagram this curve. Similarly, there is another kind of soil is there, which is known as gap graded. In gap graded soil, generally one or two fraction of soils are missing. So, gap graded also is known as a poorly graded soil.

Based on these two factors the coefficient of uniformity and coefficient of curvature, we need to determine whether it is a well graded, or poorly graded. So,

$$\text{Co-efficient of uniformity} = C_u = \frac{D_{60}}{D_{10}}$$

Similarly,

$$\text{Co-efficient of curvature} = C_c = \frac{D_{30}^{2}}{D_{60}D_{10}}$$

Then what is the meaning of D_{30}, D_{60} ? From this curve, if we draw a horizontal line like 60 percent finer, then we will get a particle size here.

So, D_{60} means, the particle size corresponds to which 60 percent are finer than this size. Similarly, D_{30} represents the diameter of the particles corresponds to which 30 percent are finer, D_{10} will also be represented by the particle size corresponds to which 10 percent are finer than this. So, this D_{10}, D_{60} and D_{30} are obtained from a particle size distribution curve.

For a well graded soil, the coefficient of uniformity should be greater than 4 and the coefficient of the curvature should be between 1 and 3. If it is not, then it will be known as poorly graded gravel. For a well graded sand, the C_u should be greater than 6 and C_c should be in between 1 to 3. Otherwise, it will be known as poorly graded sand. For well graded soil, the term W is used for the soil classification, and for a poorly graded soil, the term P is used in soil classification system.

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Next, we will discuss about the plasticity behavior of the soil. Plasticity behavior of the soil is its ability of a soil to undergo deformation due to application of the pressure. You might have seen some clay which we can mold into different shapes, when by applying some pressure, that behavior of the soil is known as plasticity. By plasticity behavior of the soil, the soil can be deformed into many shapes. Generally, the plasticity behavior of the soil depends on its mineralogical composition as well as its pore-fluid chemistry.

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Next, we will discuss about the consistency behavior of the soil. Consistency behavior of the soil, it indicates the firmness of the soil, whether the soil is soft, or whether it is medium, or it is hard. So, for example take clayey soil and add sufficient amount of water in it. When we add more water to it, the soil will behave like a liquid.

So, for example if we added a sufficient amount of water and the soil will be in state A, that means it will be behaving like a liquid. Now, what we will do is, we will gradually dry the soil such that its water content will decrease, or the amount of water will gets reduced. As the water from the soil gets reduced, the soil will start to gain some of the shear strength.

So, here you can see, the soil is in form of the liquid. Gradually when we reduce the water from the soil, the volume of the soil will also decrease, the water content will decrease. Finally, a stage will come when the soil will start to have some shear strength and it will not flow like a liquid. So, that water content at which the soil starts to gain some of the shear strength, which can be measured in the laboratory, is known as the liquid limit of the soil.

Liquid a limit of the soil can be defined as the water content at which the soil changes from liquid state to plastic state. This is the border line between the liquid state and the plastic state, that border line is known as the liquid limit. So, liquid limit of the soil depends on many factors like its mineralogical composition, its pore fluid chemistry. Generally, depends on its diffuse double layer water as well as absorbed water. Higher is the amount of water, higher will be the liquid limit. Depending on the clay minerals also the liquid limit also varies.

For example, for sodium montmorillonite, the liquid limit will be around 500 to 600, whereas, for kaolinite and illite, it will be very less. Generally, the liquid limit exhibits for clayey or silty soil. So, again the consistency of the soil can also be expressed in terms of unconfined compressive strength. Say for example, when the unconfined compressive strength is less than 25, the soil will be very soft. So, that can be like it will be on this side. Similarly, when it is between 25 to 50, the soil can be termed as soft, 50 to 100 kPa, it can be termed as medium and if it is more than 400 the soil can be termed as hard.

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Now, when we dry the soil from A onwards, it reach a state B, when the soil will develop some shear strength that water content we know as liquid limit. Now again, we dry the soil further. As we dry the soil further, again the water content will reduce, the volume of the soil will reduce and the soil now will be deformed into different shapes. The soil will show some plastic behavior here.

Now, after drying the soil further we will reach a point over here at C, at this point the soil will starts to develop some crack. So, this water content at which the soil starts to develop some cracks is known as plastic limit. Beyond this plastic limit, the soil will behave like a semi-solid state. So, again, it can be defined as the water content at which the soil changes from plastic to semi-solid state. Between this plastic limit and liquid limit, the soil can be deformed into any shapes. So, this range of water content is known as plasticity index.

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Similarly, again when we dry the soil from say states C to D, the water content will keep on decreasing and the volume will keep on decreasing. At a particular value once we reached, here at D say, the volume of the soil will not decrease further. Even if we decrease the water content, the volume of the soil will remain constant. So, that limiting water content at which the soil volume cease to decrease is known as Shrinkage limit. So, shrinkage limit is defined as the water content at which the soil becomes fully saturated, or it is a minimum water content, beyond which the soil will be fully saturated.

Again, once the soil crosses shrinkage limit state, it will be in solid form and therefore the shrinkage limit can also be defined as the water content at which the soil changes from semi-solid state to solid-state. Therefore, here shrinkage limit can also be defined as the minimum water content up to which soil remains saturated. So, point D beyond the soil will not change in its volume. This range of water content for which the soil will be in semi-solid state is known as shrinkage index. So, shrinkage index can be defined as the difference between the plastic limit and the shrinkage limit.

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And next will be the plasticity index. Plasticity index is the range of water content for which the soil will be in the plastic state.

Plasticity index = Liquid limit - Plastic limit.

So, wider is the plasticity index, the soil can be deformed into shapes quite easily.

And also, higher will be the plasticity index, the soil will also have some higher compressibility, higher water content, higher swelling characteristics, lower hydraulic conductivity. Based on the plasticity index, the soil can be defined as non-plastic, low plastic, medium plastic and highly plastic. If the plasticity index is 0, soil will be known as non- plastic. If it is less than 7, it will be known as low plastic. If it is between 7 to 17, it will be known as medium plastic and if it is more than 17, it will be known as highly plastic.

The next index is known as liquidity index. So, liquidity index indicates how close the soil near to its liquid limit.

$$\text{Liquidity index, } I_l = \frac{\text{Water content- Plastic limit}}{\text{Plasticity Index}} \times 100$$

When the water content is at liquid limit, water content becomes equals to W_L and the plasticity index, which will equal to W_L minus W_p, so the terms will be equals to 100. So, that means the soil near to its liquid limit.

Similarly, when the soil is in plastic limit, so this term this will be W_p and it terms will be equals to 0. So, that means when it is less than equal to less than 0, the soil will be in semi-solid state, between 0 to 1, it will be in plastic state, when it is 1, or more than 1, it will be known as at liquid state. Based on this value, the soil can be defined whether it is in the semi-solid state, plastic state, or the liquid state.

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Next one is a consistency index. Consistency index generally defined as the closeness of the water content to its plastic limit.

$$\text{Consistency index, } I_c = \frac{\text{Liquid limit-Water content}}{\text{Plasticity Index}} \times 100$$

When the water content equals to liquid limit, so, this terms will be equals to 0. So that means it will be not near to it is plastic limit. When the water content equals to plastic limit, then the terms

$(W_L – Wp)$/ Plasticity index = 100,

that means, the soil is near to its plastic limit.

There is another term called activity of the soil,

$$\text{Activity, } A_c = \frac{\text{Plasticity Index}}{\text{Clay fraction}}$$

Generally, higher is the activity of the soil, that means the soil will undergo a large deformation, or large swelling. Say for example, when for Sodium montmorillonite the activity of the soil can be between 4 to 7, for Illite it will be 0.5 to 1.3 and for kaolinite it will from 0.3 to 0.5.

When this activity is less than 0.75, generally the soil is termed as inactive, when it is between 0.75 to 1.25, it can be termed as normal, when it is more than 1.25, it will be known as active. Activity of the soil is directly correlated with compressibility of the soil, swelling characteristics, hydraulic conductivity. Higher is the activity, higher will be the compressibility, higher will be the swelling, higher will be the shrinkage and lower will be the hydraulic conductivity of the soil. Generally, activity of the soil depends on mineral. For sodium montmorillonite it will be very high, whereas, for kaolinite, it will be very low.

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There is another term called toughness index, which is defined as the ratio between the plasticity index and the flow index of the soil. Then it indicates the strength of the soil near to its plastic limit. The term the flow index generally derived from the Casagrande's method. While determining the liquid limit of the soil we obtain this curve, which is known as flow curve. During this determination of the water content, we have to plot the graph between the water content on Y-axis and number of blows on X- axis.

So, if this is the, if we take a value, which correspond to N1 number of blows and which corresponds to W1 water content, N2 number of blows corresponds to W2 water content, then we will get a slope of this line which will be known as flow index.

$$\text{Flow index, } I_f = \frac{w_1 - w_2}{\log \frac{N_2}{N_1}}$$

This flow index is generally tell us about the rate of increase or decrease in the strength of the soil due to change in the water content. Stiffer is the soil that means, shear strength of the soil decreases quite rapidly with a less change in the water content.

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Similarly, there is a term called sensitivity of the soil, which is defined as the ratio between undisturbed unconfined compressive strength to the remoulded unconfined compressive strength. When we take a soil and when we mold the soil into different shapes and if we leave it then the soil will start to gain its strength.

So, depending on the ratio between the undisturbed unconfined compressive strength and remoulded unconfined compressive strength the sensitivity term is there. When this sensitivity is less than 1 the soil will be termed as insensitive, when it is more than 15 it will be known as quick clay. So, based on the sensitivity of the soil, the soil type can be defined as insensitive, normal sensitive, extra sensitive and quick clays.

Similarly, the thixotropy is a properties of the soil by which a remoulded soil gains its strength. Generally, thixotropy comes from the plasticity behavior of the soil and depends on the type of mineral and the type of pore fluid of the soil. Now, when we take an expansive soil and when we put it for drying, the soil volume will decrease. So, depending on how much volume of the soil is decreasing, there are two terms we use that is known as the first one is known as the volumetric shrinkage, which is defined as the ratio between the decrease in the volume of the soil to its dry volume of the soil.

So,

$$\text{Volumetric shrinkage, } VS = \frac{V_1 - V_2}{V_d} \times 100$$

That means if we dry a soil from V_1 volume to V_2 volume, and if it is V_d is the dry volume of the soil.

$\frac{V_1 - V_2}{V_d}$ is known as the volumetric shrinkage.

Similarly, the linear shrinkage is expressed as a percentage in decrease in the length of the soil mass due to drying to the initial length at a water content equals to its liquid limit. Generally, this volumetric shrinkage and linear shrinkage help us in understanding the shrinkage behavior of the soil, mostly expansive soil. Next, we will go to the classification of the soil.

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Generally, the classification of the soil is performed to place the soil which expect to exhibits similar characteristics. Say for example, in a group of soil, the soil will have identical compressibility shear strength. Similarly, the soil classification is defined as the arranging of the soil into various groups so that soil in a particular group behaves similarly.

And also, by classifying the soil, it gives us about some engineering behavior of the soil. Generally, the purpose of any soil classifications are to put the soil in a group such that soil placed in a similar group behave similarly. Second one to name a soil, such that people can understand what the soil type is.

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Generally, the soil classification based on two things, one is the particle size, second one will be the gradation for a coarse-grained soil and for a fine-grained soil the plasticity behavior. There are various type of classifications are exist, one is known as textural classification, AASHTO classification, unified soil classification system and Indian soil classification system. Mostly all the soil classification system based on particle size, gradation and plasticity behavior.

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So, we will look into how the soil has been classified. We will look into two soil classification system, one Indian soil classification system and second one is unified soil classification system. First of all, the soil has been classified into two groups. A coarse-grained soil, that means, the particles size of this soil is more than 75 microns, next is the fine-grained soil. When the particle size is less than 75 micron, it will be known as fine grained soil.

Coarse grained soil has been further divided into gravel, which is the particle size between 80 mm to 4.75 mm; sand, particle size between 4.75 mm to 75-micron. Fine grained soil has been classified into two, one is silt and another is clay. Sometimes the organic clay also comes here. So, this is an organic clay which is can be O.

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Next, we will talk about the Indian soil classification system. So, Indian soil classification system takes two things into account. First is the soil gradation, particle size and its plasticity behavior. Say, when we take a soil first we need to determine what is the higher content in it, whether it is a coarse grained, whether it is a fine grained.

If we sieve the soil and if more than 50 percent of the soil is retained by 75 micron sieve, then the soil will be known as coarse grained soil. If more than 50 percent of the soil is passing through 75 micron, then it will be fine grained soil. If the soil is a coarse-grained soil, then it can be either gravel or sand. If more than 50 percent of coarse-grained soil is retained by 4.75 mm sieve size, then the soil will be gravel.

If not, then the soil will be sand, or, if more than 50 percent is passing through 4.75 mm sieve, then it will be known as sand. Once we know whether it is the sand and gravel, then we need to determine how much the fine content in its. If the fine content is very less say less than 5 percent then we need to check whether it is a well graded soil or a poorly graded soil.

If the soil is a fine grained soil, then we need to see whether the content is silt, clay or organic or peat, that we can do it by determining its liquid limit. Once we know the liquid limit, we have to put the soil into a plasticity chart, which I will explain later on. Based on the plasticity chart we can determine whether it is a silt, clay or organic peat. If the liquid limit of the soil is less than equals to 35 percent, the soil will be known as low plasticity, if it is between 35 to 50 percent it will be known as intermediate plasticity. If it is more than 50 percent, it will be known as highly plasticity soil.

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If we put all this into a chart diagram, so, you can see the soil here, if more than 50 percent of the soil is retained by 75 micron, if yes, it is a coarse grained soil, if no, it is a fine grained soil, if coarse grained soil if more than 50 percent coarse grained soil retained by 4.75 mm sieve, it will be gravel, if no it will be sand.

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This is a plasticity chart, here, which we will be using to know whether silt or clay.

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For a clayey soil sorry for a gravel soil, then we will see what is the fine content, if the fine content is less than 5 percent then we will determine its C_u and C_c coefficient of uniformity and coefficient of curvature. If the coefficient of uniformity is more than 4 and C_c is between 1 to 3, if yes, then soil will be known as well graded and the term will be used GW, G has come from the gravel, W comes from well graded.

If it is not satisfying both this criteria, then the soil will be known as poorly graded. So, it will be GP. Again, G comes from gravel, P comes from poorly graded soil. If the fine content is more than 5 percent, fine content is more than 5 percent, sorry, this is 12 percent, fine content is more than 12 percent then we have to use the plasticity chart, then we need to determine its liquid limit.

If the soil falls on this zone, then it will be known as clay, if the soil falls on this zone, it will be known as silt. So, this zone has been divided by a line which is known as “A” line. So, basically this is a plasticity chart, which is drawn between the plasticity index and liquid limit. So, this is the A-line which is defined by the equation

IP = 0.73 (Liquid limit – 20)

Then from the liquid limit determination, if the soil falls on, says this zone, the second terms will be like clay, if the soil falls on this zone, the second terms will be like M. If the soil falls above the A line, it will be known as GC, if the soil falls below this line, it will be known as GM. And there is a hatched portion over here, if the soil falls on this zone, then the soil can be classified as GM, GC. So, this is holds good for gravel.

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Similarly, for sand also we can determine how much is the fine content. If the fine content is less than 5 percent then we need to determine C_u and C_c, if C_U is greater than 6 and C_c is in between 1 to 3. If yes, then it will be known as well graded sand. So, the term will be used SW, if not then it will be known as poorly graded sand, the term will be used SP.

Then we will use the fine content in it. If the fine content is more than 12 percent, then we need to determine the liquid limit as we determined for the gravel. Now, we need to check whether it is falling above A-line, below A-line or in the hatched portion. If it is following above A-line, it will be termed as SC, if it is below A-line it will be termed as SM, if it falls on the hatched portion it will be SM-SC.

Now, if the fine content in is between 5 percent and 12 percent, the soil will have dual symbol like GW-GM, GW-GC, GP-GC, GP-GM. So, in that case, we need to determine from the CU and CC whether it is a well graded and poorly graded then GW or GP. Then from here we have to determine whether it is a GC or GM. So, second term will come here. The fine content is between 5 and 12 percent, in that case, we have to use both the things to get the dual symbol. Similarly, for sand also, if the fine content is in between 5 and 12 percent then we need to check whether it is as, we need to find out whether it is SW-SM, SW-SC or SP-SC or SP-SM. So, this is for a coarse-grained soil, next for a clayey soil.

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So, if the fine contents is more than 50 percent and then the soil can be known as silt or clay. Once we know that the soil is a fine-grained soil then we need to determine whether it is a silt or clay, so, we need to determine its liquid limit. If the soil is above A-line, then it will be clay. If it falls below A-line, then it will be either silt or organic content.

Then we will check what will be its liquid limit. If the liquid limit of the soil is less than 35 percent, then it will be known as clay with low compressibility if the soil is a clayey type. If the liquid limit is more than 50 percent, then it will be termed as clay with high compressibility or CH. If the liquid limit is in between 35 and 50 percent, it will be termed as clay with medium compressibility CI.

Similarly, if it is falling below A-line, the term will be used M or O. If it is organic, then we have to do some other tests to determine whether it is the organic content is there or not. Then from the liquid limit, we can find out whether it is a highly compressible or low compressible or medium compressible soil.

If the liquid limit is less than 35 percent the soil can be classified as ML or OL, silty clay, silty soil with low compressibility or organic soil with low compressibility. If the liquid limit is more than 50 percent it can be termed as MH or OH, silt with high compressibility or organic soil with high compressibility. If the liquid limit is in between 35 and 50 percent, it can be termed as silt with intermediate compressibility or organic soil with intermediate compressibility.

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So, this is a plasticity chart which we have to use, you can see a plot has been drawn between the plasticity index and liquid limit, the line this is A-line. The equation for this A-line is IP equals to 0.73LL minus 20. Now, from the liquid limit value, we need to plot over here. If it is here, then above the A-line, this is the A-line above A-line that means it is a clay, below A-line it will be silt.

Now, we need to check whether this is falling on this zone, this corresponds to 35 percent liquid limit, this corresponds to 50 percent liquid limit. So, if the soil is over here for example, then it will be known as CL, clay with low compressibility. If it falls on this zone, it will be known as CI, clay with intermediate compressibility. And if it is on this zone, it will be known as clay with high compressibility.

Similarly, if it is below it will be silt or organic clay with high organic soil with high compressibility, if it is on this zone it will be known as silt or organic soil with intermediate compressibility. Similarly, if it falls on this hatched portion, it can be termed as CL or CL and ML. This is all about the Indian soil classification system.

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Next is the Unified Soil Classification System. Unified soil classification system is almost identical to Indian soil classification system, particularly for the coarse-grained soil this is almost identical. Only because, only for this fine-grained soil, it is a bit different. In Indian soil classification system, the soil, the fine-grained soil has been classified as low, intermediate or high compressibility, whereas for unified soil classification system, it has been divided into low compressibility or high compressibility. If the liquid limit is less than 50 percent, the soil can be termed as low compressible soil. If it is more than 50 percent it will be known as highly compressible soil.

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So, here we can see, we need to determine whether it is coarse grained soil or fine-grained soil. Let it be a fine-grained soil. Then we need to see whether it is above A-line or below A-line. If it is above A-line it will be clay, if it is below A-line it will be silt or organic soil. Then we need to plot this liquid limit on the plasticity chart. Then we will see whether the liquid limit is more than 50 percent or less than 50 percent. If the liquid limit is less than 50 percent, the soil will be termed as clay with low compressibility or CL.

Similarly, if the liquid limit is more than 50 percent, the soil can be classified with clay with high compressible soil. If it is silt or organic soil, if the liquid limit is less than 50 percent, it will be termed as silt or organic soil with low compressibility. If it is liquid limit is more than 50 percent it can be termed as silt or organic soil of high compressibility. So, this is all about the soil classification system.

In the next lecture, I will explain you about some of the engineering behavior of the soil, what are the different engineering behavior and how to determine those engineering behavior in the laboratory. So, I will discuss all this thing in the next lecture. And thank you very much for your patience.