**Pavement Materials**
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**Lecture 05**
**Consistency Limits and Classification of Soils Part-2**

Hello friends, in the last class we were discussing about the classification of soil.

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And we started by discussing different field tests, which can be conducted to differentiate between different types of soil and we have tried to understand few of the test to specifically differentiate, when we encounter fine grained soil, where we want to see how the soil can be categorized as silt or as clay particles and also how the soil can be categorized as organic fine particles. Today, we will continue our discussion related to the classification of soil.

And let us see the further classification systems that are based both on the grain size analysis and also consists of additional analysis that require the values of consistency limits.

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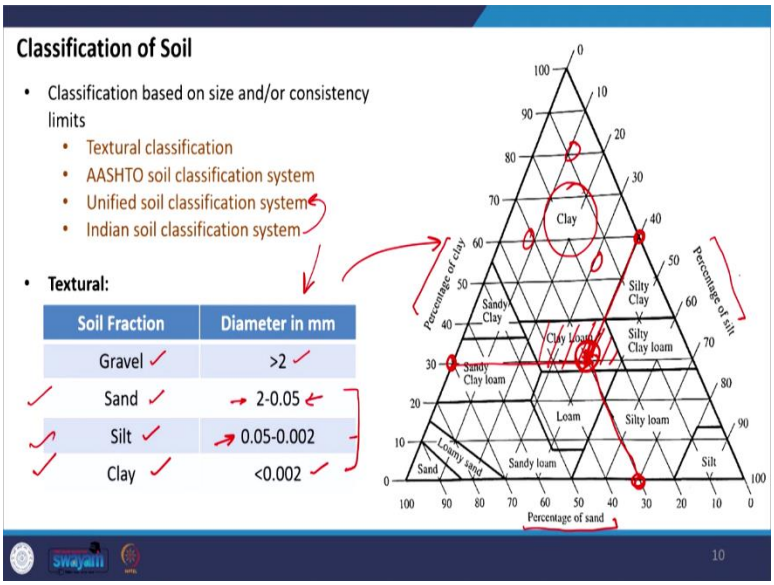


Under these classification systems, we will be discussing about the textual classification system we will be discussing about AASHTO soil classification system, we will talk about unified soil classification system and we will also discuss about the Indian soil classification system, which is very similar to the unified soil classification system with some minor differences. So, let us begin by discussing about the textural classification system.

In the textual classification system, first they have divided the soil based on the grain size. So, this is how they describe different types of soil based on the grain size for example, they considered gravel as those soil particles, which are more than 2 mm in size, sand are those particles which are in between 2 mm to 0.05 mm in size. Silt is considered as aggregates or as soil particles that ranges in between 0.05 to 0.002 mm whereas, clay particles are those which has a size of less than 0.002 mm.

So, once this size is decided then we will see that in the soil fraction, what is the proportion of sand, silt and clay? So, first we will do the classification based on the size of the soil fraction. And then in order to differentiate between these 3 fractions, we will use this particular chart here we will see that what in the Find fraction in the fine fraction, what is the percentage of clay, what is the percentage of silt and what is the percentage of sand such that the summation of all is 100 percent.

So, let us say that we did the grain size analysis we did the sieve analysis and we found that in the final fraction consists of 30 percent of clay, it consists of 40 percent of silt and it consists of 30 percent of sand. So, you can see that 40 plus 30 plus 30 is equal to 100 percent and we will just see where these lines intersect with each other in this particular chart. So, it intersect at this point and they have already identified that which location in this textural chart represents which type of soil for example, this particular soil will fall under the category of clay loam.

This type of classification system is more useful in the agricultural field where they have to identify only the type of soil but when we talk about the use of soil or identification of soil for engineering or construction purposes, then the problem with this type of classification is for example, let us say that you reach a location here somewhere maybe here, here. So, it says it is clay, but it does not tell us about the activity of this particular the clay which is present.

So, even under the clay we will have characteristics for example, clay can be highly compressible it will be under the low compressibility. So, it does not tell us much about the activity of that particular type of soil.

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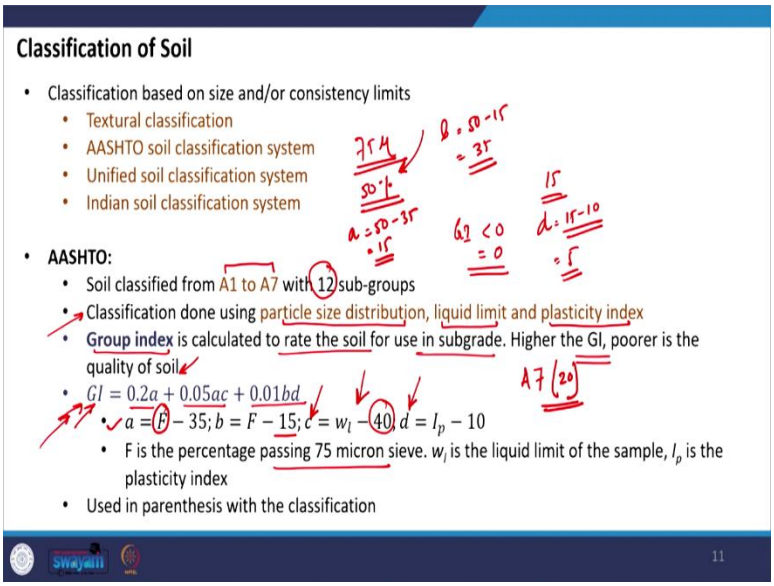


So, now, let us discuss about the AASHTO classification system. So, in the in the AASHTO classification system, the soil is classified under 7 categories A1 to A7 and with total sub 12 subgroups. So, it may happen that under A1 or A2 there are further subgroups of soil depending on the properties which they have. And these properties I am in this subgroup or the classification of soil in different groups, they are a function of particle size distribution, they are a function of the liquid limit of the soil and they are a function of the plasticity index of the soil.

So, you have to do the consistency test also in addition to the particle size distribution to identify the category of the soil or to classify that particular soil in addition to that, in addition to the classification corresponding to different groups and subgroups, another parameter is used to give some additional classification or additional index or to the type of soil and that is called as group index.

So, group index is calculated basically to rate the soil for use in the subgrade of the pavement system. So, it will tell us depending on the group index, whether the type of soil is a good soil to be used in subgrade or whether the soil is not very good to be used in the subgrade maybe it is a fair type of soil, maybe it is a

poor type of soil for use in the subgrade of the pavement. If the group index value is high, this means that poor is the quality of soil, it may happen that the group index value is also less than 0 in that case we consider it as equal to 0 and this type of soil will be in a very good, I mean this type of soil very good for construction purposes.

So, lower the value of the group index better it is there is no upper bound. So, higher is the value the poorer the soil is and how do you calculate group index it can be calculated using this empirical formula which is GI = 0.2 + 0.05 ac + 0.01 bd. And what is the definition of a b c and d? a is actually equal to that proportion of the final fraction which is more than 35 which means you will take the soil you will sieve it through 75 micron sieve and you will get the percentage of material passing 75 micron sieve.

Let us say 50 percent of the soil particles passes through 75 micron sieve therefore, a will be equal to the value in excess of 35. So, it will be 50-35 = 15. So, here F is the percentage of material passing 75 micron sieve what is b? b, is equal to that excess material passing 75 micron sieve or that proportion of material passing 75 micron sieve which is more than 15. So, again in the same example which we have taken if it is 50 percent then b = 50 - 15 = 35.

What is c? c, is the proportion of that particular material whose liquid limit is in excess of 40 which means that I will take the soil I will sieve it through for 25 micron sieve, I will measure the liquid limit of the soil and once I get the liquid limit of the soil I will deduct 40 from that particular value to get the value of c. Now, as I mentioned for example, if the liquid value of the liquid limit is less than 40 in that case this value will be negative in nature. And if everything becomes negative such that the group index is also less than 0, we will consider that to be equal to 0.

What is d? d, depends on the plasticity index it is that proportion or that value in excess of I mean the plasticity index in excess of 10. So, if the plasticity in index let us say it is 15. So, in order to calculate d you will just deduct 15 with 10. So, this will become equal to 5. So, this is how you will get the group index. And this group index is usually is not an input under the classification system, but it is used with the classification of the soil in parent thesis for example, let us say if it is A7. And the group index is let us say 15 or 20 then I will write in bracket 20.

So, this group index is just a number to rate the soil for use in the subgrade as a subgrade material, whereas, in the AASHTO classification system the general categories ranges from A1 to A7 with 12 more subgroups, which is shown in this particular table, which you see here.

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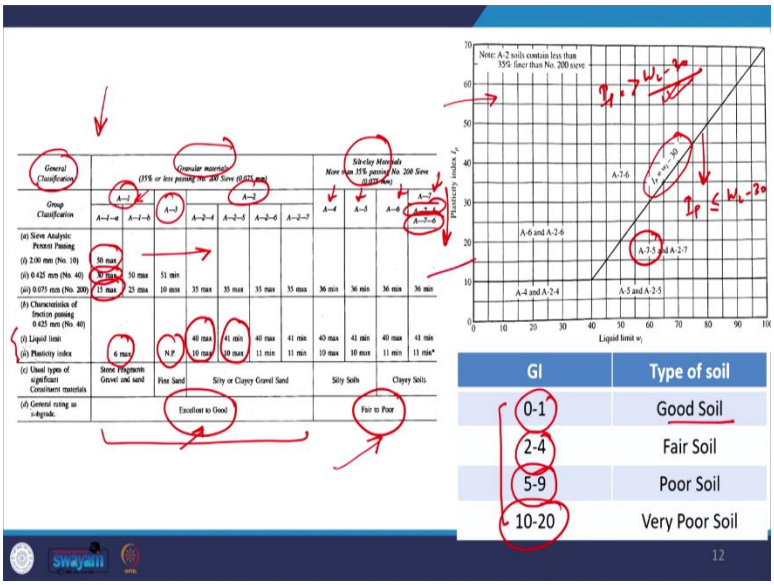


So, you can see here we can spend some time looking at the table. So, you see what is the general classification here? That if the percentage of material passing 75 micron sieve so, you take the soil pass it through 75 microns if the percentage of material passing 75 micron sieve is less than 35 percent then you call that soil as granular material. And if it is more than 35 percent then it will fall under the category of silt or clay. So, that is the first step and then depending on that, which means if it is less than 35 percent it will be either A1 type, A2 type or A3 type.

If it is more than 35 percent it will be either A4, A5, A6 or A7. Now, coming to the subgroup again we have to perform additional test. So, if let us say it is in the category of A1 then what are the requirements? The requirement is that percent passing 2 mm is limited to 50 percent maximum, percentage passing 425 micron is limited to 30 percent maximum, percentage passing 75 micron sieve is limited to 15 percent maximum and so, on you can see all the other values here.

Then, we have criteria related to the consistency limits also. So, the material passing 425 micron will be tested for liquid limit and plastic limit and plasticity index will be calculated and depending on the plasticity index ranges you can classify that particular soil in that particular subgroup. And then as I said that group index is used just as an indicator whether the soil can be used in the subgrade material or not.

So, you can see that if the soil is either A1, A2 or A3 it is in excellent to good condition which means this can be adopted in the well adopted in the for the construction of subgrade. Whereas, we have soil fear to poo r which are not generally recommended to be used as a sub grade material. So, based on group index, this is an approximate further classification that if the group index value is somewhere between 0 to 1 it is good soil.

So, this will tell me that from A1, A2 and A3 for A1, A2 and A3 the group index value will be somewhere between 0 to 1. Fear soil are those whose value ranges from 2 to 4 the group index value 5 to 9 in poor and 10 to 20 in very poor soil. So, this will fall under this category which will contain silt, clay or a mixture of these materials.

And then you can further see the difference of the subgroups. For example, if I want to compare A 7 5 and A 7 6, then I can use this plasticity chart here. And this is the equation which is used to differentiate between those subgroups. For example, if you see A 7 5 will have the value of Ip less than on the lower part of this. So, Ip here will be in this part Ip will basically be less than $W_L$ minus 30. And in this part the value of Ip will be greater than $W_L$ minus 30.

So, this is how I can differentiate, or I can see the difference between those subgroups which falls under the same category that is A 7 5 and A 7 6 for example. So, the plasticity chart and this table in conjunction can be used to classify the soil as per AASHTO classification system and in addition to that group index value can be used to see whether that soil is good to be used as a subgrade material.

Now, let us go to the next classification system which is the unified classification system and a very similar classification system we use in India also to classify the soil.

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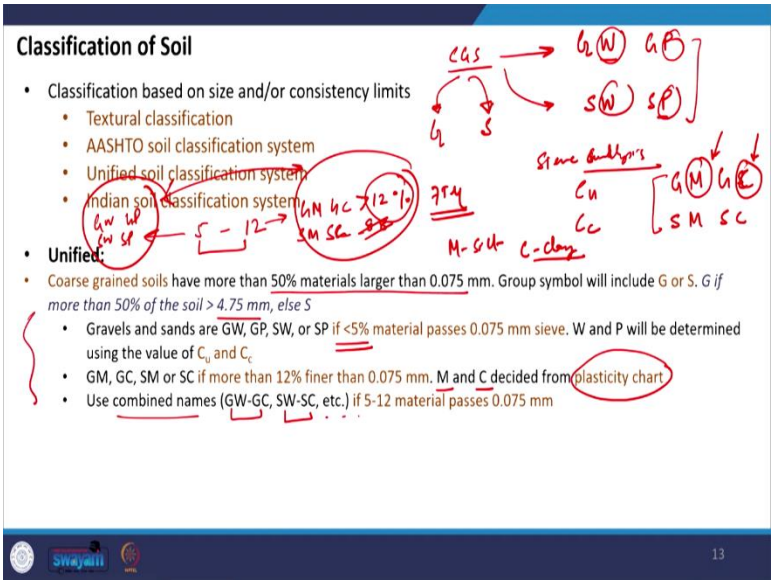


Let us try to understand step by step that how the unified soil classification system works. In this first you have to categorize the soil as either coarse grained soil, as fine grained soil, which means if I have a soil

mass the first thing which I will identify that should I call this soil as a coarse grained soil or as a fine grained soil. So, this is a first decision which has to be made and for that what I will do I will just do the sieve analysis, after doing the sieve analysis, if I find that more than 50 percent of materials are larger or gets retained in the 75 micron sieve I will call those material or that particular soil as coarse grained soil.

Now, once I identify that this particular soil is a coarse grained soil, then under the coarse grained soil, I want to know whether these are gravels or whether it is sand. So, these are the 2 subcategories under the core coarse grained soil and how will I know that I will know that depending on the proportion of the coarse grain material, which means the materials which are retained on 75 micron sieve corresponding to 4.75 mm sieve.

So, the coarse grain material which I have I will further see through the sieve analysis data that what is the percentage that is retained on 4.75 mm sieve and what is the percentage that passes 4.75 mm sieve. If in the course grain soil more than 50 percent of materials are larger than 4.75 mm then that particular course grain soil will be called as gravel. And if it is less than I mean less than 50 percent material retains which means more than 50 percent material passes 4.75 mm sieve, then I will call it material as sand, but this does not end the classification completely then what we will see.

So, this is the first letter which I decide for this particular soil category and then we have to do the sub classification. So, then we will see that what is the actual percentage passing 75 micron if the actual percentage of material of that soil which passes 75 micron is less than 5 percent, then I will call these soils as either GW or GP if it is a gravel or SW or SP if it is a sand and what is this W and P here, W indicates well graded soil, P indicates poorly graded soil.

And how do I again identify whether it is a well graded soil or poor graded soil through the sieve analysis and we have learned while discussing about sieve analysis that we have parameters like Cu and Cc looking at the range of which I will know whether this material falls under the well graded category or poorly graded category. So, then what is the next step or next classification system?

Let us say when I did the sieve analysis I found that more than 12 percent material is passing 75 micron sieve. You see still if 12 percent material passes 75 micron sieve which means almost 88 percent material is retained on 75 micron sieve. So, it is still a coarse grained soil. But now, I am looking at the percentage that passes 75 micron. So, if it is less than 5 percent these will be the respective classifications. If it is more than 12 percent then I will not classify them as GW, GP, SW or SP then what symbols or alphabets I will use, I will use M and C as the second letter to identify the soil which means it can be for example, I know that it is either G or S.

And then I will have other letters that is either it can be GM or GC or it can be SM or SC. Now, the question is what is M and C? M and C corresponds to the consistency limit of the soil. So, M indicates silt and C indicates clay and then again how do I know whether it is a silt or clay? I will do the consistency limits test I will find out the liquid limit in plastic limit and then I will use the plasticity chart to see based on the liquid limit and plastics limit the fine particles are clay or are they silt and then I will decide what is the respective classification?

Now, under the same category the third question is what if the percentage of material passing 75 micron is between 5 to 12. So, less than 5 I already know the categories are GW, GP, SW or SP, if more than 12 percent I know it is GM, GC, SM or SC, but what if it is somewhere in between, then what we do we use combined names to classify the soil which means that I will have to do the grain size analysis also I will have to calculate this value of Cu and Cc also and also I will have to test the material passing 425 micron sieve and I need to get the consistency limits and I will have to use the plasticity chart.

So, the soil can either be GW, GC, SW, SC and so on. So, I will use both this classification system and I will just combine them. So, I will use dual names to categorize or to classify the soil. So, I hope you understand that how coarse grain materials are classified.

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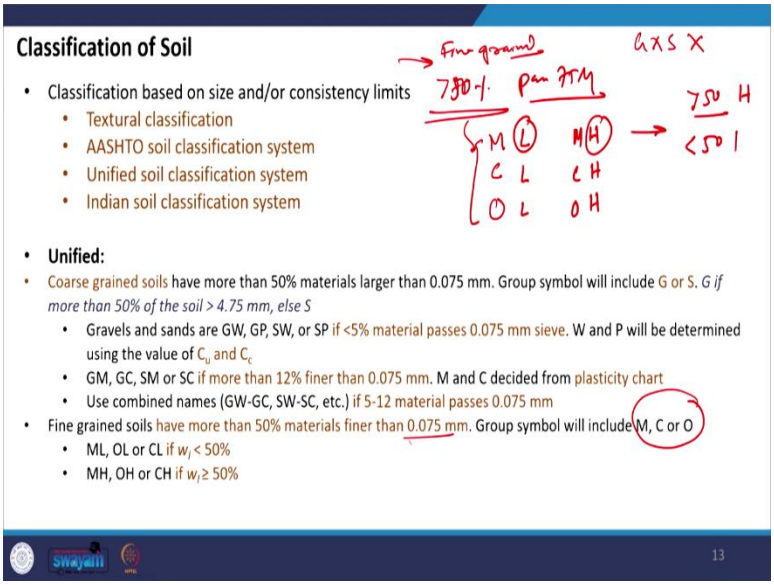


Now, let us go to the next step or the next domain that let us say that I took the soil I saved it through 75 micron and I found that more than 50 percent passes 75 micron which means that this soil now does not fall under the category of coarse grained soil that is gravel or sand no which means that this soil will now be classified using the primary classification will be either as silt or as clay or as organic silt or clay.

So, this will be the primary alphabet that we will be using to classify that soil and this soil we will call as fine grained soil. So, fine grained soils have more than 50 percent material passing 75 microns sieve groups symbol will include M, C or O. Now, coming to the sub classification, then fine grain soil can be further classified as soil having low plasticity or low compressibility or a soil having higher plasticity or higher compressibility.

So, how do we decide whether it will be L or it will be H, this again depends on the liquid limit and plasticity index. And depending on whether the liquid limit is more than 50 or the liquid limit is less than 50 it will be categorized as low plasticity or high plasticity if the liquid limit is more than 50 percent then that will fall under the high plasticity category if the liquid limit is less than 50, it will fall under the low plasticity category.

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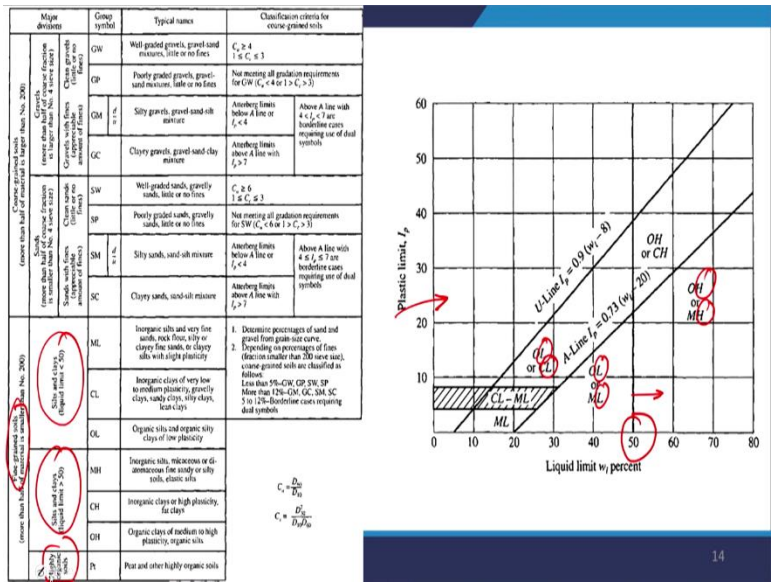


Now, I will just try to explain whatever we have discussed you see this particular chart you do not have to get worried if you see so, many things written on the chart, it is very easy to follow because we have already completed the discussion. So, as I said first step is sieve the material to 75 micron corresponding to 75 microns if let us say more than 50 percent materials get retained on 75 microns which means the classification system will be under the coarse grained soil category.

Then the next step is you have the coarse grained soil which is retained on 75 micron sieve. Now, you will see what proportion of coarse grained soil passes 4.75 mm sieve or gets retained on 4.75 mm sieve, if more than 50 percent gets retained or 4.75 mm sieve it is a gravel, if it passes 4.75 mm sieve it will be a sand. So, this is the first alphabet which you will get under the corresponding category of the soil then, we will see what is the percentage material passing 75 micron the actual value if the actual value is less than 5 percent then the soil will be categorized using the value of Cu and Cc.

So, it will be either GW or GP or it can be SW or SP depending on the value of Cu and Cc here. If the percentage passing 75 micron sieve is more than 12 percent then it will be either GM GC or it will be SM SC or we will have to refer the plasticity chart here. To see whether it is a silt or a clay depending on the liquid limit and plasticity index, and if the value is in between 5 to 12 then we will use dual classification process, which means, we will combine the first 2 methods.

Say, the soil which was first initially sieved through 75 micron sieve 50 percent of the material passes 75 micron, which means this soil is a fine grained soil under the fine grained soil you have to decide whether the fine grained soil is a silt is a clay or is it organic material, then again you have to see the corresponding plasticity chart depending on the value of liquid limit and plastic limit, you can determine the type of soil and further you have to see that within that category, whether the soil falls under the low compressibility or low plasticity category or high plasticity category that will be decided based on the liquid limit of 50.

So, on the right side of the chart, you will get the value or corresponding to high plasticity on the left side of the chart you will get value corresponding to the low plasticity.

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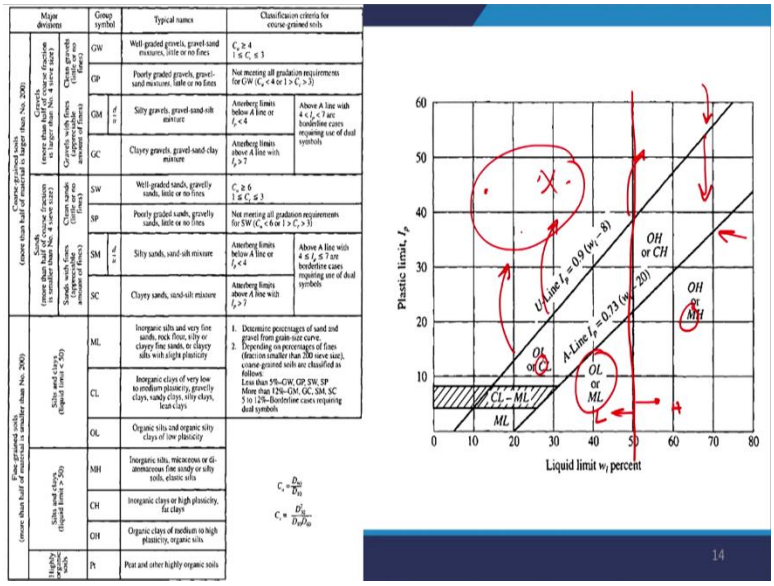


And I have already explained about this this A line. This was developed by testing various types of soil by Casagrande there is also a an equation for the upper limit of this plasticity chart which means soils are not found to lie somewhere here the values are does not like every all the values will be below this and this is the standard a line based on which soil can be identified at different location and we have this line here which distribute the soil as high or low plasticity and then we have other locations and which tells us whether it is a clay or a silt or what type of material it is.

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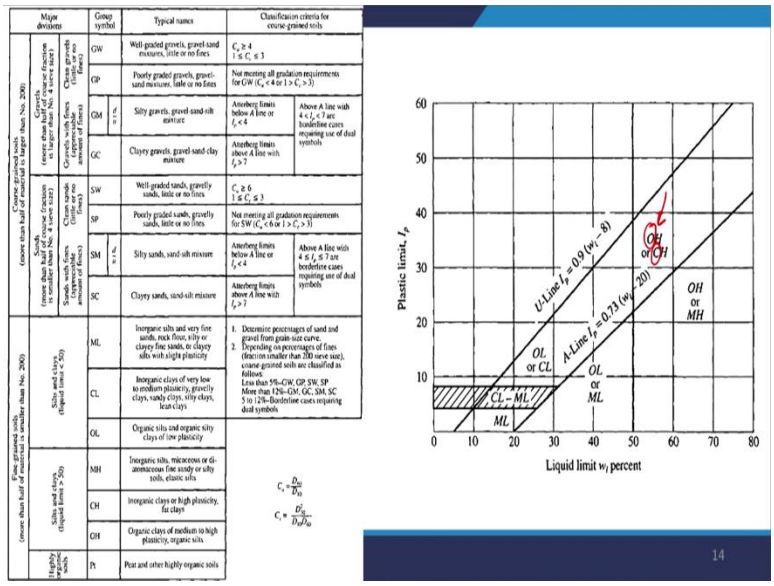


Now, in this plasticity chart one additional point which you have to know is that you see here you have OH or CH which means though the soil is more of clay nature, but you do not know whether it is an organic type of fine grained soil or inorganic type of. So, usually the organic type of fine grained soil as I mentioned previously are identified based on appearance, based on the smell of that particular soil. So, that is again one of the ways of identifying the type of soil I mean differentiating between inorganic and organic soil.

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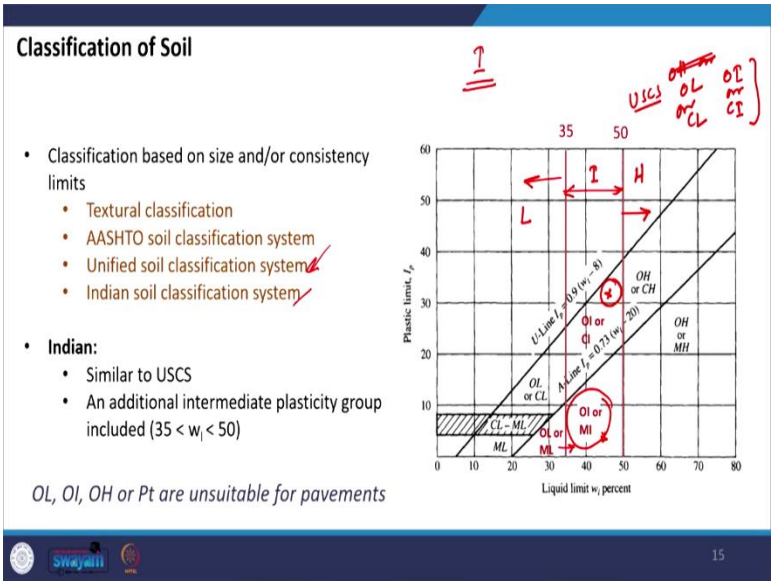


Now, let us talk about the last classification system that is the Indian soil classification system, we use the same method we use the same definition to define the materials just like the unified soil classification system just one additional category here and that to for fine grained soil is that we have the category called as intermediate plasticity or compressibility also. So, there are 3 sections rather than 2 in this if the liquid limit is less than 35 percent the material classified as low compressibility if it is in between 35 to 50, it is

of intermediate compressibility or intermediate plasticity and if it is beyond 50 it corresponds to high plasticity.

For example, in the unified soil classification system, if your soil falls here then you will say that that type of soil is either OH or it is either OL or CL in the unified soil classification system, but in the Indian soil classification system you will call this OI or CI. Similarly, you see here that if your soil falls here, this will be OI or MI instead of OL or ML in case of unified soil classification system.

So, there are 3 divisions to differentiate between the type of soil or fine grain soil and then you have to decide whether that type of soil can be used for construction or not for example, as per Indian specification given by Ministry of road transport and highways, the soil that falls under the category of OL, OI, OH or Pt, they are usually not suitable for pavements, not even to be used in embankment and subgrade. So, it depends on the type of specification which type of soil are permissible.

Further if the soil is very weak in nature, before construction, it might be recommended that you have to stabilize the soil, you have to modify the properties of the soil so that the minimum desired properties can be achieved before you can do the construction. So, we stop here today, and we have completed our discussion on classification of soil.

In the next class we will start talking about the compaction characteristics of the soil. And we will also discuss about various strength properties of the soil that we need to understand and that we need to evaluate specifically when we talk about construction of pavements. Thank you.