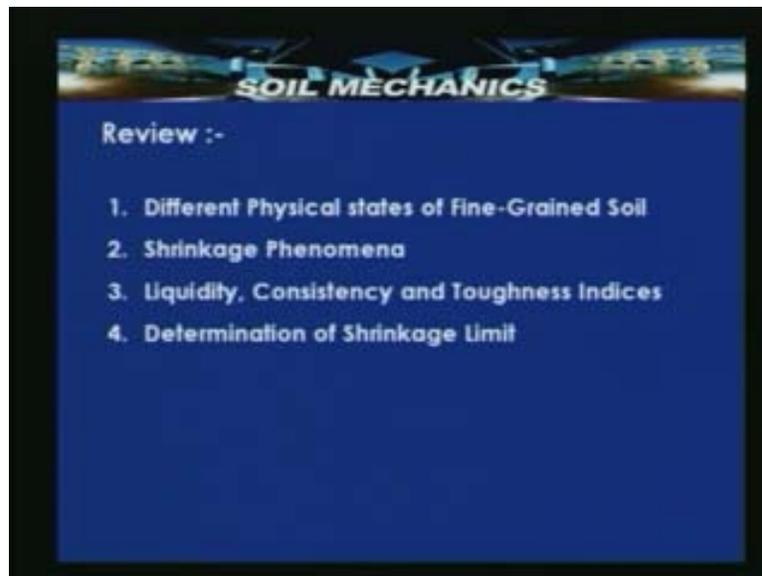


**Soil Mechanics**  
**Prof. B.V.S. Viswanadham**  
**Department of Civil Engineering**  
**Indian Institute of Technology, Bombay**  
**Lecture - 9**

Welcome to index properties and soil classification systems - IV. In the previous lecture, we have covered different physical states of fine-grained soil, we have introduced Atterberg limits, the mechanism behind shrinkage behaviour of the soils and we also defined number of indices like liquidity index, consistency index and toughness index, basically to understand the consistency of a soil. We also discussed about the laboratory procedures for determining liquid limit, plastic limit and shrinkage limit.

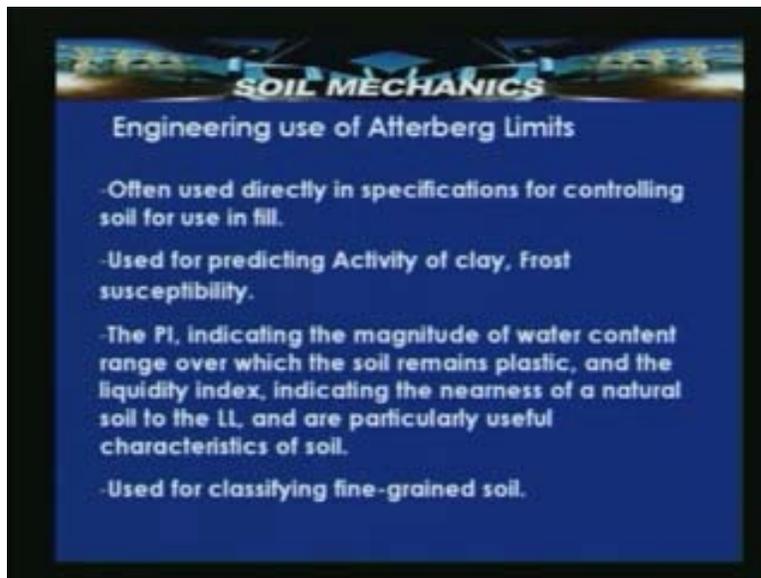
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In this lecture, we will understand the engineering uses of Atterberg limits. How this Atterberg limits are useful in classifying the soil and also putting the soil in a correct group that is basically done by soil classification systems. We will introduce the soil classification systems basically to group the soils which are exhibiting similar features in reference to exhibiting the similar properties.

Engineering use of Atterberg limits, are primary soil properties or index properties that are required to be determined and often used directly in specifications for controlling soil for use in the fill and used for predicting the activity of clay or frost susceptibility. This Atterberg limits will be useful for predicting activity of clay and will be defining this activity of the clay in the due course of this lecture.

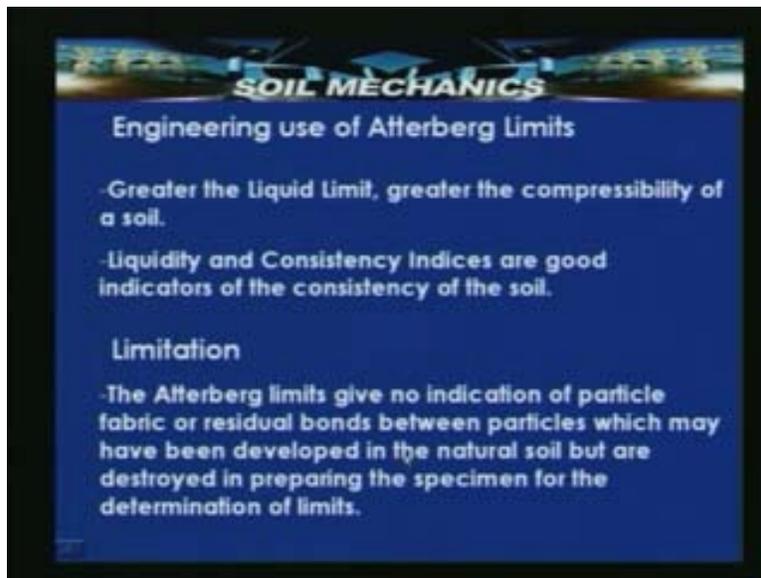
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The Plasticity index indicating the magnitude of water content range over which the soil remains plastic and the liquidity index, indicating the nearness of a natural soil to the liquid limit and are particularly useful characteristics of soil. Ultimately these Atterberg limits are useful for classifying basically fine-grained soils. Fine-grained soils in the sense soils which are finer than silt size particles. So greater the liquid limit we will understand that greater is the compressibility of the soil. In the due course of the lectures we will understand the meaning of the compressibility of the soil and so on.

Liquidity and consistency indices are the good indicators of the consistency soil. If you want to understand about whether the soil is soft or stiff or medium stiff or very stiff or hard, you are required to know the liquidity and consistency indices of the soil, as they are the good indicators of consistency of the soil. The one limitation which comes across with the Atterberg limits is that it will give no indication of particle fabric or residual bonds between particles which may have been developed in the natural soil but are destroyed in preparing the specimen for the determination of limits.

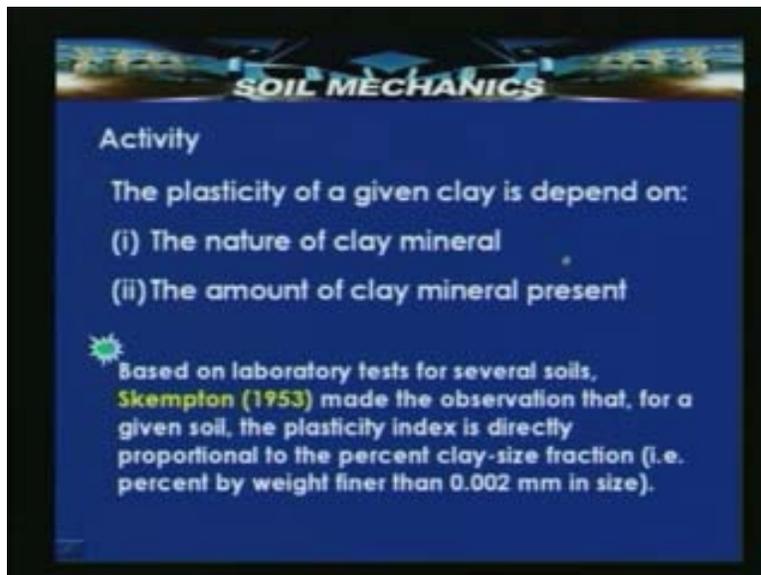
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One of the serious limitations is that the particle fabric that is the soil fabric which was in the original state may not be represented in the test which is being carried out in the laboratory by using the remolded samples. The Atterberg limit suffers from a serious limitation that is they will not give any indication about the particle fabric or natural residual bonds between particles which may have been developed in the natural soil but are destroyed in preparing the specimen for the determination of liquid limits or plastic limits and other limits. Here what we do is that, once we take the sample from the natural state when we do or remold a sample, it loses its natural residual bonds and the natural particle fabric. These are not represented in the tests which are used for determining these Atterberg limits.

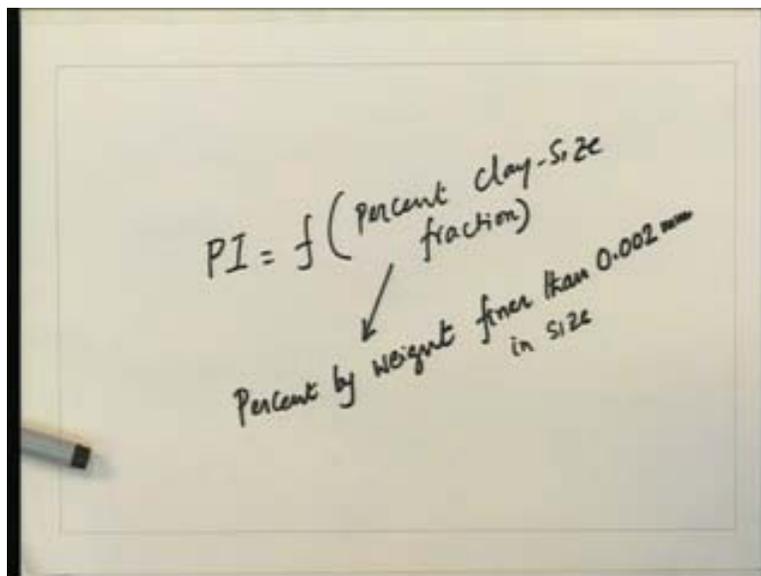
Having seen engineering use of Atterberg limits, let us define another important parameter activity or activity number. The plasticity of a given soil as we know depends upon the nature of the clay mineral that is the type of the clay mineral whether it is a Kaolinite or Montmorillonite or Illite or the amount of clay mineral present.

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Based on the laboratory test for several soils, Skempton (1953) made the observation that for a given soil, the plasticity index is directly proportional to percent clay-size fraction. So it has been found out that the plasticity index (PI) is a function of percent clay-size fraction. This means percent by weight finer than 0.002 mm that is 2 micron in size.

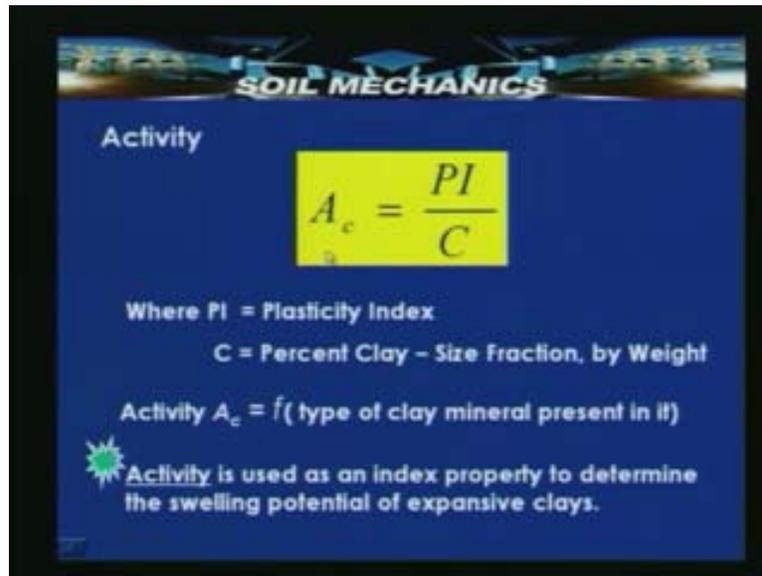
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Based on this, Skempton defined the activity value or activity number which is notated as  $A_c$ , as  $PI$  by  $C$ , where  $PI$  is the plasticity index of the given soil which is nothing but (liquid limit minus plastic limit) and  $C$  is the percent clay size fraction by weight. Activity  $A_c$  which is found to be a function of the type of the clay mineral present in it. Activity is a parameter which is widely used as index property to determine the swelling

potential of the given soil. Activity is an important index property which is being used for determining the swelling potential of a given soil that is whether the soil has got the swell susceptibility or not. Without understanding or without testing for minerals but by looking at these values alone, one can get an idea about the swell susceptibility of the soil that is swelling potential of a given soil.

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Activity

$$A_c = \frac{PI}{C}$$

Where PI = Plasticity Index  
C = Percent Clay - Size Fraction, by Weight

Activity  $A_c = f(\text{type of clay mineral present in it})$

Activity is used as an index property to determine the swelling potential of expansive clays.

Let us look into some activity values of clay minerals. For example in this table form which is shown here Mineral and Activity value, Sodium Montmorillonite got an activity value 4 to 7, Calcium Montmorillonite has got 1 to 1.5. The distinct difference between Sodium Montmorillonite and Calcium Montmorillonite can be seen, Calcium Montmorillonite exhibits very low activity value and Sodium Montmorillonite exhibits a value in between 4 to 7. Illite in the range of 0.5 to 1.3, Kaolinite is 0.3 to 0.5, Halloysite which is hydrated is around 0.1, The Quartz which is primarily sand-grained mineral exhibits activity value equal to 0. This table is after Skempton (1953) the Sodium Montmorillonite which exhibits around 4 to 7, Calcium Montmorillonite around 1.5, Illite 0.5 to 1.3, Kaolinite 0.3 to 0.5, Halloysite hydrated exhibit a low value of 0.1 and Quartz which is a predominant mineral of sand exhibits 0 value.

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Activity Values of Minerals

Mineral	Activity Value
Na - Montmorillonite	4 - 7
Ca - Montmorillonite	1.5
Illite	0.5 - 1.3
Kaolinite	0.3 - 0.5
Halloysite (hydrated)	0.1
Quartz	0

After Skempton (1953)

Based on this, one can understand that how the type of the mineral plays a role in the activity value. As we know, the black cotton soils which are predominantly having Montmorillonite mineral exhibit very high activity value. For example, Bentonite has got an activity value of around 7.2 that indicates the swelling potential of particular clay under consideration. Kaolinite exhibits here 0.3 to 0.5 that tells us about the particular soil, whether the soil is assertable to swelling or not.

If you look into this slide, activity minerals that is activity value or activity which we are discussing now, clay minerals with Kaolinite, a stable clay mineral, which we have discussed earlier about the structure of the Kaolinite mineral, will have low activity whereas those soils with Montmorillonite known to be a type subject to large volume changes depending on available water, will have high activity value. This is the same phenomena which we have discussed earlier with black cotton soils. Based on this, soil classification can be carried out by using the activity value. This table shows soil classification based on activity values where activity value and classification is given here. If the activity value is said to be less than 0.75 then the particular clay is said to be Inactive and if it is in between 0.75 to 1.25 then we say that they are Normal clays and greater than 1.25 is called Active clays. For those clays containing Montmorillonite or predominantly say Bentonite soil can exhibit activity value as high as 7.2.

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**SOIL MECHANICS**

**Activity**

> Clay minerals with kaolinite, a stable clay mineral, will have low activity, whereas those soils with montmorillonite, known to be a type subject to large volume changes depending on available water, will have a high activity value.

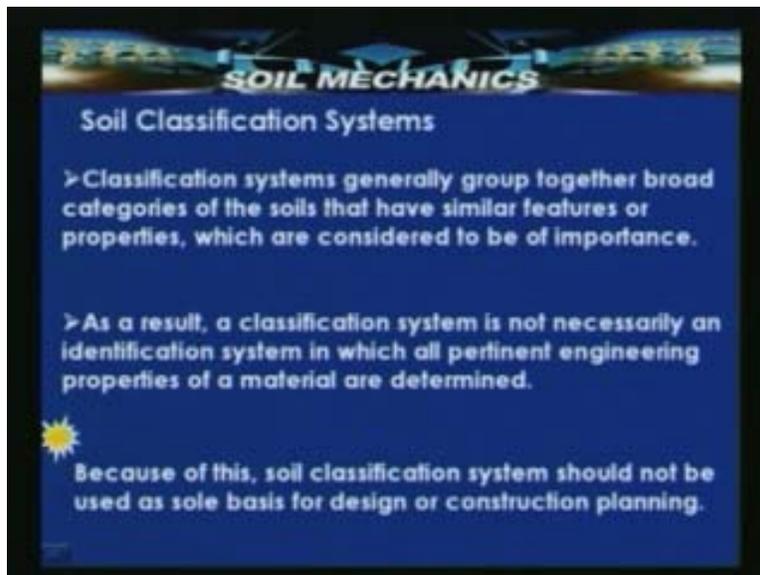
Soil classification based on activity value:

Activity	Classification
< 0.75	Inactive Clays
0.75 - 1.25	Normal Clays
> 1.25	Active Clays

We have discussed that activity value which is nothing but the ratio of plasticity index to the percentage clay fraction. With this we will be able to access the swelling potential of a given soil. We have seen the activity value, to determine the grain size distribution of a given soil and plasticity characteristics particularly Atterberg limits of fine-grained soils. With all these things now it should be possible for us to group the soils that we will be introducing in the form of soil classification systems. Classification systems generally group together broad categories of soils that have similar features or properties, which are considered to be of importance.

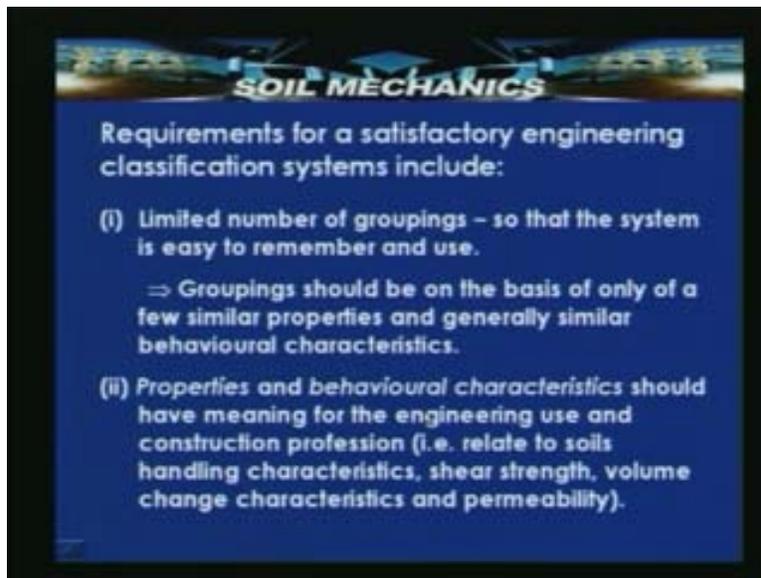
As a result, a classification system is not necessarily an identification system in which all pertinent engineering properties of a material are determined. Because of this, soil classification system should not be used as a sole basis for the design or construction planning. This should be an initial stage where we know to select the soil for a particular site and can be used as a guiding system or guide lines for selecting a certain soil for certain application.

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What are the requirements of a satisfactory engineering classification system? Let us look into this, with lists like this. We knew that there are wide varieties of soils, if you look into it, the system should be having a limited number of groupings so that it is easy to remember and use this particular soil classification system. Grouping should be on the basis of only of a few similar properties and generally similar behavioral characteristics. Properties and behavioral characteristics should have meaning for the engineering use and construction profession. That is to relate to the soils handling characteristics, shear strength, volume change characteristics and permeability. So properties and behavioral characteristics should have relevance to the site and particularly in reference to soil handling characteristics, compressibility, shear strength, volume change characteristics and permeability etc.

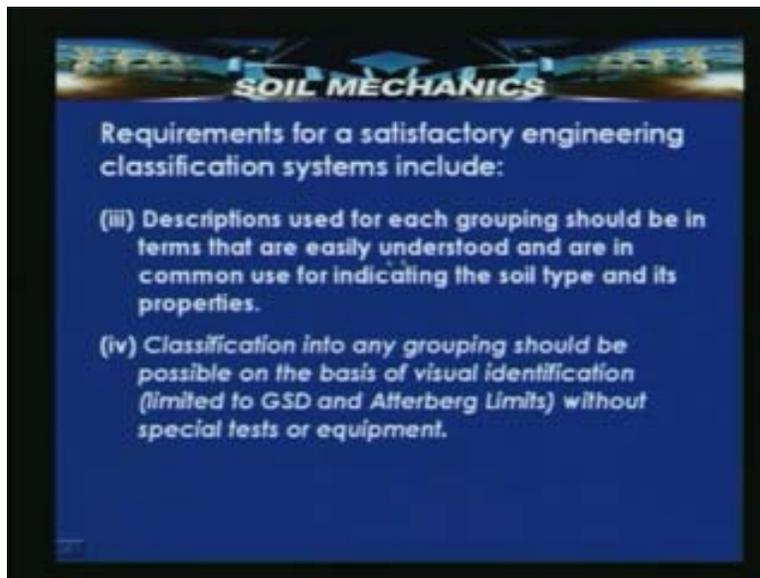
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We have seen two requirements, one is that there should be limited groupings and the other one is that properties and behavioral characteristics should have meaning for the engineering use and construction profession. The third one is descriptions used for each grouping should be in terms that are easily understood and are in common use for indicating the soil type and properties. That means that the descriptions for example, if there is a sand then it should be indicate as S and if the sand is well graded then it should be indicated with W.

By looking at the group itself you should be able to understand the basic constituents of the soil and as well as its nature, whether it is well graded or poorly graded or whether it has got a silt or a clay fraction unit. Once the soil has been selected based on this criteria then the advanced test can be determined like properties of comparison, characteristics or shear strength characteristics etc. The fourth requirement what we have seen is that classification into any grouping should be possible on the basis of visual identification, basically limited to grain size distribution and Atterberg limits without any special tests or equipments.

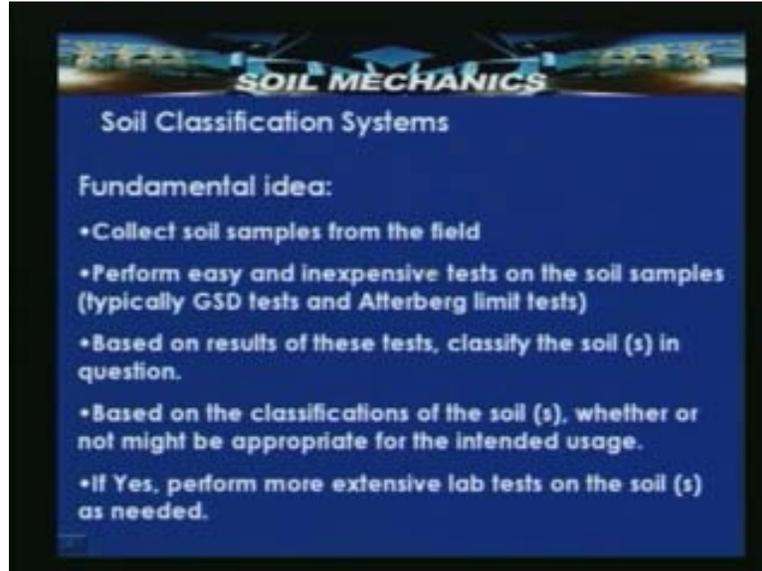
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The fundamental idea behind soil classification system is that collect the soil sample from the field. That means, it can be from the borrow area or it can be from the area from which the soil is being procured and used in the particular construction site. Perform easy and inexpensive tests on the soil samples, typically grain size distribution curve and sieve analysis like coarse sieve analysis and fine sieve analysis or if there is a predominant clay fraction then hydrometer analysis are done.

After getting the grain size distribution curve, one can grade the soil. Atterberg limit test and the fine fraction passing 425 micron sieve. One can carry out Atterberg limits to understand liquid limits, plastic limits and other shrinkage limits etc. Based on the results of this test classify the soils in question. Basically liquid limit, plastic limit and plasticity index are used for classifying the soils. Based on the results of this test, classify the soils in question. Based on the classification of the soils, whether or not might be appropriate for the intended usage. If yes, perform more extensive lab tests on the soils as needed.

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Historically if we look into it, most widely used methods of classifying the soils has been through the visual identification. In the sense whether it is sand or whether it is clay or whether it is silt is identified through some visual identification. We can identify size of the grains up to 75 micron size that is the size of the grain up to the silt size. Visual identification or size of the soil grain and plasticity of the soil can be used for the classifying the soil. Sometime most of the classification systems have been evolved by keeping the grain size distribution of the soil or plasticity characteristics of the soil. Both grain size distribution and plasticity characteristics of the soil will cover both coarse grained and fine grained soils. These are basically used as a basis for indicating the soil type. Visual identification, size of the soil grains and plasticity of the soil are used as a basis for indicating the soil type.

For example, if you look, how to distinguish between silt and clay? Both are fine grained. Because of the smooth texture some times silt soils are confused with clay size particle. Basically silt size particles which are having sizes greater than 2 microns and less than 75 microns that is less than 0.075 mm and clay which is the colloidal fraction is sometimes less than 2 micrometers.

In that case, how to distinguish between these two typical soils?

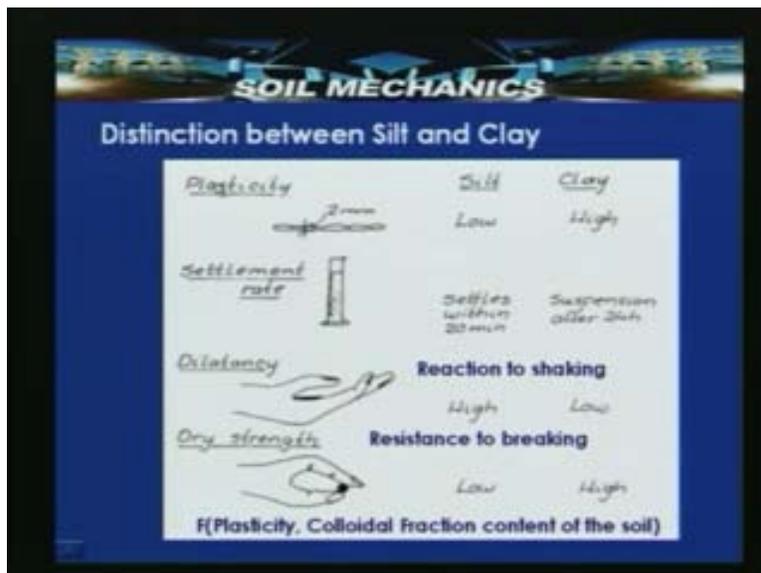
Let us look into some typical identification methods which are used. If you see, the methods which are used for distinguishing silt and clay are as follows particularly plasticity characteristics. If you look into this, the silty soils are mostly non-plastic soils. So they exhibit low plasticity. Clayey soils which are plastic in nature exhibit very high plasticity; the results have been discussed earlier. So plasticity is one indicator where we will be able to distinguish between silt and clay. The other one is that settlement rate. For example, if you take a jar of water and if you disperse silty soil and clayey soil, the silt settles within 20 minutes whereas clay suspension may even take sometimes more than 24 hours. The dispersion rate or a settlement rate is very high for silt size particles

because the particles are heavier in size. They settle within 20 minutes whereas the clay in the liquid is still appears to be in muddy size because of the constant bombardment of particles. They remain in suspension for a long time, even after 24 hours. So the settlement rate is one indicator to distinguish between silt and clay. The other one is Dilatancy that is the reaction to shaking.

Suppose, if you take a soil in your palm with two different soils, one is silt type soil and another one is clay type soil. Once you subject the silt type soil to shake with the little amount of water, that is if you mix water to the silt soil and allow it to shake, the surface becomes shiny and very quick reaction will be observed for clay type particles but very slow reactions is observed for silt size particle. So the reaction for shaking is high for silt size particle and low for clay size particle.

The other property which is an indicator to distinguish between the silt and clay is the dry strength, which is nothing but the resistance to breaking. If you take a block of soil which is containing silt and clay, the silt exhibits very low resistance to breaking in contrast to this the clay size soil exhibits very high resistance to breaking. This dry strength is the function of plasticity and colloidal fraction content of the soil. So, higher the colloidal fraction content of the soil and higher the plasticity is higher the resistance. These four typical tests are used for distinguishing between the silt and clay. The plasticity is low for silt size soils and high for clay size soils. Dilatancy that is the reaction to shaking is very high for silt soils and low for clay soils. Dry strength which is the resistance to breaking is low for silt soils and high for clay size soils.

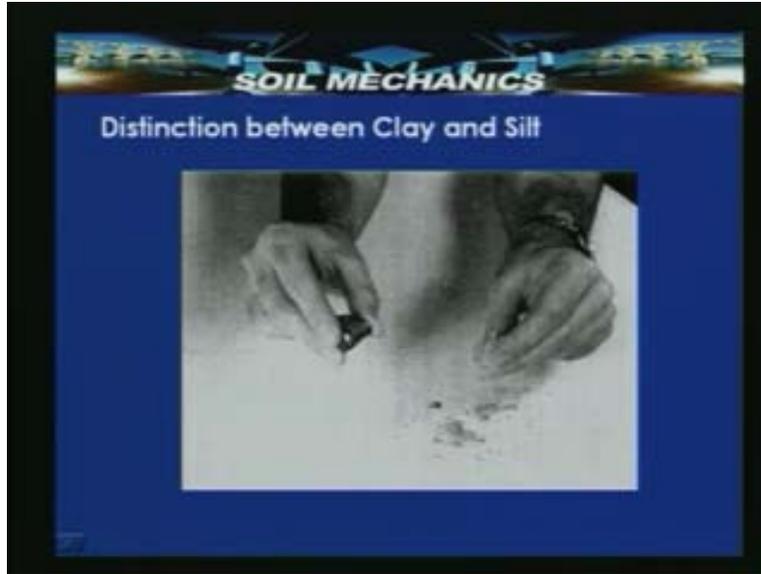
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Here in this slide, typically a clay size block or soil lump and silt size lump is shown. We have discussed that if the colloidal fraction content and the plasticity is more then the resistance to breaking is also more. One can experience difficult to break the block by applying energy to thumbs or within the fingers. So it is very difficult to break the clay

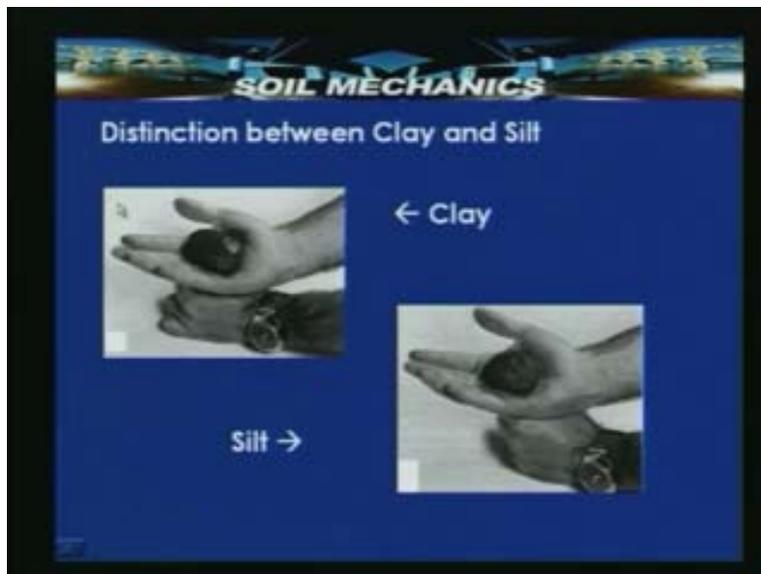
size particle whereas silt type soil is easy to crush into pieces. This is called Preliminary crushing strength test, which is used immediately to identify clay and silt type soils.

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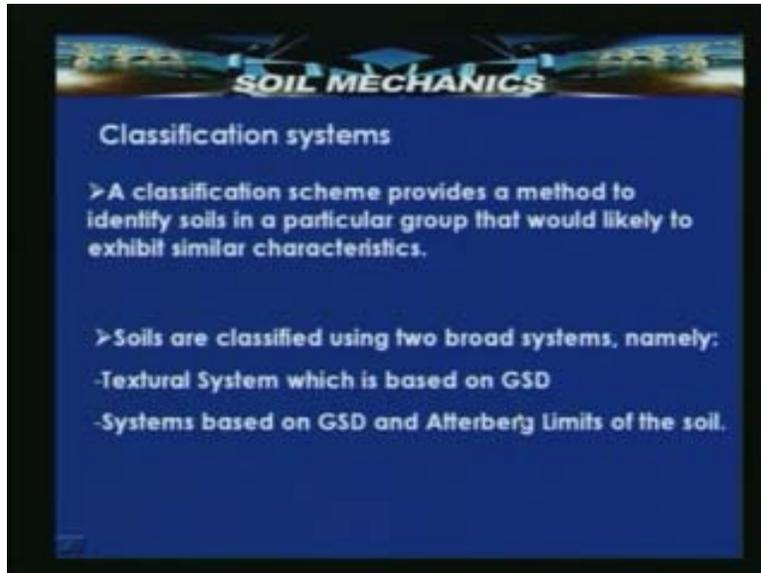
Similarly, here the distinction between clay and silt is shown. The clay exhibits very shiny appearance and even sticky in nature which sticks to the hands and so on. That is actually a mere indicator of clay and silt exhibits dull appearance. That is actually an indication of silt size soils.

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Having seen about the visual identification test or test for distinguishing silt and clay. Let us look into classification system. A classification scheme provides a method to identify soils in a particular group that would likely to exhibit similar characteristics. Soils are classified using two broad systems, namely: Textural system which is primarily based on the grain size distribution curve and systems based on grain size distribution and Atterberg limits. There are two broad methods to classify soils either by using textural system or by using textural system as well as Atterberg limits of a given soil.

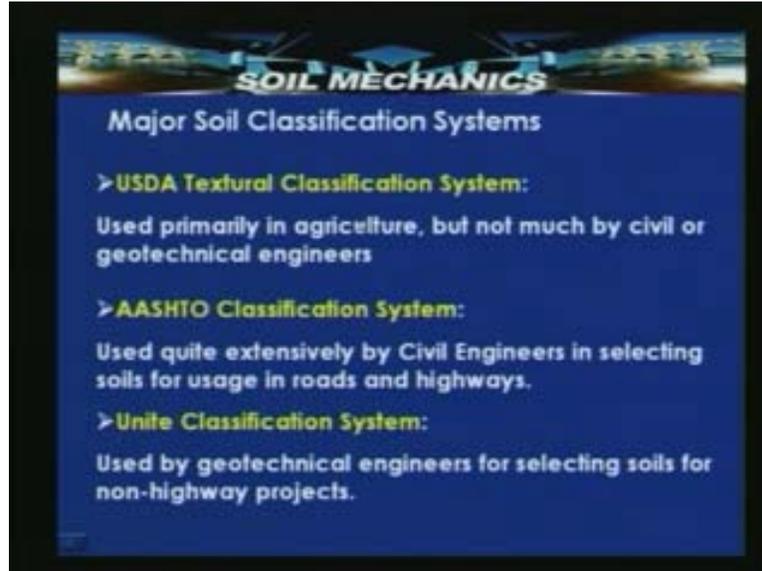
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In the second case, it covers both coarse grained and fine grained soil whereas in the earlier one, it covers only coarse grained soils. That is the main intension that we have discussed. The major soil classification systems have been developed by keeping the view of the textural system as well as textural system and Atterberg limits or plasticity characteristics of a fine grained soil.

USDA textural classification system is primarily used in agriculture but not much by civil or geotechnical engineers The second one is AASHTO classification system used quite extensively by civil engineers in selecting soils for usage in roads and highways. This system is the old system where it has been developed by civil engineers in selecting soils for usage in roads and highways. Unified classification system or Unite classification system is used by geotechnical engineers for selecting soils for non-highway projects.

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Let us discuss different classification systems and then will try to classify the soils by considering the properties. Let us look into the different classification systems, which are existing for classifying the soil on the basis of its grain size. According to IS (Indian standard code) 1498, the classification is worked out as follows: here in the top most is the broad groups are clay, silt, sand, gravel and cobble. Sand is further divided into F indicates fine, M indicates medium and C indicates coarse. Gravel is divided into two sub-groups namely fine and coarse. Here on this axis the particle size is indicated in millimeter. Anything which is greater than 80 mm is said as cobble. Anything which is greater than 4.5 and less than 80 mm is treated as gravel. 4.75 to 20 mm grain size is indicated as fine gravel and 20 mm to 80 mm is indicated as coarse gravel. Sand which is ranging from 0.075 to 4.75 mm, indicated with different sub-grading like fine, medium and coarse.

For example, fine sand is ranging from 0.075 to 0.425 mm, medium sand is 0.425 to 2 mm and coarse sand is 2 to 4.75 mm. If anything is greater than 0.002 mm and less than 0.075 mm is treated as silt and anything which is less than 0.002 mm is treated as clay. According to Unified soil classification system (which is almost highest classification system), except typical sizes like 0.074 mm or 0.42 mm. Similar groups have been made like clay, silt, sand, gravel and cobble. According to unified classification system, 4.76 mm to 76 mm is gravel and sand is 0.074 to 4.76 mm. So there are similarities between Unified soil classification systems and IS classification system which is based on the grain size.

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The image shows a slide titled "SOIL MECHANICS" with the subtitle "Classification of soil on the basis of grain size". It contains two tables. The first table is "According to IS: 1498" and the second is "According to Unified Soil-Classification System". Both tables show soil classifications based on grain size ranges in millimeters.

According to IS: 1498							
Clay	Silt	Sand			Gravel		Cobble
		F	M	C	F	C	
0.002	0.075	0.425	2	4.75	20	80	

According to Unified Soil-Classification System							
Clay	Silt	Sand			Gravel		Cobble
		F	M	C	F	C	
0.002	0.074	0.420	2	4.76	19	76	

Now let us look into other classifications like ASTM classification and British Standard classification system. According to American Society of Testing and Materials, that is ASTM soil classification system, is slightly different where the grain size is indicated in mm from here onwards and from here onwards it is indicated in micrometers. It is subdivided into colloids which are finer than 1 micron, clay is ranging between 1 micron to 5 micron, silt is ranging from 5 micro meters to 75 microns that is 5 microns to 0.075 mm and sand is from 0.075 to 4.75 mm, here there is no difference. Gravel in which cobbles have been removed and anything greater than 4.75 mm is treated as gravel in case of ASTM classification system.

British soil classification system is slightly different where the groups are clay, silt, sand, gravel and cobble. Silt is further divided into fine, medium and coarse silt. Sand is further divided into fine, medium and coarse sand. Gravel has got three sub-groups fine, medium and coarse. Anything which is greater than 60 mm is treated as cobble. Here if we look into this, the silt size particles are ranging from 2 micron to 60 micrometers. Sand is ranging from 0.06 mm to 2 mm. Anything greater than 2 mm and less than 6 mm is treated as fine gravel. The gravel which has got sub-group namely medium size gravel is 6 to 20 mm and coarse gravel is 20 to 60 mm.

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**SOIL MECHANICS**

**Classification of soil on the basis of grain size**  
According to **American Society for Testing and Materials**

Particle Size	Clay	Silt	Sand			Gravel
			F	M	C	
	1 $\mu$	5 $\mu$	0.075	0.425	2	4.75

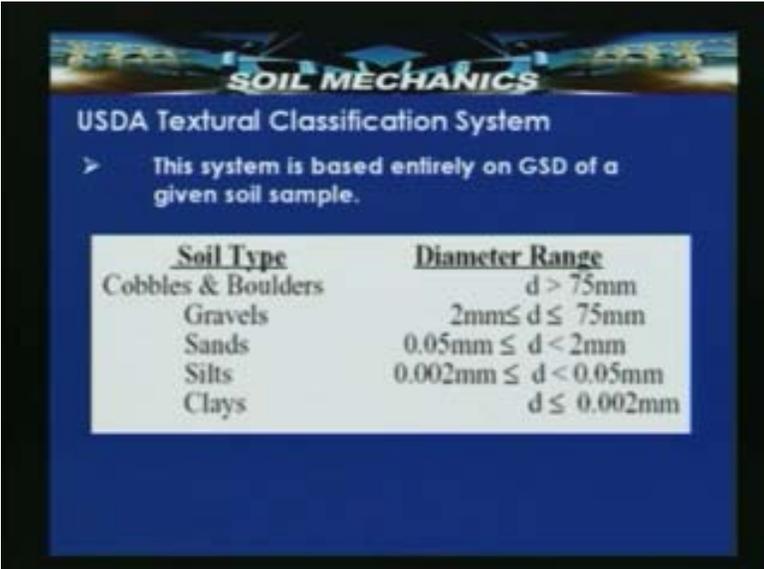
**According to British Soil Classification System**

Clay	Silt			Sand			Gravel			Cobbles
	F	M	C	F	M	C	F	M	C	
	2 $\mu$	6 $\mu$	20 $\mu$	60 $\mu$	0.2	0.6	2	6	20	60 200

We have seen the classification of soil on the basis of grain size by using four different methods that is according to Indian standard code, second one is unified classification system, third one is according to ASTM soil classification system and the fourth one is British soil classification system. If once the grain size distribution of the given soil is available then based on this it is easy to segregate the soil and categorize, whether the clay content, percentage clay and percentage sand, and with the typical sizes we can even subdivide soil into groups like fine gravel, coarse gravel or fine sand, coarse sand or medium coarse sand. We can group the soil with the help of its particle size or grain size.

The next classification system, we have introduced is the USDA textural classification system. We have discussed that this system has got much application in agriculture but very little application for civil engineers or geotechnical engineers. This system is based entirely on grain size distribution of a given soil sample. Here in this table, soil type and diameter range is shown. Cobbles and Boulders is taken as greater than 75 mm in this system. Gravels range from 2 to 75mm. Sands ranging from 0.05 m- m to 2 mm. Silts ranging from 0.002 mm to 0.05 mm. Clays are anything less than 0.002 mm. This USDA textural classification system is based entirely on GSD of a given soil sample. They have got further sub-divided into groups like cobbles and boulders, gravels, sands, silts and clays. Diameter ranges are given here, where d greater than 75 mm indicates the cobbles and boulders, Sands ranging from 0.05 mm to 2 mm.

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**SOIL MECHANICS**

**USDA Textural Classification System**

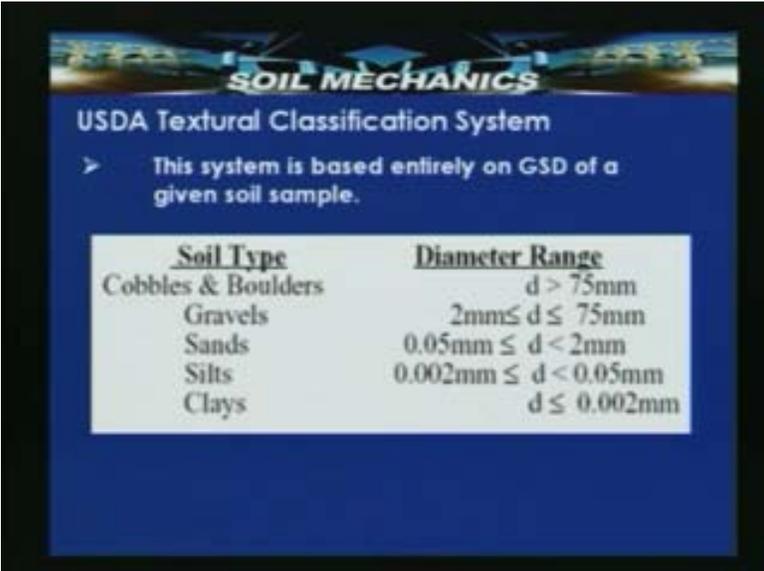
> This system is based entirely on GSD of a given soil sample.

<u>Soil Type</u>	<u>Diameter Range</u>
Cobbles & Boulders	$d > 75\text{mm}$
Gravels	$2\text{mm} \leq d \leq 75\text{mm}$
Sands	$0.05\text{mm} \leq d < 2\text{mm}$
Silts	$0.002\text{mm} \leq d < 0.05\text{mm}$
Clays	$d \leq 0.002\text{mm}$

There is a relative grading is done to classify and use for the USDA textural classification chart. The chart is not shown here but the primary features are discussed here based on the relative percentage sand, percentage silt and percentage clay. Let us look into how to determine this relative percentage of sand? For example, if you have got percentage of particles greater than 2 mm that indicates that the gravels fall in the range of 2 mm to 75 mm. Then relative percentage of sand is determined like (percentage with 0.05 mm to 2 mm size) by (100 minus percentage with particles greater than 2 mm).

Similarly, relative percentage of silt in a given soil is determined like (percentage with particles ranging from 0.002 mm to 0.05 mm size) by (100 minus percentage with particles greater than or equal to 2 mm). Similarly relative percentage of clay is determined as (percentage with  $d$  less than or equal to 0.002 mm) by (100 minus percentage  $d$  greater than equal to 2 mm). Like this if you are able to estimate relative percentage silt, relative percentage of sand and relative percentage of clay then by using the USDA textural classification system, we can classify the soil.

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**SOIL MECHANICS**

**USDA Textural Classification System**

> This system is based entirely on GSD of a given soil sample.

<u>Soil Type</u>	<u>Diameter Range</u>
Cobbles & Boulders	$d > 75\text{mm}$
Gravels	$2\text{mm} \leq d \leq 75\text{mm}$
Sands	$0.05\text{mm} \leq d < 2\text{mm}$
Silts	$0.002\text{mm} \leq d < 0.05\text{mm}$
Clays	$d \leq 0.002\text{mm}$

Having seeing this let us look a typical example to classify the soil by using USDA textural classification system. Let us consider for a given soil the percentage gravel is 18 percent, percentage sand is 51, percentage silt is 22 and percentage clay is 9. This has been obtained from the grain size distribution analysis. The solution is that we have to determine as discussed earlier. Relative percentage sand which is nothing but percentage sand that is particles in the sand ranges from 0.05 to 2 mm that is 51 by (100 minus percentage gravel).

Percentage gravel means particle greater than 2 mm. Here gravel is 18 percent. So 100 minus 18 that is 82. Then percentage sand is (51 by 82) into 100 is equal to 62 percent. Similarly percentage silt is (22 by 82) into 100 is equal to 27 percent. Relative percentage of clay is (9 by 82) into 100 is equal to 11 percent. According to USDA textural classification system, due to the presence of the 18 percent gravel in the soil, it is called as gravelly sandy silt.

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**SOIL MECHANICS**

**USDA Textural Classification System**

Example 1:  
Classify the soil by USDA Textural Classification System

Given:  
% Gravel = 18; % Sand = 51; % Silt = 22; % Clay = 9.

Solution:

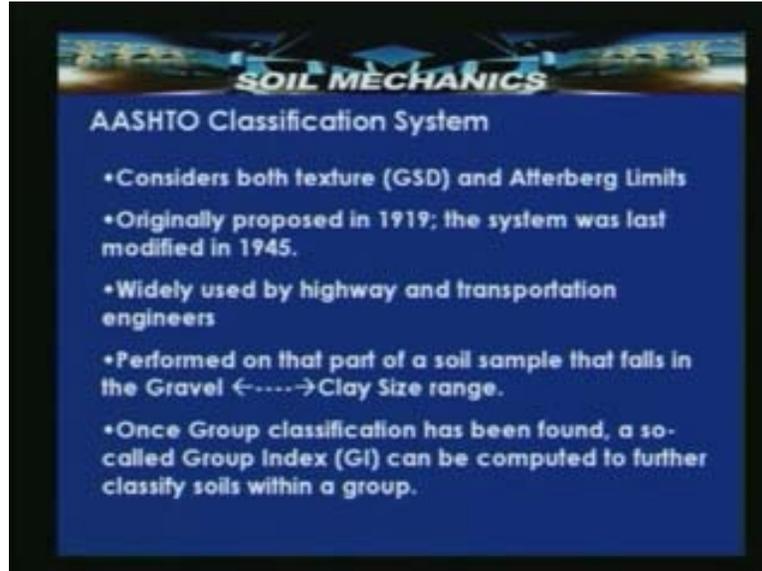
rel. % sand = $51/82 = 62\%$	$\rightarrow$ %Sand /
rel. % silt = $22/82 = 27\%$	(100-% Gravel)
rel. % clay = $9/82 = 11\%$	

Due to presence of 18 % Gravel in soil, it is called as "Gravelly Sandy Silt"

Gravelly sandy silt is the deduced classification for this type of the soil. In this example what we have done is that based on the results obtained from the grain size distribution curve, we have graded the percentage gravel, percentage sand, percentage silt and percentage clay. Based on that result we have computed relative percentage of silt, relative percentage of sand and relative percentage of clay. Once after getting that, by considering the presence of the gravel, we deduced a classification by using USDA classification system. It is gravelly, sandy and silts.

The next classification system as we discussed the AASHTO classification system considers both texture that is grain size distribution and Atterberg limits. AASHTO classification system originally proposed in 1919 and the system was last modified in 1945. It is widely used as highway and transportation by engineers. Very wide range it covers that performed on that part of a soil sample that falls in the gravel and percentage clay size range. Once the group classification has been found, group index can be computed to classify the soils further within a group. In AASHTO classification system, the soils have been ranging from percentage gravel to percentage clay have been covered.

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Let us look into what is group index in AASHTO classification system? Here different groups have been termed like A-1 which has got two sub-groups like A-1-a, A-1-b, Then A-2 has got, A-2-4, A-2-5, A-2-6, A-2-7 and A-3, A-4, A-5, A-6, A-7-5, A-7-6 and A-8.

In the chart which is given, when you go from the left to right, the suitability of the soil for a particular application like a sub-grade keeps on decreasing. For the soils in the AASHTO group A-3 or lower: the group index is given by the expression,  $GI = (F - 35) / (0.2 + 0.005(LL - 40)) + 0.01(F - 15) / (PI - 10)$ . For soils in A-1 or A-2: Group Index is equal to  $0.01(F - 15) / (PI - 10)$ .

In both the formulas, F is the percent of the soil sample passing the ASTM number 200 sieve that is 75 micron size. Group Index which is basically in the AASHTO classification system is a function of grain size distribution, shape and surface area of a given soil particle. The chart is not shown here, but has got primarily different AASHTO groups. For this the requirement is that we should have the grain size distribution of a given soil like percentage clay, percentage silt and percentage sand.

Based on the Atterberg limits and grain distribution curve and also by using eliminating process, we keep on working by using the chart from left to right hand side and arrive at a certain group. Based on these properties, properties in the sense grain size distribution, liquid limit and plastic limit arrive at the group index. Once this group index is known for example, if A-7-6 is the group and the group index value is 40. The classification work load is to be A-7-6 (40). That is the classification of the given soil and is used for classifying the soil based on AASHTO soil classification system. Group Index is the means of rating the values of the soil as a sub-grade material within its own group.

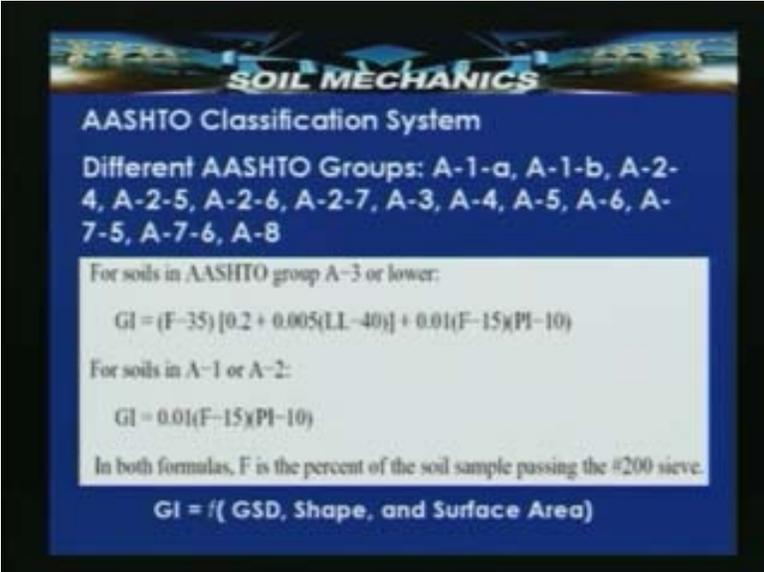
Group Index is also a mean of rating the value of the soil as a sub-grade material within its own group. Higher the value of the group index the poorer the quality of the material.

For example, the group which is A-7-5 and A-7-6 indicates the clay sub-grades and A-8 is the peat sub-grade in the group. If you are indicating a particular group classification with higher GI value that is group index value that indicates poorer is the quality of the sub-grade.

Useful hints for using the AASHTO classification to classify the soil: always begin on the left hand side with A-1-a group and check each of the criteria. You have got all the grain size distribution of the soil in your hand and also Atterberg limits of the given soil. By using these two results and also the elimination process, always begin on the left hand side of the chart with A-1-a group and check each of the criteria.

If a particular criteria is not eliminated then next criteria is to be taken and repeat the process. If any criterion is not meet then step to the right and repeat the process, that's what it has been discussed. Do not begin at the middle of the chart. One feature is that you should not begin at the middle of the chart to classify the soil by AASHTO classification system. So always begin on the left hand side with A-1-a group and check each of the criteria.

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A slide titled "SOIL MECHANICS" with a blue background. The main heading is "AASHTO Classification System". Below it, it lists "Different AASHTO Groups: A-1-a, A-1-b, A-2-4, A-2-5, A-2-6, A-2-7, A-3, A-4, A-5, A-6, A-7-5, A-7-6, A-8". There are two formula boxes: one for soils in AASHTO group A-3 or lower, and one for soils in A-1 or A-2. A note states "In both formulas, F is the percent of the soil sample passing the #200 sieve." At the bottom, it says "GI = f( GSD, Shape, and Surface Area)".

**SOIL MECHANICS**

**AASHTO Classification System**

Different AASHTO Groups: A-1-a, A-1-b, A-2-4, A-2-5, A-2-6, A-2-7, A-3, A-4, A-5, A-6, A-7-5, A-7-6, A-8

For soils in AASHTO group A-3 or lower:

$$GI = (F-35) [0.2 + 0.005(LL-40)] + 0.01(F-15)(PI-10)$$

For soils in A-1 or A-2:

$$GI = 0.01(F-15)(PI-10)$$

In both formulas, F is the percent of the soil sample passing the #200 sieve.

**GI = f( GSD, Shape, and Surface Area)**

Let us look at the soil classification system based on the AASHTO classification system. Let us assume that the given soil has got percentage passing number 10 sieve is equal to 100 percent; percentage passing number 40 sieve is equal to 80 percent; ASTM number 10 sieve; ASTM number 40 sieve; percentage passing 200 that is 75 micron sieve is 58; liquid limit is 30 and plasticity index is 10. Group classification can be obtained from the chart. So you can obtain this classification by using the chart as say A-4. From the given data F is equal to 58 that is percentage passing 200 sieve is 58. This gives the Group Index is equal to 3.45 which is used as a round figure of whole number 3. Hence the group classification A-4 is obtained from the chart and 3 is the GI value. If this group is

there, it is called fair to poor sub-grade rating. Group classification A-4 is obtained by using all these features and from the given data. So the group classification is A-4 (3).

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**SOIL MECHANICS**

**AASHTO Classification System**

**Example 2:**

Given: % passing No. 10 = 100; % passing No. 40 = 80;  
% passing No. 200 = 58; LL = 30; PI = 10.

Group classification is A-4 and  
from the given data  $F = 58 \Rightarrow GI = 3.45 \rightarrow (3)$ .  
Hence Group classification is: A-4 (3)  
[Fair to poor Subgrade rating]

Let us look into other example that is example 3, where the given percentage of the passing number 200 sieve is 95 percent (mostly fine-grained soil); Liquid Limit is equal to 60 and Plasticity Index is equal to 40. The group classification using the chart which is not shown here, the classification is A-7-6. This is actually obtained by using the elimination process from the left hand side to right hand side and also by fulfilling all this criteria. From the given data, percentage passing 200 sieve is 95 which gives the Group Index value is equal to 42 (very high value). This predominantly a fine-grained soil, we can see here percentage passing number 200 sieve is 95 percent. Hence the group classification works out to be A-7-5 (42). This indicates a poor sub-grade rating.

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**SOIL MECHANICS**

AASHTO Classification System

Example 3:

Given: % passing No. 200 = 95; LL = 60; PI = 40.

Group classification is A-7-6 and  
from the given data  $F = 95 \Rightarrow GI = 42$

Hence Group classification is: A-7-5 (42)  
[Poor Subgrade rating]

One of the AASHTO limitation, we have seen that the groups are like A-1-a, A-2, A-3, A-7-5, A-7-8 and A-8, which are slightly deviating from the criteria like easy to remember and by seeing the group we are not able to identify the particular type of the soil. This is one criterion. The criteria for the groupings are logical, but shortcomings include requirement for laboratory testing that is of course it is required and in order to determine the classification and the difficulty in using the code designation, remembering the requirement for each of the designations. That is one of the limitation of the AASHTO classification systems.

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**SOIL MECHANICS**

AASHTO Classification System

Limitation:

- > The criteria for the groupings are logical, but shortcomings include requirement for laboratory testing, in order to determine a classification, and the difficulty in using code designation and remembering the requirement for each of the designations.

In this class, what we tried to understand is that we tried to understand the engineering use of Atterberg limits and also defined the activity value. We also said that the active value is the important parameter to indicate the swelling potential of the clays. Then we introduced these soil classification systems and different soil classification systems which are based on texture as well as Atterberg limits. We tried to introduce and discussed about AASHTO classification system.

In the next class, we will be seeing in detail about the unified classification system.