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ADVANCED GEOTECHNICAL
ENGINEERING

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Lecture No. 07

Module – 1
Soil Classification

Welcome to lecture number seven of module 1. In the previous lecture we have introduced ourselves to how to determine different types of alter berg limits having determined alter berg limits and also understood about arriving at the grain distribution. With the help of this data it is possible to classify the soil. So in this lecture we will try to see the soil classification systems which are widely used and then we discuss about some salient aspects with reference to the limitations of alter berg limits and all so this lecture seven is about the soil classification.

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Engineering use of Atterberg Limits

- Often used directly in specifications for controlling soil for use in fill.
- Used for predicting Activity of clay, Frost susceptibility.
- The PI, 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 LL, and are particularly useful characteristics of soil.

Used for classifying fine-grained soil.

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So if you look into the alter berg limits we have liquid limit, plastic limit and shrink case limit, if you try to see the engineering use of liquid limits they are often use directly in specifications for controlling soil for use in fill materials or any other application. Used for predicating also activity of the clay the activity of the clay is defined as plasticity index over is a ratio of plasticity index or percentage clay passing to micron.

So this alter berg limits are used for predicting activity of the clay or frost susceptibility also, the plasticity index indicating the magnitude of water content range or which the soil domains plastic and the liquidity index indicating the nearness of a nature soil to the liquid domain, if the liquid index is close to the liquid limit that means that it is almost you know in a fluid state and are particularly useful for characteristics of the soil.

So these are used for classifying fine grain soils alter berg limits are very much useful for classifying fine grain soils.

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Engineering use of Atterberg Limits

- Greater the Liquid Limit, greater the compressibility of a soil.
- Liquidity and Consistency Indices are good indicators of the consistency of the soil.

Limitation

- The Atterberg limits 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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Further greater the liquid , the greater to the compressibility of the soil some soils exhibit very high liquid limits for example detonate has got very high liquid limit and greater the liquid limit greater the compressibility. Liquidity and the consistency in disease or good indicators of the consistency of the soil, so if you have a soil which is actually having a low consistency index that means that if you have a consistency index of 0.4 that indicates a soft state of the soil

So the limitations as far as the alter berg limits are concerned the alter berg limits give no indication of the particle fabric or residual bonds between the particles which may have been developed in the natural soil but are destroyed in preparing the specimen for the determination of limits. As you all know we do the liquid limit test on a remodeled sample which actually passing say 0.4 to 5mm sieve or 425 micron.

The alter berg limits give no indication of the particle fabric or residual bonds between particles which may have been developed the natural soil, so the bonds which are actually existing in the natural soil may and might not or being represented in the you know liquid limit test but are destroyed in preparing the specimen for the determination of limits this is one of the you know limitations of you know alter berg limit or you can say that the limitations in determining liquid limit test.

And we also discussed in that with the help of alter berg limits we can estimate or say excess the activity of the soil. So the plasticity of given clay depend up on the nature of the clay mineral.

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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.

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So the type of the clay mineral the amount of the clay mineral present. Based on the laboratory in model test laboratory test for several soil Kempton 1953 made the observation that for a given A_c activity = plasticity index over percent clay fraction where PI = plasticity index and the C is the percentage clay size fraction by weight. So activity A_c is a function of type of clay mineral present in the soil. So activity as used as the index property to determine the swelling potential of an expansive soil. So if you know the activity it is possible to you know to assess the swelling capability or expansion of a given soil.

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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)

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So in this table different activity values of minerals are given, the sodium based montmorillonite can have activity values in the range of 4 to 7. Calcium montmorillonite can have activity values up to 1.55. Illite as 0.5 to 1.3 kaolinite will have low value 0.3 to 0.5, Hallo site hydrated can have 0.1 and quartz activity value is 0.

So the activity value of Has and for example which is predominately having quartz can be 0 so activity value of the minerals like sodium montmorillonite is very high and when it comes to Illite it is 0.5 to 1.3 and then Kaolinite 0.3 to 0.5.

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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.

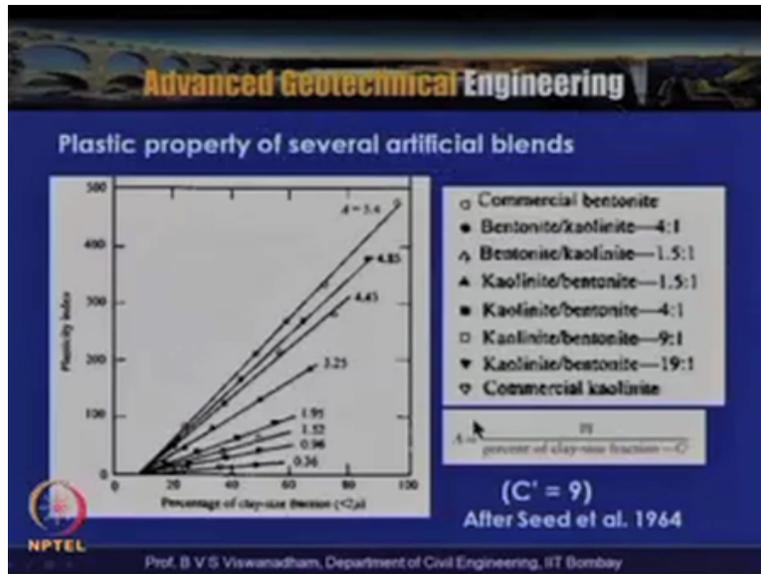
Soil classification based on activity value:

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

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The clay minerals with kaolinite a stable clay mineral will have low activity that is what we have discussed in the previous slide where as those soils with montmorillonite know to be subject to large volume changes depending on the availability of water will have high activity values. so the soil classification can also be made based on the ranges of the activity values. When the activity value is < 0.75 this soil is classified as.

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In this slide you know according to seed et al. 1964 they have presented the investigated about the plastic properties of several artificial blends of bentonites, kaolinite and kaolinite, bentonite in different blends and it is presented here with plastic index on the y axis and percentage clay size fraction on the x axis so here activity value as high as 5.4 is reported here so it according to seed et al. 1964 the activity is defined suggested that they have that $PI / \text{percentage clay size fraction} - C'$ where C' which is the correction which is given as suggested as 9.

So with this the you know this the particularly the plastic proprieties of several artificial blends of bentonite, kaolinite yields that the relationship between activity and plasticity index and percentage clay size fraction is modified as $a = \frac{PI}{\text{percentage clay size fraction} - C}$ where $C' = 9$.

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Soil Classification Systems

- Classification systems generally group together broad categories of the 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 sole basis for design or construction planning.

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Now coming to the soil classification systems classification systems generally group together broad categories of the soil that I have similar features or properties which are considered to be of importance. For many projects it is required to identify the soils which are actually having identical properties or board categories of the you know characteristics of board characteristics so as result a classification system is not necessarily an identification system in which all pertinent engineering properties of a material are determined.

But however it can work out as a guide line for you know selecting the material and investigating further by based on the classification which has been made, so because of this the soil classification should not be used as the soul bases for their design or construction planning so classification systems are generally they group together broad categories of the soils that have similar features or properties which are consult to be of importance.

So the soil classification systems should not be used as the soul bases for the design or construction planning the requirements for a satisfactory engineering classification systems include.

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Requirements for a satisfactory engineering classification systems include:

- (i) Limited number of groupings – so that the system is easy to remember and use.
⇒ Groupings should be on the basis of only of a few similar properties and generally similar behavioural characteristics.
- (ii) Properties and behavioural characteristics should have meaning for the engineering use and construction profession (i.e. relate to soils handling characteristics, shear strength, volume change characteristics and permeability).

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Limited number of groupings so it is required so the system is easily to remember and use the symboling as to simple so that the classification the limited number of groupings and then the system is easy to remember and use so grouping should use on the bases of only of a few similar properties and generally similar behavioral characteristics so if the grouping is made the proof should have soils which are actually having similar behavioral characteristics and properties and behavioral characteristics should have meaning for the engineering use and construction profession.

That is relate to soils handling characteristics shear strength volume change characteristics and permeability so the 2 important requirements which we have discussed in the slide one is that limited number of groupings and properties and behavioral characteristics should have meaning for the engineering use and construction profession.

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Requirements for a satisfactory engineering classification systems include:

- (iii) Descriptions used for each grouping should be in terms that are easily understood and are in common use for indicating the soil type and its properties.
- (iv) Classification into any grouping should be possible on the basis of visual identification (limited to GSD and Atterberg Limits) without special tests or equipment.

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Thirdly the descriptions used for each grouping should be in terms that are easily understood and are common use for indicating the soil type and its properties as a 4th point 4th requirement classification into any grouping should be possible on the bases of visual identification limited to grains and distribution and Alter berg limits without special test are equipments so if we have the data of grains and distribution and Alter berg limits so the classification into any group it should be possible on the basis of the simple test that is article sized distribution data and Alter berg limit test.

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Soil Classification Systems

Fundamental idea:

- Collect soil samples from the field
- Perform easy and inexpensive tests on the soil samples (typically GSD tests and Atterberg limit tests)
- Based on results of these tests, classify the soil (s) in question.
- Based on the classifications of the soil (s), whether or not might be appropriate for the intended usage.

If Yes, perform more extensive lab tests on the soil (s) as needed.

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So the fundamental idea of the soil classification system is to collect the soil samples from the field at different depths and locations and perform easy and inexpensive tests on soil samples, typically grain size distribution tests and Atterberg limit tests. Based on the results of these tests, the soils are classified. This means that whatever the soils that are tested, they can be used to help classify the soil in question.

And based on the classifications of the soil, whether they are not appropriate for the intended usage, one can guess. If yes, perform more extensive lab tests on the soils as needed. So if a particular soil is classified into a particular group, it is suited for a particular application. Then perform more extensive lab tests on the soil as needed.

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Soil Classification Systems

➤ Historically, the most widely used method of classifying soils has been through:

- (i) Visual identification
- (ii) Size of soil grains
- (iii) Plasticity of the soil

being used as the basis for indicating the soil type.

For example, how to distinguish between Silt and Clay?

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So historically the most widely used methods of classifying soils has been through visual identification and size of the soil grains so we have different sizes bulk particles bulk size ranging to flaky particles to very plate silt particles so some of the particles cannot be seen but visual identification will allow to some extent then size of this soil grains and plasticity of the soil be used as a basis for indicating the soil type for example if we have silt and clay there is the possibility that you know some times it is required how to distinguish between silt and clay this possible with some identification methods like which is suggested here to distinguish between silt and clay.

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Distinction between Silt and Clay

Property	Silt	Clay
Plasticity	Low	High
Settlement rate	Settles within 20 min	Suspension after 24h
Reaction to shaking	High	Low
Dry strength	Low	High

f (Plasticity, Colloidal fraction content of the soil)

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So if we look into these plasticity the silt will have low plasticity and clay will have high plasticity and if these equal amount of soil which is owned derived and a dried is dispersed in a jar having a water then silt settles the rapidly and the clay remains in suspension even after 24 hours and direct and see that is reaction to shaking is high for silt and low for clay so with this is possible to distinguished between silt and clay and dry strength the soil which is silt soil the resistant to breaking is very low and clay in the dry state some clays were they having high plasticity characteristics they have very high over dried strength.

So the this is the function of plasticity collateral fraction content of the soil that is that which is actually having very fines which are actually more than 2 micron if it is high and so this is this particular distinguish between silt and clay is possible with simple method which are actually suggested one is by plasticity other one is that settlement rate and militancy and dry strength so which is basically a function of plasticity and colloidal fraction of the soil.

So the classification of the soil can also be done by basis of the grain size In the previous lectures we have actually discussed in that soil which is regarded as you know which is less than 4.75, which is actually called as sand, slit and clay.
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Classification of soil on the basis of grain size
According to **BIS: 1498** (particle sizes in mm)

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	

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And the once which are actually greater than 4.75 and less 20mm which is called as gravel and above that is 20 to 80 amount and then more than 80 as cobble so here the classification of soil on the basis of the grain size according to Bureau of Indian standard 1498 is shown here and the particles I just which are actually indicated here they are in millimeters so the clay which is less than two micron that is 0.02mm is regarded.

As the size of the soil particles which are actually less than 0.002mm is regarded as a clay and the size of the soil particles which is less than 0.075 and greater than 2 micron are 0.002mm is regarded as silt and in the sand we have fine sand which is per 0.425 to 0.075 mm medium sand it is 0.425 to 2 and coarse sand as 2 to 4.75.

And then we have gravel and then we have cobble, according to so unified soil classification system which we are actually going to discuss in length so if more or less the division is identical where you have the particles which are actually more than 19mm gravel particles which are actually which are occur in the soil which are more than 19mm they are called as large size particles and this the one the classification which is actually shown here all or a symbols almost equivalent to the BIS 1498.
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**Classification of soil on the basis of grain size
According to American Society for Testing and Materials**

	Clay	Silt	Sand			Gravel
mm			F	M	C	
	1 μ	5 μ	0.075	0.425	2	4.75

According to British Soil Classification System

	Clay			Silt			Sand			Gravel	
		F	M	C	F	M	C	F	M	C	C - b b o o s
	2 μ	6 μ	20 μ	60 μ	0.2	0.6	2	6	20	60	200

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And in this slide the classification of the soil on the basis of the grain size according to ASTM that American Society for Testing and Materials and when they classify anything greater than 4.75 as gravel and between 0.075mm to 4.75mm is classified as sand which is actually simpler to the previous two classification systems of a soil on the basis of the grain size and clay which is actually regarded as 1 micron to 5 micron and slit which is recorded as 5 micron to 0.075 and according to British soil classification system which is actually shown here as gravel which is actually more than 2mm and sand particularly here 60 micron, micron 2 which is actually regarded as a sand and silt and then clay.

So a different classification systems adopted different you know size limits for the soil but the anything, any soil portion or a fraction which is passing 75 micron or 0.075mm is called as percentage points, which is actually having great relevance in influencing in engineering properties of the soil.

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Soil Classification
Soil classification is the arrangement of soils into various groups or subgroups to provide a common language to express briefly the general usage characteristics without detailed descriptions.

Two widely used soil classification systems:

- AASHTO system and
- Unified Soil Classification system

Both systems use simple index properties such as GSD, LL, and PI of the soil.

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So the soil classification methods if you look into it there are two types of methods widely used there are many methods but here in this we are limited to AASHITO classification system and other one is the unified soil classification system. The soil classification is basically the arrangement of the soil into the various groups is some groups to provide a common language to express briefly those general usage characteristics without detailed descriptions.

So by knowing the particular group it is possible to guess how the particular characteristics can be so the soil classification aim basically is to arrive at the arrangement of the soils into various groups or some groups to provide a common language to express or briefly to address the usage of the characteristics usage general usage characteristics without detail descriptions. So by knowing that or seeing that group we will be able to excess the soil whether it is more preamble or whether it is more compressible or has got high compressibility characteristics or has got high plasticity characteristics etc. So the both the systems what we are going to discuss AASHITO system and unified soil classification system they use simple index properties like grain as distribution data and liquid limit and plastic limit properties of the soil.

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AASHTO Classification System

- Considers both texture (GSD) and Atterberg Limits
- Originally proposed in 1919; the system was last modified in 1945.
- Widely used by highway and transportation engineers
- Performed on that part of a soil sample that falls in the Gravel <----> Clay Size range.
- Once Group classification has been found, a so-called Group Index (GI) can be computed to further classify soils within a group.

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Now let us discuss AASHITO classification system and this considers both texture that is GSD classification system and GSD grain size distribution data and Alter berg limits. This originally proposed in 1919 and the system was last modified in 1945. Widely used for highway and transportation engineers. And this is performed on the part of the soil sample that falls in the gravel to clay size range that means that it actually classifies the soils and put the soils in different groups based on in the size just ranging from for the gravel to clay size range.

Once the group classification has been form so here a group classification is arrived based on the properties which are actually used from the grain size distribution data and Alter berg limits data and it is now this reference index which is actually used in this particular classification system is named as group index which is indicated as GI and this is used to computer further classified as soils, so if you have the high value of the group index that in indicates that the soils or particular soil it has inferior characteristics.

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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 **And above**

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

For soils in A-1 or A-2:

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

0.075 mm sieve

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

GI = (GSD, Shape, and Surface Area)

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So in the AASHITO classification system divides the groups into soil into A-1-a, A-1-b, A-2 to A-2-4, A-2-5, A-2-6, A-2-7, A-3, A-4, so A-4, A-5, A-6 A-7-5, A-7-6 and A-8, A-8 is basically so total 8 groups and then there are some sun groups within it, and here A-8 is some for the soils like which are PT or mud in nature or organic soils are put based on the visible identification they are put in the A-8 group. So the group index for the, in the AASHITO classification system for the groups which are actually A-8 and above that means that A-3 to above can be computed by using this particular expression $GI=(F-35) F$ is nothing but the percentage of soil sample passing 0.075mm sieve that is 200mm sieve, $+0.005(LL-40)$ and $+0.01(F-15)(PI-10)$.

So here the plasticity index was used and percentage points were use and so with this the group index parameter can be obtained. The course fraction is nothing but 100-% passing 200 sieve so if percentage is if f_1 is the percentage passing four number same that is 2 mm but retained in 75 microns same that is sand so if f_1 less than $R_{200}/2$ then the course fraction is more gravelly than sand that means that if f_1 is less than R_{200} that is which is nothing but $100-f_{200}$ which is actually given above And if f_1 is less than $R_{200} y2$ then the course fraction is more gravelly than sand and if f_1 is greater than $R_{200}/2$ then the course fraction is more sand than gravel.

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Unified Soil Classification System

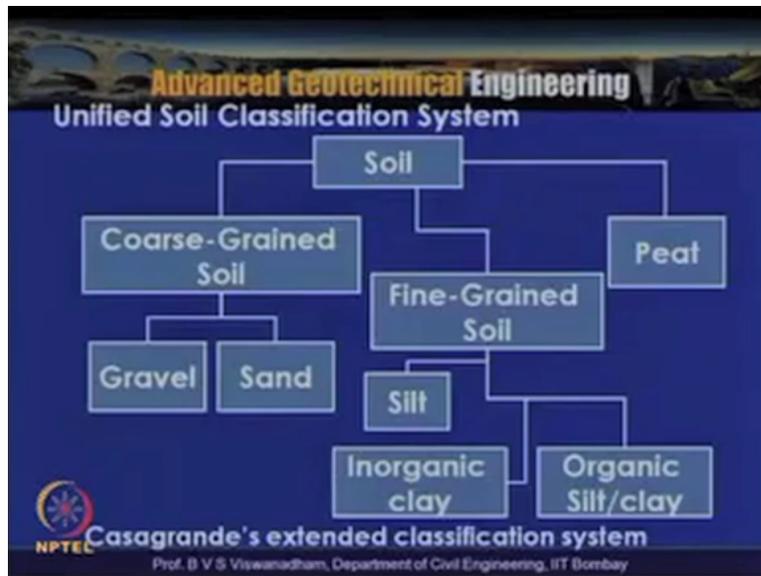
- Originally proposed by A. Casagrande in 1942
- Revised by the Corps. of Engineers and US Bureau of Reclamation in 1952.
- Widely used by various organizations, geotechnical engineers in private consulting business, and building codes.

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The step 3 is nothing but that is actually addressed by using Casagrande transit chart and that helps us to you know classify the soil based on the so this unifies soil classification system is original proposed by A.Casagrande in 1942 and revised by the Corps of Engineers and US bureau of Reclamation in 1952 and recently in 1991 widely used in the various organizations geotechnical engineers in private consulting business and building codes.

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So the unified soil classification system divides and subdivides the soil into the following heads. One is that soil is basically divided into three prominent types: one is coarse-grained soil, another is fine-grained soil, and the third is peaty types of soil which are actually organic soils having peat or muck nature. So they are actually divided into subdivided categories: coarse-grained and fine-grained soils.

And coarse-grained soils are prominently gravel and sand, and fine-grained soils are silt, inorganic clay, organic silts, and clays. So we have fine-grained soils which are prominently divided into silt, inorganic clay, and organic silt and clay. It is also known as Casagrande's extended classification system.

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Unified Soil Classification System

➤ **Two major divisions:**

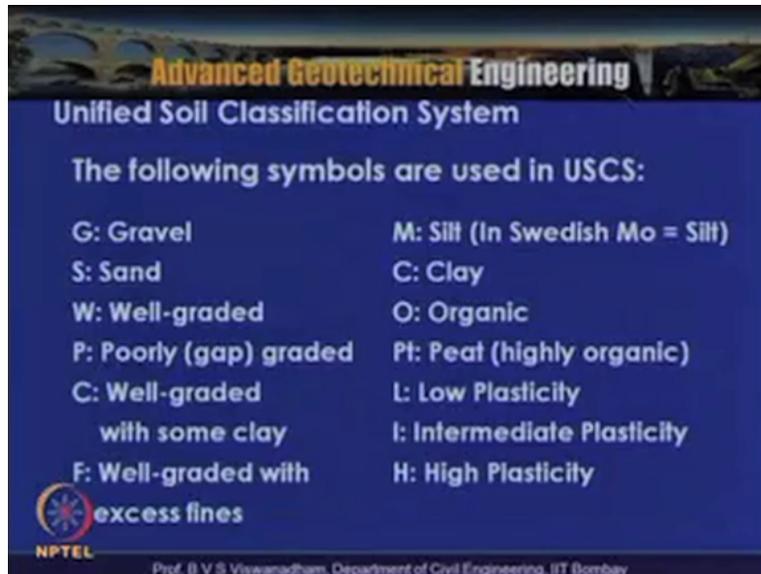
- A soil is coarse-grained (gravelly and sandy) if more than 50 % is retained on a No. 200 sieve and
- as a Fine-grained soil (Silty and clayey) if more than 50 % is passing through a No. 200 sieve.

➤ **Soil is further classified by a number of sub-divisions with primary and secondary characteristics.**

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So the two measured divisions which are there a soil is coarse grained gravel and sand if more than 50% retained on a 200 amount sieve that is 200 on a 200 number sieve that is 0.075 or 75 microns sieve as a fine grained soil the silt and clay if more than 50% passing through a 200 number sieve so if percentage fines is more than 50% which is passing that is classified as a fine grained soil so soil is further classified a number of sub divisions with primary and secondary characteristics.

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So here the following symbols are used gravel which is indicated as G and silt which is actually indicated as M the original origin of the name of the silt is Swedish some more which is a silt and S for sand and C for clay W for well-graded that means that it actually has got you know various ranges of the soil particles.

And P for poorly graded or the gap graded and O organic and Peat type of soils or highly organic soils and C well graded with some clay and L which is indicated for low plasticity I for intermediate plasticity and h for high plasticity F well graded with excess fines so this F symbol which is actually used for well graded for the excess fines which is not generally comes if the grouping of the soil.

But what you will find is that suppose if you got a some clays with low plasticity then it can be indicated as a CL or say some clay which is actually having with high plasticity it can be indicated as a SH or if you have S sand which is well graded in nature then can be indicated as SW and if the sand which is actually having same size of the soil particles are uniform size of soil particles then it can be indicted as SP.

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Unified Soil Classification System

➤ Criteria of classification for coarse-grained soils into four groups.

W: Well-graded ($C_u > 4$ for gravels $C_u > 6$ for sands and $C_c: 1 - 3$) with fines (finer than 75μ) less than 5 %

P: Poorly-graded ($C_u < 4$ for gravels $C_u < 6$ for sands and C_c not between 1 - 3) with fines less than 5 %

C: Plastic clayey fines ($PI > 7$) with fines more than 12 %

M: Non-plastic silty fines ($PI < 4$) with fines more than 12 %

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So the criteria of classification of coarse grained soil into four groups one is W well graded C_u as to be 4 for gravels and C_u has to be greater than 6 for sands and C_c has to be 1-3 so here both C_u and C_c have to be satisfied and with fines that is finer than 75 microns and less than 5% so it is said that has well graded thus a fine should not be more than 5% in the poorly graded C_u is less than 4 that means in the poorly graded the slope of the grain and distribution is very stream so the C_u will be less than 4 for gravels and less than 6 for sands and C_c will be not between 1-3 so in case of poorly graded or gap graded the C_c will not be between 1-2 with fines again less than 5%.

And see plasticity, plastic clay fines with PI greater than 7 with fines more than 12% and M non plastic silt fines PI less than 4 so with fines more than 12% so fines more than 12% but non plastic silt fines and they are indicated as with M with plasticity indexed less than 4 so the criteria for the soil classification of the fine grained soils basically it is done by using the plasticity chart.

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Unified Soil Classification System

Criteria of classification of Fine-grained soils
- Casagrandes Plasticity Chart

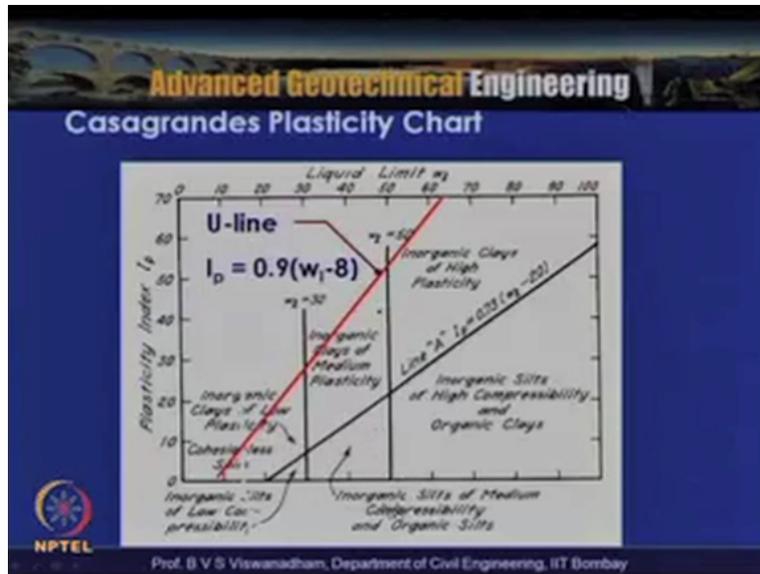
Basis of Plasticity chart:
Experimental results from soils tested from different parts of the world were plotted on a graph of plasticity index (ordinate) vs. liquid limit (abscissa). It was found that clays, silts, and organic soils lie in distinct regions of the graph.

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So basis of the plasticity chart is that once you have got liquid limit and plasticity index and which is actually plotted then it is possible for you to express to classify the soil so the experimented results from this soils tested from different parts of the world were plotted graphically of plasticity index verses liquid limit a plasticity index from y axis and liquid limit on the abscissa it was found that clays, silts and organic soils lie in distinct regions of the graph.

So this particular chart was a arrived based on the data which is actually collected from the number of soils like clays silts and organic soils and they found that it is found to be distinguished with the help of the chart.

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So here in this particular slide a Casagrande plasticity chart is shown here and on the x axis what you see is liquid limit which is shown here on the y axis the plasticity indexed is plotted and here this particular line which is called the A line the equation of the A line is that $I_p = 0.75 \cdot w_L - 20$ so you need soil which is actually so if it is remarketed in 3 zones 1 here and 1 here and 1 here and here this particular zone the soil actually which have low plasticity and medium plasticity.

And here the soils actually have high plasticity you need soil which is actually lies above a line is called organic clays of high plasticity the particularly if you are having a liquid limit more than 50 and if it is lies below the line then it is called a inorganic silts of high composite and also some organic clays are grouped here and here in this particular zone where liquid limit greater than 30 and less than 15 and here with plasticity index in this boundaries where inorganic cells of medium compressibility.

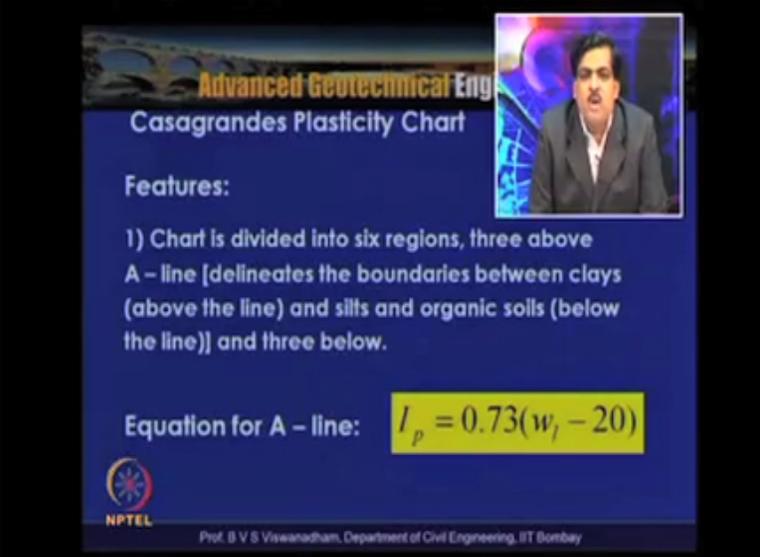
And organic silks, for example if you have got a soil which is actually having identical liquid limit but have different plasticity characteristics they are actually classified differently. So if I have one soil here and one soil here they are actually marked as a different types, so here in this zone particularly these are actually for the co shell soils or the soils which are having possessing non plastic or low plastic silks.

So these are actually having the plasticity less than 4 to 7 they are actually put here in this particular zone and what we see here the red line which is nothing but called u line, so any data which is actually following in this region that means that the test that has to be repeated and this

is actually upper bound value which is actually plotted, upper bound line the equation for the u line is indicated as $I_p = 0.9 \times W_L - 8$.

So if you have the mostly all these soils which are actually above a line on or above line are classified as inorganic and below or all organic. So you can see that these are all the some inorganic silts and no plasticity silts are placed here.

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Casagrandes Plasticity Chart

Features:

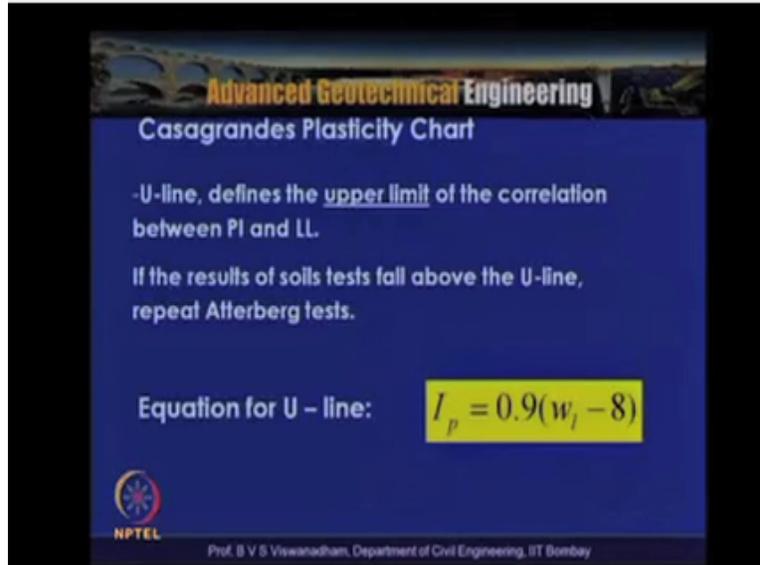
1) Chart is divided into six regions, three above A - line [delineates the boundaries between clays (above the line) and silts and organic soils (below the line)] and three below.

Equation for A - line: $I_p = 0.73(w_L - 20)$

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The features are that the chart is divided by six regions, 3 above that is A line delineated the boundaries between the clays above the line and silts and organic soils below the line and three below. So equation of the A line is $0.73 \times W_L - 20$.

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Casagrandes Plasticity Chart

-U-line, defines the upper limit of the correlation between PI and LL.

If the results of soils tests fall above the U-line, repeat Atterberg tests.

Equation for U – line: $I_p = 0.9(w_l - 8)$

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At U line defines the upper limit of the correlation between the plasticity index and the liquid limit, if the results of the soils fall above the U line repeat the Alter berg tests and the equation for the U line is given as $I_p = 0.9 \times Wl - 8$.

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Casagrandes Plasticity Chart

2) All points representing inorganic clays lie above A-line, and all points for inorganic silts lie below it.

Points representing organic clays are usually located within the same region as those representing inorganic silts of high compressibility and organic silts in the region assigned to inorganic silts of medium compressibility.

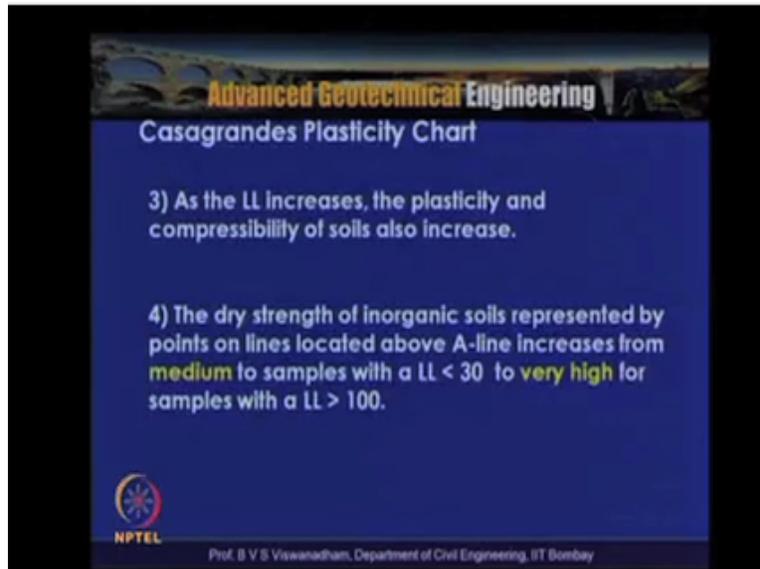
In doubtful cases, LL should be determined for an oven-dry specimen as well as a fresh one. If drying decreases LL by 30 % or more, the soil may be classified as organic.

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So all points representing inorganic clays lie above A line and all points for inorganic silts lie below A line. Points representing organic clays are usually located within the same region as those representing inorganic silts of high compressibility and organic silts in the region assigned to inorganic silts of medium compressibility. So in doubtful cases liquid limit should be determined for an oven dry specimen as well as the fresh one if the decreasing liquid limit is say 30% or more than the soil is classified as organic.

Because of the loss of organic matter, so in the doubtful cases the liquid limit should determine for a oven dry specimen as well as the fresh one without oven drying, if the decreases liquid limit by 30% or more than the soil may be classified as organic.

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Casagrandes Plasticity Chart

3) As the LL increases, the plasticity and compressibility of soils also increase.

4) The dry strength of inorganic soils represented by points on lines located above A-line increases from **medium** to samples with a LL < 30 to **very high** for samples with a LL > 100.

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Thirdly as the liquid limit increases the plasticity and the compressibility soils also increases, so the dry strength of inorganic soils represented by points on lines located above A line increases from medium to samples with liquid limit < 30 to a very high for samples with a liquid limit > 100.

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So let us now club the unified soil classification charts obtained from the data and plasticity chart which is actually discussed in the previous slide. So here in this category which is actually defined the grains soils major division present is passing number $200c < 50$. And it travels which is % passing $4.75C < 50\%$.

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Major division	Typical names	Criteria of classification
Course-grained soils (percent passing No. 200 sieve < 50%)		$C_u = \frac{D_{60}}{D_{10}} > 4, C_c = \frac{(D_{30})^2}{D_{10} \times D_{60}}$ between 1 and 3
Gravels (percent of coarse fraction passing No. 4 (4.75 mm) sieve < 50%)	-Well-graded gravels, gravel-sand mixtures (little or no fines) GW	Not meeting the two criteria for GW
Gravels with little or no fines	-Poorly graded gravels, gravel-sand mixtures (little or no fines) GP	
Gravels with fines	-Silty gravels, gravel- sand-silt mixtures GM -Clayey gravels, gravel-sand-clay mixtures GC	Atterberg limits below A- line or $PI < 4$ Atterberg limits above A- line with $PI > 7$


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So here with the C_u value > 4 and C_c between 1 and 3 and so gravels with this well graded gravels, gravels sand mixtures with little or no fines are classified as GW, so well graded gravel it indicates the GW. Similarly poorly graded gravels are gravel and sand mixtures little or no fines which is indicated as GP. So here the gravel which is actually almost size particles so that is actually grouped as GP.

Similarly Alter berg limits below A line and $PI < 4$ so silt gravels are gravels and sands silt mixtures, so if I have silt which is actually blended with gravel than it is actually indicated as GM. Similarly gravels with fines having plasticity index more than 7 Alter berg limits lie above A line then it is indicated as GC. So here with gravels soil we have seen that GW, GP, GM and GC.

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Major division	Typical names	Criteria of classification*
Sands (percent of coarse fraction passing no 4 (4.75 mm) sieve > 50)	Well-graded sands, gravelly sands (little or no fines) SW	$C_u = \frac{D_{60}}{D_{10}} > 6; C_c = \frac{(D_{30})^2}{D_{10} \times D_{60}}$ Between 1 and 3
Clean sands (little or no fines)	Poorly graded sand, gravelly sands (little or no fines) SP	Not meeting the two criteria for SW
Sands with fines (appreciable amount of fines)	Silty sands, sand-silt mixtures SM	Atterberg limits below A-line or $PI < 4$
	Clayey sands, sand-clay mixtures SC	Atterberg limits above A-line with $PI > 7$

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Similarly here for sand similar trend we have adopted here SW, SP, SM and SC, here this value has the discussed earlier it is C_u value is more than 6 and C_c value between 1 and 3. And for meeting the 2 criteria and here the poorly graded and C_c value not between 1 and 3 then it is actually said SP. So the sand with fines silt sand mixtures with plasticity index < 4 and they are actually indicated as silt sand silt mixture with SM.

And clay sands and sand clay mixtures is indicated as SC, so here we have seen that the sandy type soils with different types of relationship SW, SP and SM with some silt mixtures or with the clay sands or sand clay mixtures indicated as SC the symbol or the group which is indicated as SC.

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Major division	Typical names	Criteria of classification
Fine grained soils (percent passing No. 200 (0.0075 mm) sieve > 50)	Inorganic silts, very fine sands, rock flour, silty or clayey fine sands ML	Plasticity Chart
Silts and clay (LL < 50)	Inorganic clays (low to medium plasticity), gravelly clays, sandy clays, silty clays, lean clays CL	
	Organic silts, organic silty clays (low plasticity) OL	


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And fine sand soils with the % passing 75 micron C_u is $> 50\%$ so here according to plasticity chart is the criteria which is we have discussed when inorganic silts with very fine sands and rock flour and silty or clay or fine sands indicated as ML and there is also a boundary soil which is actually indicated as CL, ML that means that doubtful cases where we have got the twin grouping which is called CLML grouping.

And silts and clay with liquid limit less than 50% in organic clays low to medium plasticity the gravity clays and sand clays lean basically they are actually grouped as CL organic soils and organic silt clays of having the low plasticity they are grouped as OL. So here for the fine grain soils we are actually seeing groups like ML CL and OL. And for the silts and clays liquid limit > 50 which is inorganic silt.

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Major division	Typical names	Criteria of classification
Silts and clay (LL > 50)	Inorganic silts, micaceous or diatomaceous fine sandy or silty soils, elastic silts MH	Plasticity Chart
	Inorganic clays (high plasticity), fat clays CH	
	Organic clays (medium to high plasticity), organic silts OH	
Highly organic soils	Peat, mulch, and other highly organic soils Pt	

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Micaceous or diatomaceous and fine sandy and silty soils and elastic silts which is indicated as MH inorganic clays with high plasticity and fat clays having high compressibility and high plasticity indicated as CH. So MH and CH organic layers with medium to high plasticity indicated as OH. So here you can see that OH and PT are mulch and other high organic soils are indicated as Pt.

So here according to Astor classification system we classify the Pt of soils as A height and here it is indicated as Pt that is the, for the highly organic soils and classification based on the percentages defines.

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Classification based on percentage of fines

Percent passing No. 200	Classification
< 5	GW, GP, SW, SP
> 12	GM, GC, SM, SC
Between 5 to 12	Borderline-dual symbols required Such as GW-GM, GW-GC, GP-GM, GP-SC, SW-SM, SW-SC, SP-SM, SP-SC

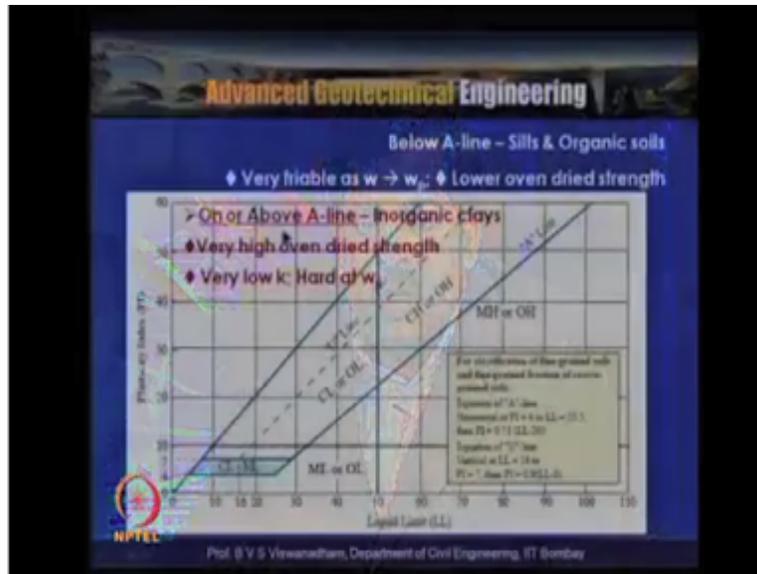

 Alterberg limits above A - line and plasticity index between 4 and 7 are borderline cases. It needs dual symbols.

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So if the percentage passing number 200 seen that is 75 micron seen is less than 5 then it is indicated as GW,GP,SW and SP and greater than 200 it is indicated as GM,GC and SM and SC between 5 to 12 these are actually called as the border line symbols so they carry dual groups which is nothing but if you have percentage passing greater than 5 < 12 then we have G it can be GW,GM and R GW,GC or GP, GM,GP, SE, SW,SM or SW, SE.

And SP, SM and SP and SE so alter berg limits above A line and plasticity index between 4 and 7 are borderline case so it needs dual symbols alter berg limits above air line and plasticity index between 4 and 7 are border line cases and it requires it needs dual symbols so as I said there that is actually on the left side left bottom of the plasticity chart and which is actually indicated as CL, ML group so in this particular chart what you see.

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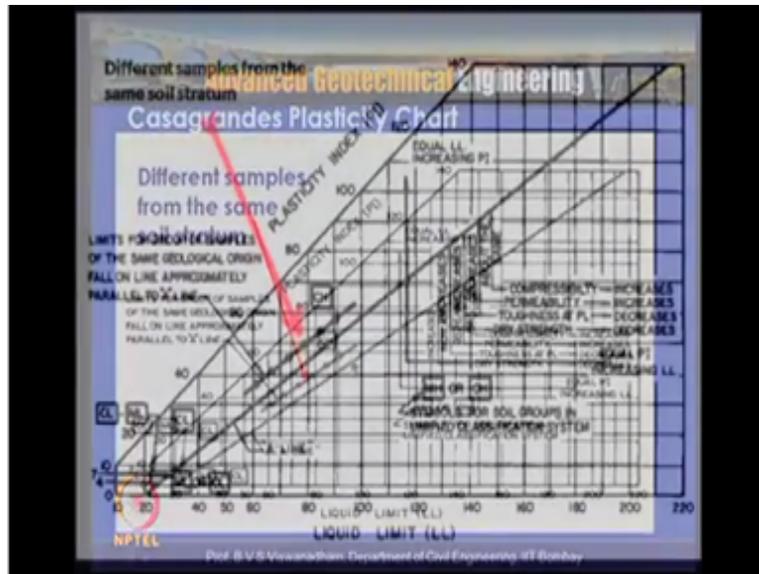


On the above A line they are actually called as inorganic clays and below A line they are actually classified as silts and organic soils so the plasticity chart which is here the equation of this is the A line and this is the U line this is the U line what we have actually discussed so here the horizontal for the at $PI=4$ that is $PI=4$ and liquid limit is equal to 22.5 so any soil which is actually falling in this zone is carrying a dual symbol that is called CL, ML and the equation of the U line that is here vertical at liquid limit is equal to 16 that is somewhere here.

And then it actually starts here so this is for the you know the U line which is actually shown here so any soil which is actually falling above A line and in organic place very high oven dried strength and very low clay and they have high hard at plastic limit so these soils which is actually having falling on above A line they exhibit high oven dried strength and very low what we see that k which indicates that permeability and they are actually very hard at plastic limit and similarly the soil characteristics which are below A line that is in this zone they are basically silts.

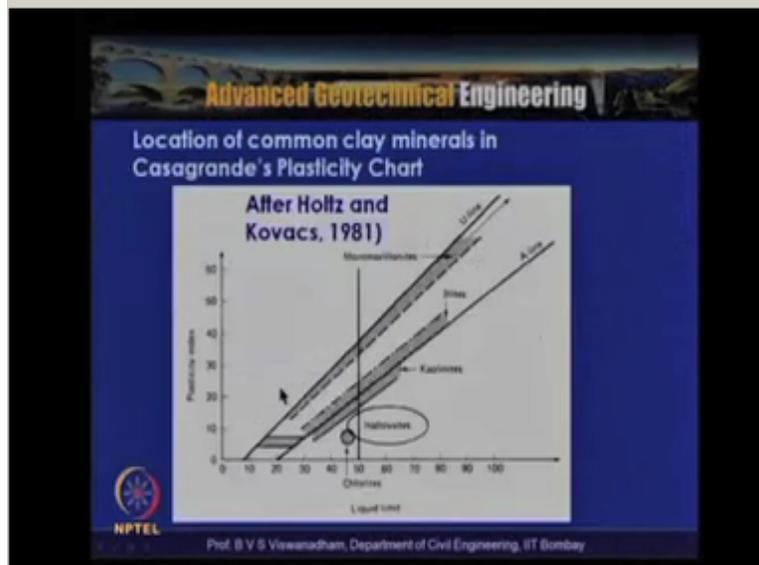
And organic soils it is very friable as because, water content is closed to plastic limit and the lower oven dried strength that means let the they possess actually the low oven dried strength but similarly if you see a soil which is actually having identical liquid limit but which is actually falling in this region can exhibit high oven dried strength so here in these particular chart it indicates.

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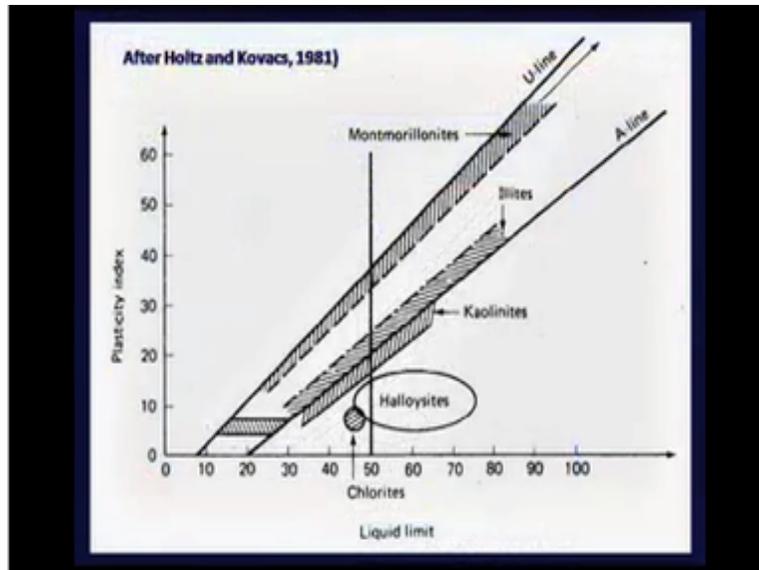
So the characteristics you know whatever the geotechnical origin they have identical characteristics so they actually fall and then which of the same soil stratum and they actual fall here so here what is actually shows that the compressibility increases the permeability of the soil will be very low and so this is you know another additional feature of the chart with soils with geotechnical stratum they fall approximately parallel what you can see the parallel to the A lin.

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So here basically the location of the common clay minerals in the Casagrande's plasticity chart is shown

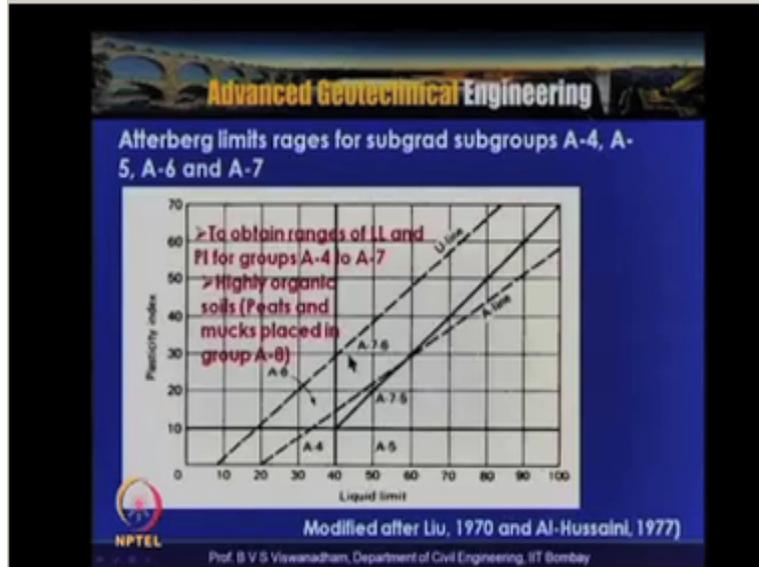
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So here what has happened is that this is the A line and this is u line which is indicated so all the three common claim which are thing but clear light and light mostly based on soils they actually fall below A line what you can see is that is the general classification which is actually given after the holtz and kovacs is that this one and alights they fall somewhere here.

And here in this Joan there is a possibility that here it actually below right below U line it is actually positing very high liquid plasticity index and liquid limits they matrimonial based mineral soils will actually fall here so if you look into this the light based soils theoretically they actually fallow fall below A line lights somewhere here and then based on minerals save as somehow here.

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And here in this particular slide alter berg limits ranges for the sub graded sub groups a4,a5,a6 and a7 are shown here so here what has happened is that the U line and the A line are super impose the data which are actually shown so it can be seen is that A4, A5, A75 they are actually falling below A line and to obtain the ranges of liquid limit and plasticity index for groups a4 to a7.

And high organics soils peats and mucks groups are actually placed in so astral groups are actually super imposed on the plasticity chart so it indicates that here above A line so this is soils which is actually having medium plasticity and here which is soil which is actually having high plasticity that is not addressed in Astor classification system so PT type of soils which are actually indicated as A8.

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Example 4

For a soil specimen, given:

Passing 2 mm sieve = 100 %; Passing 0.425 mm sieve = 85 %;

Passing No. 200 sieve = 38 %

LL = 20 % and PI = 12 %

Classify the soil by the Unified soil classification system

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So in the example 4 for a soil specimen given passing through 75 μm sieve let us say that 100% and passing point 4.25 mm sieve is 85% and passing 200 μm sieve is say 38% liquid limit is 20% and plastic index is 12% so we need to classify the soil.

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Solution for Example 4

- Soil is a coarse grained soil (Percent passing No. 200 sieve < 50).
- Sands (percent of coarse fraction passing No. 4 sieve > 50)
- Since more than 12 % passes No. 200 sieve, it must be SM or SC
- $PI = 20 - 12 = 8 > 7$ [above A-line]

Hence the soil classification is SC

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By the unified classification system so here based on the data which is actually given and what with the whatever we have discuss since more than 12% passing is number 200 sieve is SM or SE the plasticity index is 7 so the soil classification can be worked out as SC so in this particular lecture what we tried to understand is that we have an tried to look into the significance of the triple limits what are the requirements of the uses of the alter berg limits and limitation of the alter berg limits.

And how we can actually classify soil based on the activity and also how to classify the soil with the available data with grains machine particularly and distribution of different types of soils and alter berg limit test data so in this lecture we have discussed about two methods that is Astor classification system for soil classification system which is actually while we adopted for the high way construction and uniform solid is classification system which is used for the universally but however as discussed earlier this particular grouping indicates the particular characteristics but this should not be used as a bases for based on this the further investigation have required to be carried out.

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