Geotechnical Measurements and Explorations

Prof. Nihar Ranjan Patra

Department of Civil Engineering

Indian Institute of Technology, Kanpur

Lecture No. # 29

So, last class we have covered this shrinkage limit. Shrinkage limit is the water content behind

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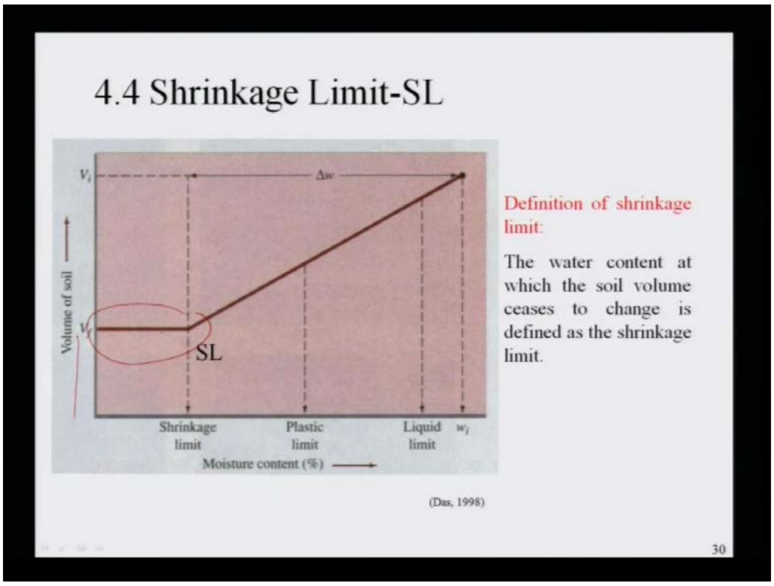

which there is no more change in volume of soil .So, basically if this is my shrinkage limit beyond which there is no more change in volume, volume remains constant. So, this shrinkage limit will give this state that means solid state of soil and

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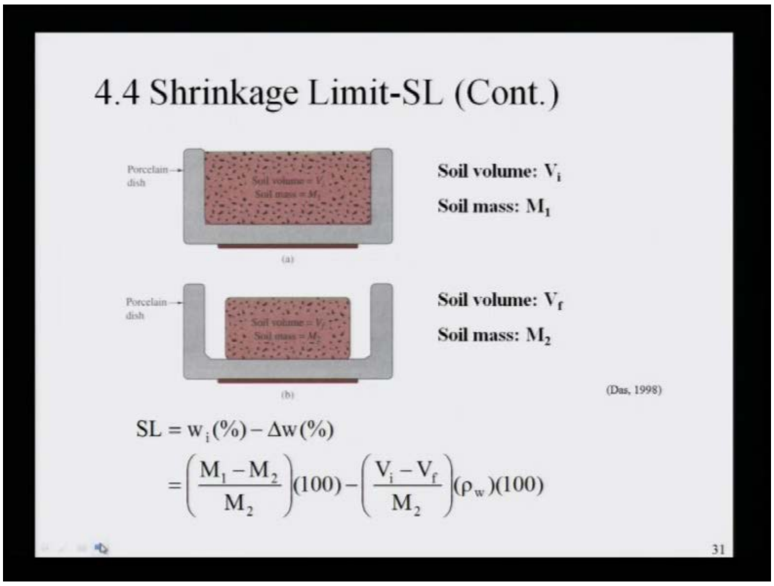

we have discussed about the shrinkage limit. How to find it out? We can find it out by taking the volume of soil and water and making it dry and find it out mass and volume of soil, dry soil from there you can find it out shrinkage limit.

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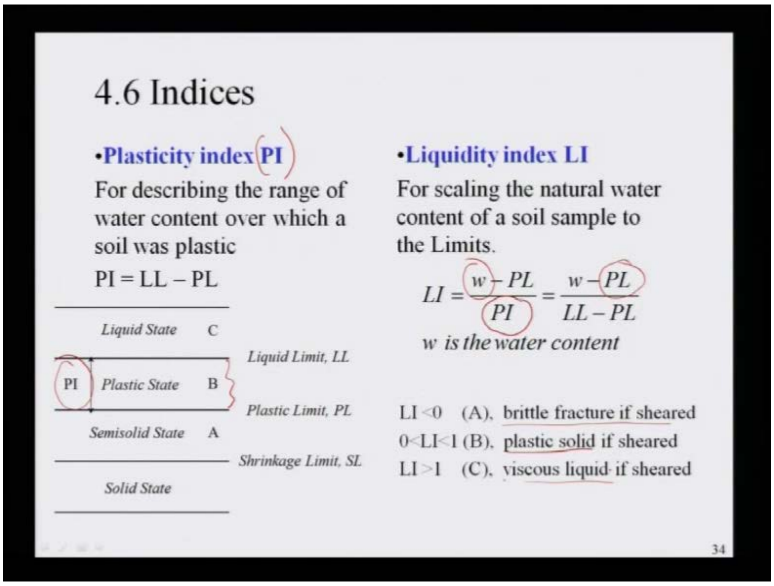

Then we will start this with this liquid limit plastic limit and shrinkage limit. What are the with this limit? What are the parameters we are suppose to get or indices? First one is your plasticity index that is called P I, if it is name P I then it means plasticity index it is describing the range of water content over which the soil is plastic. Once it is said plastic limit that means the water content, the range of water content at which over, which the soil is a plastic.

So, plasticity index is liquid limit minus plastic limit so, plasticity index basically its shows the plastic state of the soil. If this is the liquid limit it lies between liquid state and plastic state and plastic limit lies between plastic state and semi-solid state. Shrinkage limit lies between semisolid state and solid state. P I is your plasticity index basically it terms your plasticity plastic state complete plastic state.

Similarly, liquidity index or it is called L I liquidity index is a natural water content of soil sample to this limit. If I say liquidity index it can be calculated as I said w minus p l by liquid limit minus plastic limit or plastic index w is your natural moisture content or the water content of the soil it has then plastic limit P l is your plastic limit. So, if liquidity index is less than 1, less than 0 then it is it terms as a brittle fracture. If a soil having liquidity index less than 0, if you shear it then a brittle fracture failure you will get it if liquidity index between 0 to one then, if we shear it then will get a plastic solid state you find it out. If liquidity index is greater than one then it is viscous liquid we termed as a viscous liquid.

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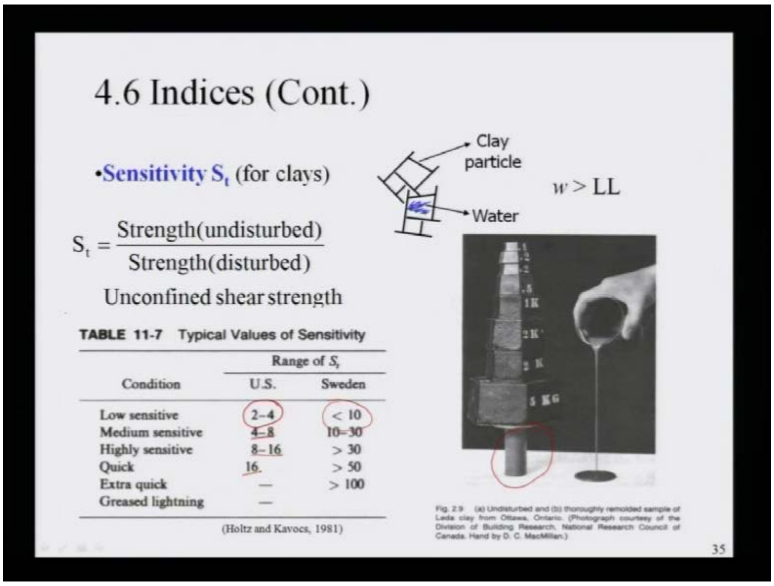

Then next index indices is your sensitivity S t this sensitivity is specially use for clays. So, sensitivity S t is strength undisturbed that means strength in undisturbed divided by strength in disturbed conditions so, if you look at here undisturbed a is your undisturbed this is my a undisturbed and b is your thoroughly remolded sample of clay from ottawaontario. This is thoroughly remolded clay and it has been put by this compression.

And unconfined shear strength typical value of sensitivity based on the unconfined shear strength you can say that sensitivity based on this report has given by holtz and kovacs 1981. Low sensitivity is called as for the U S it is 2 to 4 as for U S code. As for Sweden if it is less than 10, it is low sensitivity medium sensitivity between 4 to 8, high sensitivity 8 to 16 then quick is your 16 that means how far it is sensitive as compared to your disturbed sample and strength of disturbed sample. If I take the ratio the strength of undisturbed sample how far it is sensitive as compared to your strength of disturbed sample.

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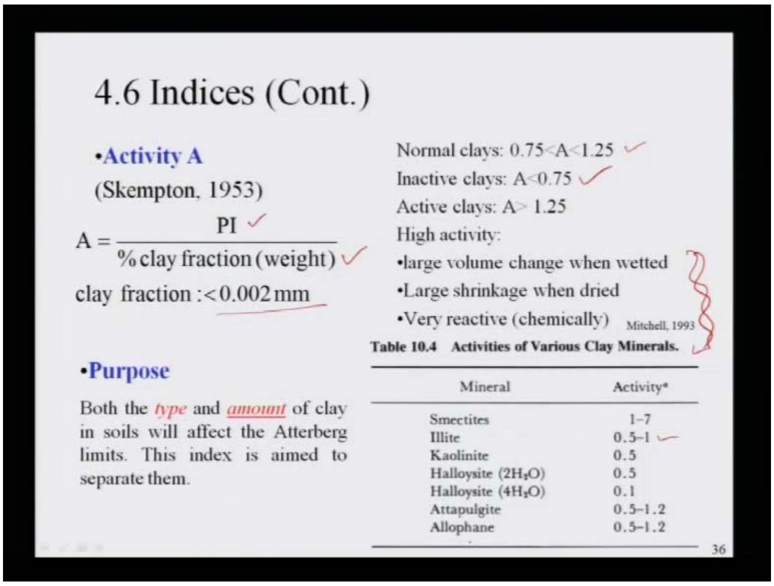

Now, next indices is your activity is like a it it has been given by Skempton 1953 it is called A, activity means A it is your plasticity index P I divided by percentage of clay fraction by weight. So, clay fraction has been taken as far this Skempton generally, if it is soil particles passing through the shape 0.022 mm that means 2 micron shape below this if soil fraction, soil particles passing this is called clay fraction.

Purpose is both the type and amount of clay in soil will affect the Atterberg limit that means, why we are doing this activity? Activity is a kind of plasticity index in terms of percentage clay fraction activity is the representation of plasticity index in terms of percentage clay fraction that means it will, it will give both type and amount of clay.

What type and what is the amount of clay in soil that affects your Atterberg limit? This index is aimed to separate them that means, what type and what amount of the clay in the soil that means it will separate the clay fraction completely from the soil. If I say it is a normal clay the activities varying from 1.25 to 0.75. In inactive clay, it is a is less than 0.75 Active clays a is greater than 1.25, if I say it is inactive clay what is it mean that means percentage of clay fraction is very less that means percentage of clay fraction in the soil sample is very less that is why it is called inactive. Highly active or high active that means large volume change high active means percentage of clay fraction it shows.

The moment you say that the soil sample has high activity that means it shows percentage of clay fraction is much more, that means there might be a chance that large volume of change will occur. Then once it is dried then large shrinkage may be occurred or very reactive to chemical, this is the indication that means; it gives indirectly or directly you can say how much percentage of clay fraction in a soil sample suppose, you take a soil sample of 200 to 300 gram.

Once you do this classification and other things then you will have to find it out what is its activity after doing liquidity indices indeed plastic index and shrinkage limit all this liquid, liquid limit plastic limit and shrinkage limit from there, you find it out P I plasticity index. From there you get your activity once you find it out activity then you classify, if activity is greater than 1.25 that means percentage of clay fractions are much more in the soil sample as compared to other soil grains. Clay silt sand gravel these are the fractions as compared to silt sand and gravel the clay fractions are more this activity it shows it means there will be a large change in volume when in it.

When it is weighted that means when there is a rainy season large change in volume and large shrinkage will occur. When it is dry that means in summer season and it may possible that it is very reactive, when the chemicals added any chemicals. So, activity of various clay minerals also it has been given by Mitchell 1993, if we see Illite is 0.5 to 1 Kaolinite is 0.5 then Allophane is 0.5 to 0.22.

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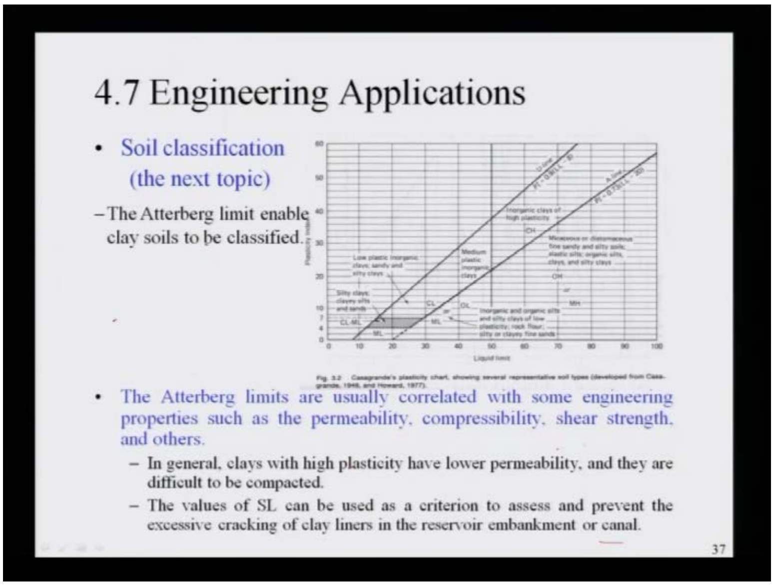

What are its engineering application? What we have done this Atterberg limits or grain size distribution right now, means we have finished this grain size distribution for coarse-grained for fine-grained soil we have finished this Atterberg's limit. That means liquid limit, plastic limits, shrinkage limit and indices liquidity indices of plasticity index and your activity. What is it mean, how far it is it applied in engineering application its basically applied for soil classification. Soil classification the Atterberg limit unable clay soils to be classified that means; it allows the clay soil to be classified. If I will take the Casagrande's plasticity chart 1977.

If you look at here plasticity index P I plasticity index that means P I versus your liquid limit if I plot it look at here 10 to 20 percent. Two lines I ploted this is your plasticity index of this is A line and U line called A line is your 0.73 liquid limit minus 20 and U line is your plasticity index P I is equal to 0.9 liquid limit minus 8 in between in this range.

If you look at this two range medium plastic inorganic clays it lies of liquid limit between 40 to 50 with this plasticity index of U line and A line and between 50 to liquid limit of 50 to 70. If you look at your liquid limit of 50 to 70, if you draw it between 50 to 70, this is my range in this range inorganic clay of high plasticity it term as C H, C for clay, H for high plasticity and medium plastic inorganic clays, it is between from here to here, here to here that is called C L. L is your low plasticity. H, H is your high plasticity that means; this says that inorganic clay of high plasticity termed as C H. Inorganic clay of medium plasticity is called C L, then M L is your low plasticity, you see this the classification.

Now, if you go if you look at here it, it it is clearly arrow marked low plasticity inorganic clays sandy or silty clays, then here this range particularly. If I take this range of plasticity index between 4 to 6, a line has been drawn 4 to 6 where it intercept with here U line as well as A line and this has been marked with shaded this has been shaded, if you look at how does it mean the soil belongs to this range it is silty clay or clay silt and sands look at the classification then. What is the meaning of O L or O H. O means organic inorganic or organic silt inorganic or organic silt clay of low plasticity L means plasticity in terms of low plasticity. M is your silt here M is silt, M is equal to terms to silt.

C is your clay, O is your organic soil, then your H is your high plasticity, then L is your low or sometimes called medium plasticity. Now, in this term if this is, this is lying below what about the soil it is lying below A line, if you look at here it is line below a line this is called from here to here 50 percent this is called O L that means inorganic and organic silt and silty clays of low plasticity rock, silty or clay, clay fine sands. Now, if I come to here if I come to between this 50 to 80 percent below a line either this is O H or M H.

H means is your highly plasticity, O means organic or M is your silt that means if you look at here the classification has been made micaceous or diatomaceous fine sandy and silty soils elastics silts organic silts O for organic you see organic silts clays and silty clays that means; if I look at this particularly look at this reason for doing this Atterberg limit for fine-grained soils. Liquid limit, plastic limit, shrinkage limit, liquidity index, plasticity index activity if I do it, it means I want to classify where it exactly lies the clay sample or the clay soil or may be the fine-grained soils. What is its classification? this classification has been given by Casagrande plasticity chart in nineteen seventy seven, this the Atterberg limits are usually correlated with some engineering properties. Why we are doing this one is your soil classification first one is your soil classification, this Atterberg’s limits that means whether is a highly inorganic or organic whether, it is plastic or low plastic or high plastic this classification point of view we do this Atterberg’s limit.

What is the next step, the Atterberg limits are usually correlated with some engineering properties look at here some engineering properties such as permeability, permeability is termed as small k compressibility, compressibility nothing, but your consolidation that means C c then shear strength, shear strength parameter is your c and phi. And others that means directly or indirectly this Atterberg's limits is an indicative. This Atterberg's limit is an indicative of engineering property indicative that means is gives an indication of engineering properties like what is its permeability?

This kind of soil is there suppose, clay 20 percent of clay is there. What its permeability? its giving and what its permeability means, what is its coefficient of consolidation or compressibility how much time it take to consolidate and how long you can get it indirectly all or are also you can get it. What is the shear strength? What is the strength for design a foundations?

Then in general if I make it clay with high plasticity just a classification. How it is useful for ours engineering property finding out the engineering properties clays with high plasticity have low permeability, low permeability means water passing through the soil will be very less. It takes long time for permeable and they are difficult to be compacted it is not very easy to be compacted, that means once it is low permeability. That means, the compressibility capacity number of days to required the water to come out how long it will take to consolidate, that means it will be very high the value of SL shrinkage limit can be used as a criterion to assess and prevent the excessive cracking of clay liner,in the reservoir embankment or canal.

Look at here the moment you find it out this shrinkage limit, if you know this shrinkage limit is very high then if you know this shrinkage limit, the value then you can say that if there is a chance of any cracking of clay liner generally, clay liner provided in reservoir embankment in canals then you can design also then we can prevent also. So, in a way this Atterberg's limits indirectly or indicative of your engineering properties of soil and as well as also it has been use for soil classification.

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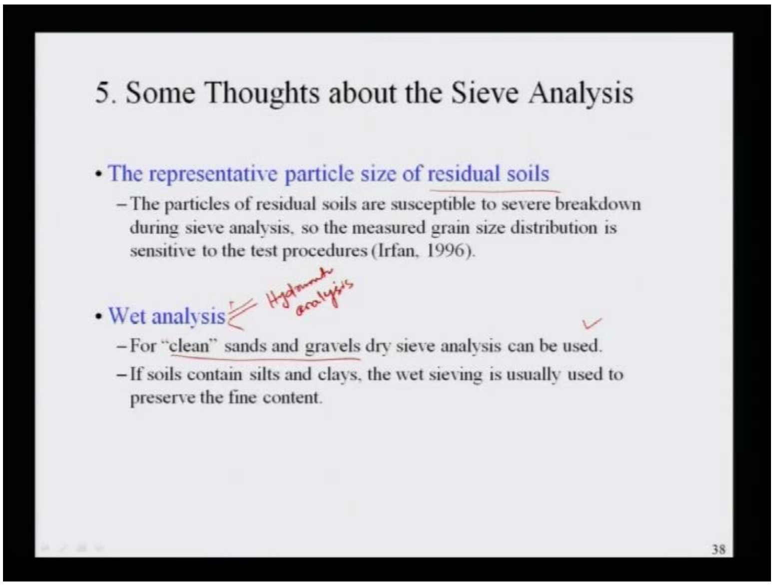

The representative particle size of residual soil the particles of residual soil are susceptible to severe breakdown during sieve analysis. So, the measured grain size distribution is sensitive to test procedures that means the particles of residual soils these are it may chance. Once you take the residual soil it may chance that there is a it maypossible that there is severe breakdown during this Sieve analysis, that means the particle will breakdown. So, measured grain size distribution is sensitive particularly this grain size distribution if you conduct for residual soil it will be very sensitive. Then this is your grain size some thought about the Sieve analysis I means while doing this residual soils you should be carefully do this residual soil. What will happen while doing this a grain size distribution particularly residual soil over the once, we put the soil in the Sieve then go for shaking in a Sieve shaker.

What will happen this particle breakdown further breakdown it may not give the accurate result of your particularly grain size distribution curve in wet analysis also, me thought for clean sand and gravel for clean sand and gravels dry sieve analysis can be used, it is not possible to go for a Wet analysis or Hydrometer analysis for particularly clean sand and gravel you go for wet analysis if soils contains silt and clays.Wet analysis or Hydrometer analysis, wet analysis means I mean say that it means Hydrometer analysis wet analysis or Hydrometer analysis is usually use to preserve the fine content, is usually use to preserve the fine content. What will happen if I put this fine content fine particles in sieve it may chance that it will breakdown to preserve it particularly, fine-grained soils wet analysis is required these are all some thoughts about this Sieve analysis.

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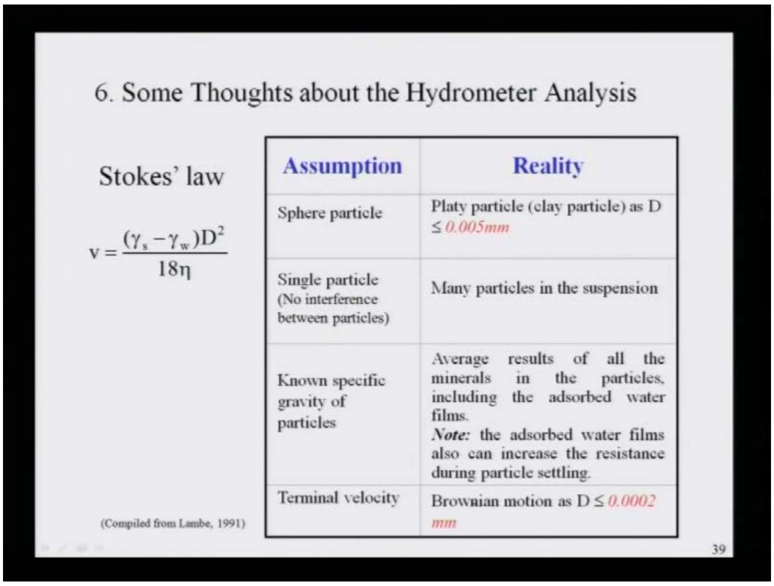

Now, what mechanics has been used in this Sieve analysis or Hydrometer aye sorry in wet analysis or Hydrometer analysis if we look at this, this mechanics behind is your Strokes' law that means assumption is that, in this Strokes' law how much time it takes to settle in a in a like a particularly in a jar full of soil and water that means particles. How much time it will take particle to settle based on that this you can it has been classified accordingly, whether it is more fine or less fine assumption the basic assumption of the Strokes' law is that all particles should be spherical particles, which is not true this is also drawback, but despite this drawback it has been used so, particle platy particle reality is as D is less than 0.005 mm, single particle another assumption is your it says that single particle that means no interference between particles that means each particle once, I put it in a beaker what will happen. In Hydrometer analysis you take a jar you take a measuring jar, in this measuring jar mixing with water with this deflocculated agents then put this particles soil particles inside this water. So, the assumption is that each particles inside this soil it is should be a single particle it should not be like a 2,3 particles will mix and it will make bond and it will settle. So, many particles in the suspension this assumption in the actually reality this assumption is not true.

That it is as behave like a each of the particle will settle now, it may possible that two three particle it makes many particle will be in suspension known specific gravity of particles that means you know that is specific gravity, known specific gravity of this particle based on that you are finding this Hydrometer analysis. Average actually reality is average results of all the minerals in the particles including this adsorbed water film that means the adsorbed water films also can increase the resistance during particle settling.

Then assumption is your terminal velocity so, it is not true in reality it is Brownian motion as D is less than 0.0002 mm, these are all these are this has been taken some thoughts has been taken from lambe 1991 means basically, its says that what is the assumption actually what is the reality? If you look at the assumptions, assumption one is your sphere particle and it should behave like a single particle and is specific gravity of the particle is known, then it is a terminal velocity actual reality it is not a spherical particle it is not a single particle inside the soil.

Many particle may be as behave like a as one particle like many particles means one particle, other particle like this 3,4 soil particle it will makes it will behave like one particle. Then terminal velocity is not possible in case of D is less than equal to 0.0001 or you can say that, this is the assumption and this is the drawback reality or this is the drawback particularly in case of Hydrometer analysis despite this drawback and assumptions this has been used popularly everywhere else, to find it out this fine-grained soil classification based on your hydrometer analysis.

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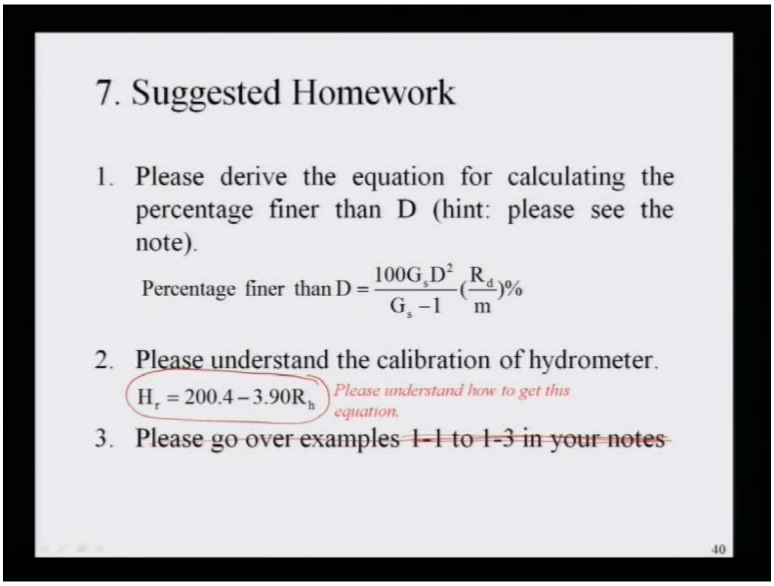

Now, these are for your homework please drive the equation for calculating the percentage finer than D that means percentage finer than d is 1000 G s d square by G s minus 1 R d by m percentage you derive it please understand, the calibration of hydrometer that means H r 200.4 minus 3.90 R h why, what is this calibration this is for your homework you can try and you can just explain yourself .What is this H r is equal to 200.4 minus 3.90 R h then this notes because I have to solve it again this place remove this example I will solve it may be later on,

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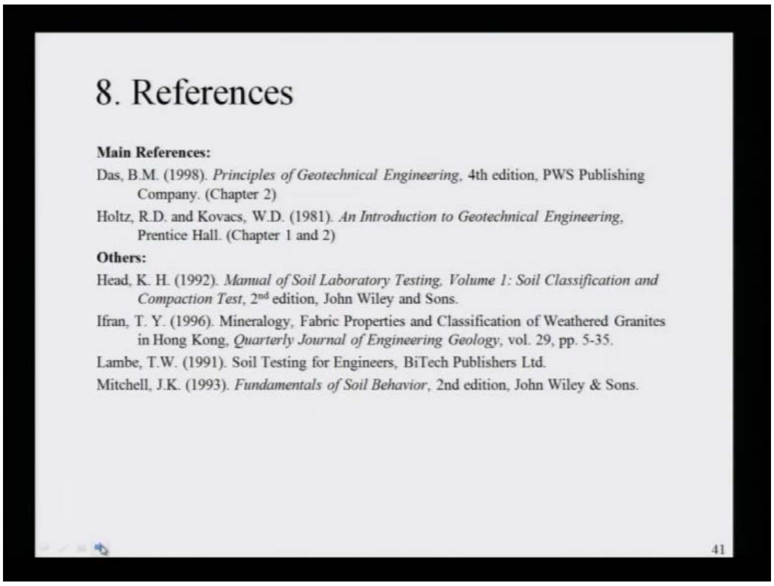

these are the reference basically, these are the reference has been taken from Das, B. M head lambe Whitmanlambe then Mitchell.

Next part of your geotechnical measurements and exploration,

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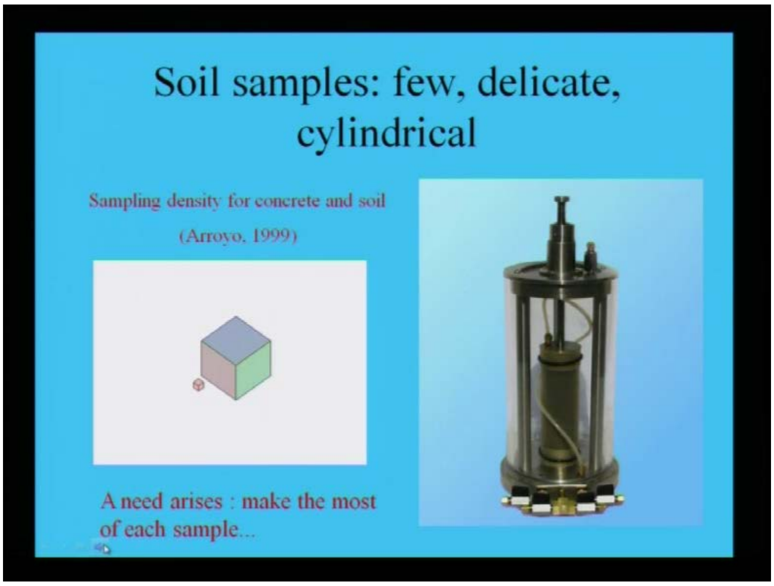

in laboratory particularly this use of bender element in laboratory also by using bender element you can measure dynamic property of soil by means of means you can measure this shear wave velocity in a triaxial cell. You can place your bender element and go for test you can find it out. What is the shear wave velocity of the soil? Now, make

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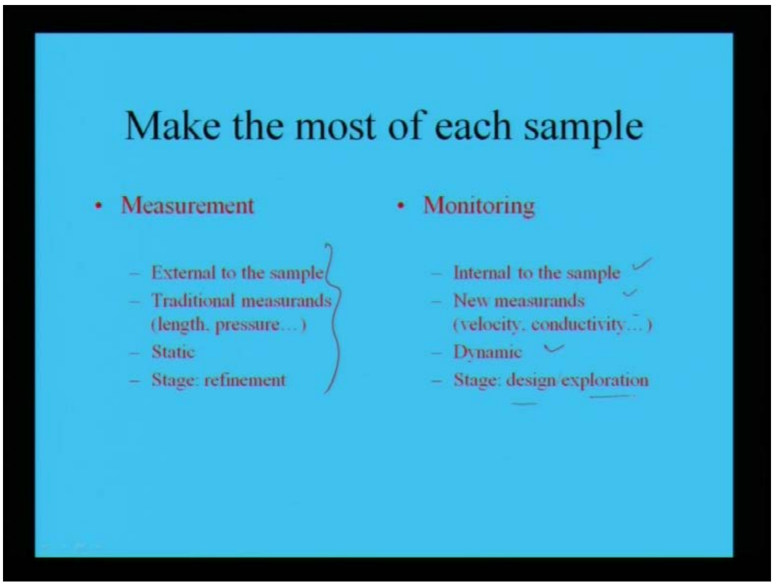

the most of each sample measurement external to the sample, these are all your traditional measure and length and pressure static and in stages it is refinement. Monitoring internal to the sample leave up to monitor new measurements velocity and conductivity these are earlier measurements. Now, in this monitoring velocity and conductivity and dynamic it has been use in design and explorations.

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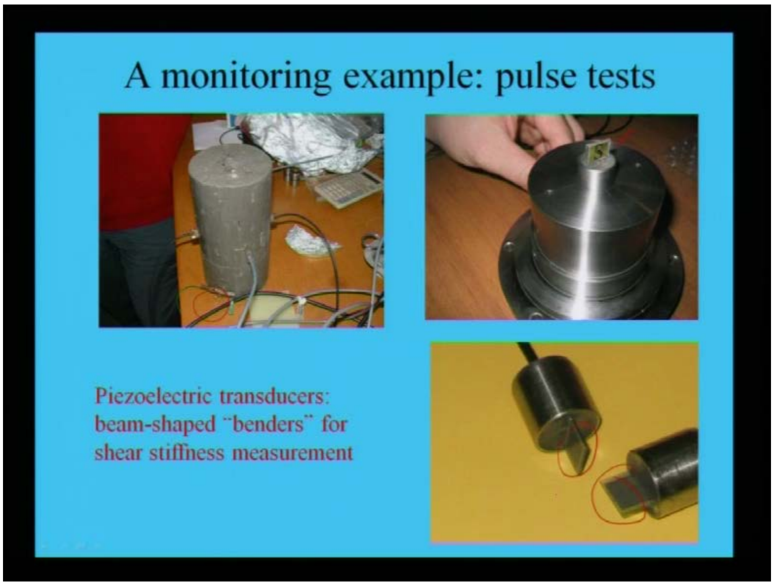

Now, if you look at here this is basically I am showing a bender element, how it has been placed inside this triaxial cell equipment. So, there are two methods one is your in suit methods by seismic downhole or by means of seismic crosshole, you can find it out shearwave velocity if you do not have any shear wave velocity data, in field you can conduct also in the laboratory either in undisturbed sample or in remolded sample.

If you look at here these are all Piezoelectric transducers these are beam-shaped benders these called beam-shaped benders these are two benders beam-shaped bender. If I look at here these are all your sensors this bender element has been used one has been used as a receiver other is your as a like source, one part is a source that means from where the wave will be propagate other part of your bender element has been used as a receiver. T

hat means the wave transmitted from here two from inside the soil mass, one has been put at the bottom one has been put at the top particularly these are all beam-shaped beam-shaped benders it is called beam-shaped bender as it looks like beam. So, there are two benders element one has a source another as a receiver one put at the bottom one put at the top these are all sensors beam-shaped with this bender these are all sensors it has been pushed inside the soil at the top and bottom.

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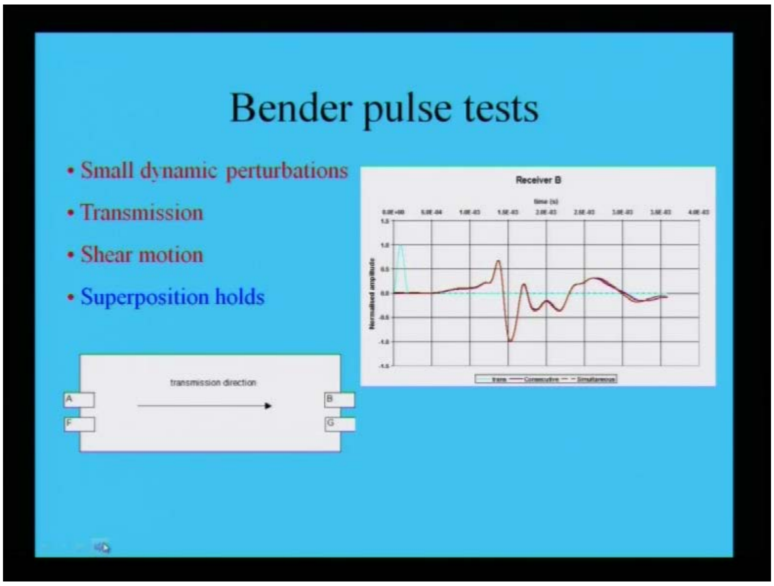

Shear motion and superposition hold if you look at the bender pulse test from transmission direction from source to receiver normalize amplitude in the receiver. If I plot it travel, travel, travel it receive and it go.So, this is a bender pulse test means how this pulse moves inside this soil sample.

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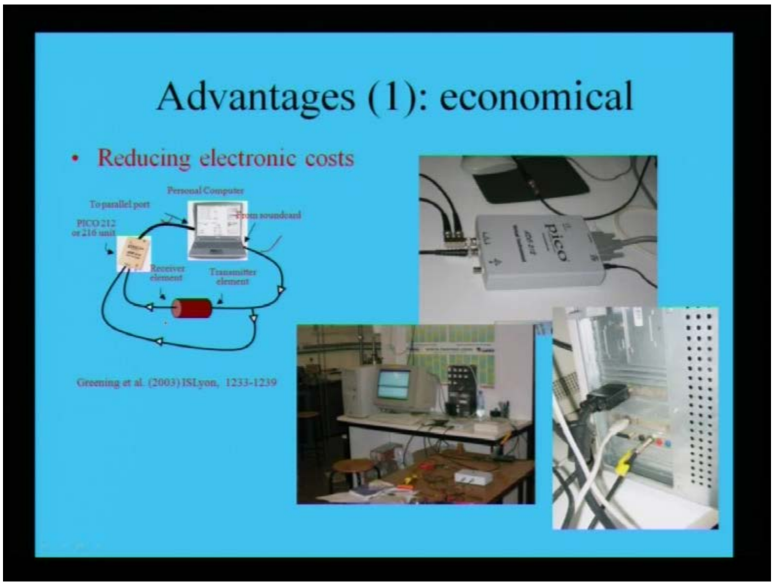

Now, there are many advantage before I go for the test detail, there are many advantage first one is your it is economical, it is very cheaper as compared to field test lot of money you want to you have to spend, but this is very economical a personal computer from there two ports are required, two port this is your port surrounded and this is your soil element this is your soil element.

With this soil element one part of your receiving element, one is your source this is my source means the wave have been propagated or generated in the source in the bender element and this is a receiver then with this you can record, how this bender pulse travel inside the soil and it, it does not require much time, much money its step one is it is very economical as compared to field test.

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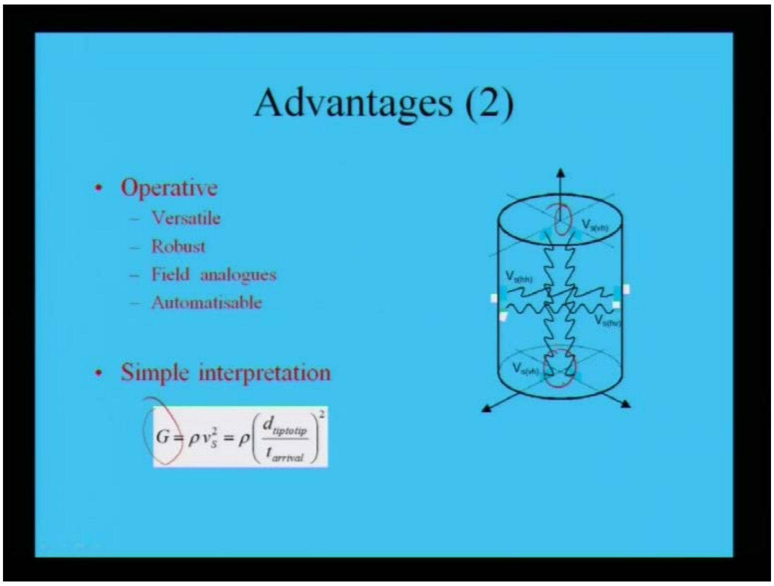

Advantage two is your its operative its means its very versatile and robust and it analogous to your field condition and simple interpretation you can simply interpret. If you look at here my this is my soil that means shear wave has been means if wave has been generated at the bottom by source you receive at the top, that means you can find it out simple interpretation G or shear modulus you can find it out by means of rho in to V s, V s is your shear wave velocity.

And that is your distance from tip to top, tip to tip from here to here distance travel from here to here, by how much time it takes it very simple to interpret. So, this is your advantage two and it is quite operative means versatile robust and it simulative is your field condition for field analogous and its automated you can make it automatic, this pulse or data you can generate or record inside your computer.

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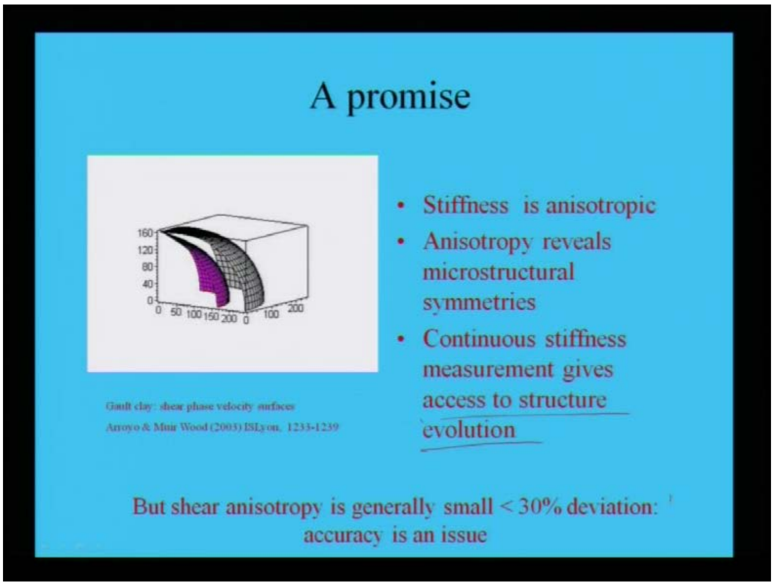

A promise third advantage is promise means stiffness is anisotropic, you can measure the stiffness anisotropic. Anisotropy reveals micro-structural symmetry anisotropy, isotropy means x, y, z direction. It will be same anisotropy means x, y, z it is different. So, continuous stiffness measurement you can measure your continuous stiffness gives assess to structure evolution, that means what is microstructure inside that you can asses it, but shear anisotropy is generally small less than 30 percent deviation accuracy is an issue this is, this is really accuracy it is an issue.

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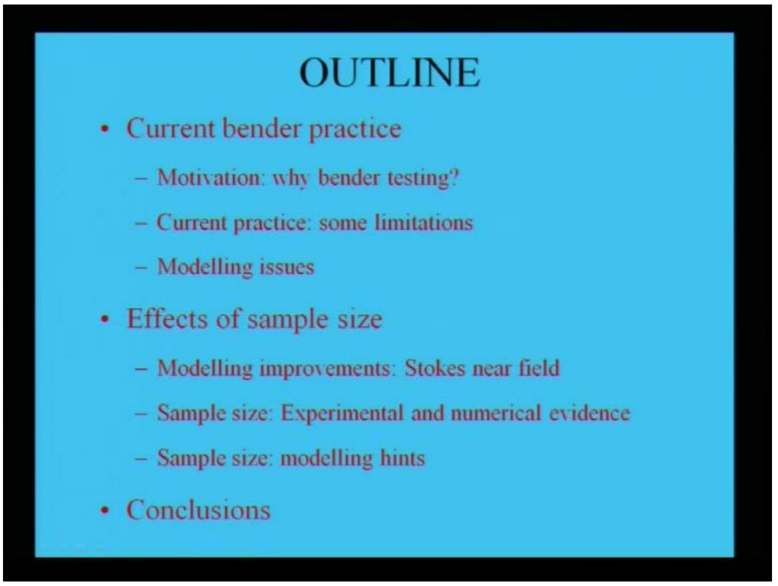

Then what are the outlines we are going to discuss, that means current bender practice motivation. Why bender testing, what for this bender testing is required? As I said the bender testing is required it is more robust, more easily you can find it out in the laboratory particular soil, you can find it out particularly soil. What kind of shear wave velocity inside for that soil you can find it out. What is your shear modulus G? Once you find it out G, G is nothing, but your dynamic property of soil this can be used for design purpose of the or ground response analysis of soil. Then current practice means there are definitely in laboratory test there are sort some limitation, will discuss and modeling issue as I said while doing analysis.

How the bender element results are using in the modeling issue? Then what kind of sample in soil sample in the lab your doing going to do that means effect of sample size also on bender limit will discuss effect of sample size means. If I take a sample size of 38 by 72 or may be 50 by 100 sorry, 38 by 76 or 50 by 100 or 100 by 200. Its meaning is this is your diameter, this is your length, this is your diameter, this is your length, this is your diameter, this is your length that means, what kind of sample size I should take in the lab I have the variety of sample size, I can take also I can take is 38 by 76 or 50 by 100 or 100 by 200 or also 150 by 150 by 300 or also 200 by 400. This I can take it that means reliability of the test, it depend upon your sample size. What minimum sample size is required for this test?

Then modeling, modelling improvements particularly. How the modeling as be to improved? That means in near field one is your far from the field, one is your near field. How it will accuracy data you are going to use? So, that modeling has to be improved then sample size, How it has effect particularly experimental and numerical point of view? How it has effect then also sample size modeling hints also it has to be discussed then, last one your conclusion in this particularly this bender element use I am going to, we are going to discuss one by one all this things may be I will discuss in the next class.