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ADVANCED GEOTECHNICAL ENGINEERING

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Lecture No. 08
Module – 1
Soil Compaction – 1

Welcome to module number 1, lecture number 8 of advanced geotechnical engineering course. So in this lecture we are going to introduce ourselves to soil compaction.

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And we will discuss this in two lectures. Before discussing soil compaction 1, we will try to do some example problems based on the previous lecture that is based on soil classification. We have discussed about activity which is nothing but ratio of plasticity index tool percent clay fraction. And we said that this can be used for classifying some expensive soils.

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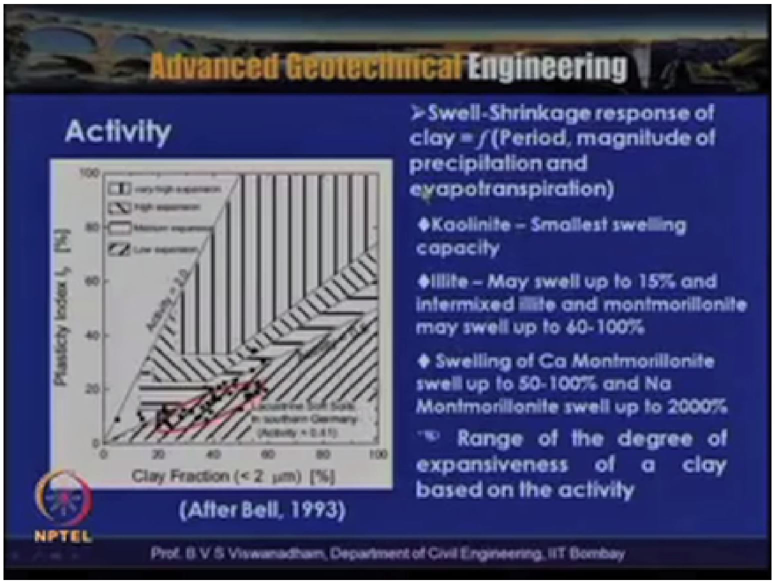

So if you look in to this slide, after Atter Bell 1993, a plasticity index and clay fraction which is less than two micron is plotted. And here different degrees of expansions are indicated, very high expansion somewhere in this zone, and high expansion, medium expansion and low expansion. So the swell-shrinkage response of a clay depends upon the period and magnitude of precipitation and evapotranspiration which actually takes place.

If you look into the minerals Kaolinite has got the smallest swelling capacity and you likes may swell up to 15,000 and intermixed illite and mantmorillonite can may swell up to 60-100%. And as we discussed earlier the swelling of calcium mantmorillonite can be there up to 50-100% and sodium mantmorillonite can be as high as 2000%. So the swell-shrinkage response of a clay depends upon the period and magnitude of precipitation and evapotranspiration which actually takes place in the ground.

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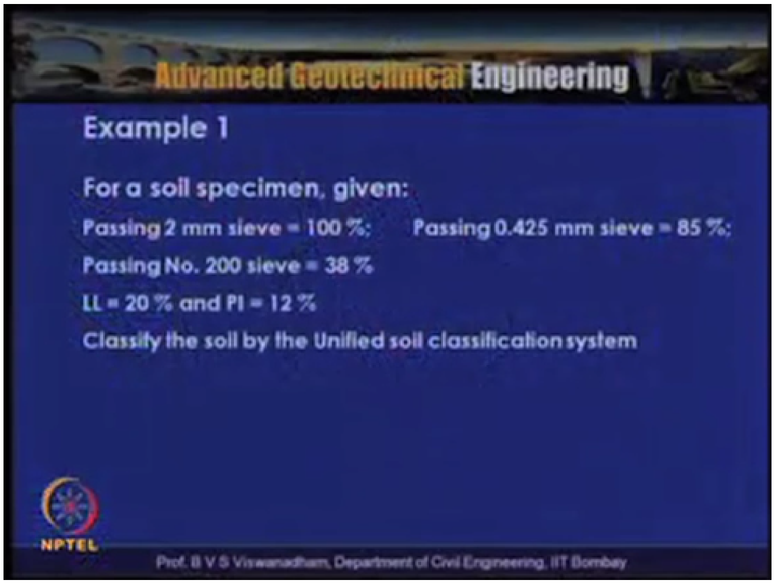

So let us take this example 1, in the example we have been give for a soil specimen that percent is passing 2mm sieve is 100% and percent is passing 0.425 mm sieve is 85%. And percent is passing 200 sieve that is 75 micron sieve is about 38%. And liquid limit of give soil is 20% and plasticity index is 12%. So what we need to do is that classify the soil by the unified soil classification system. Solution for the example 1 was known like this.

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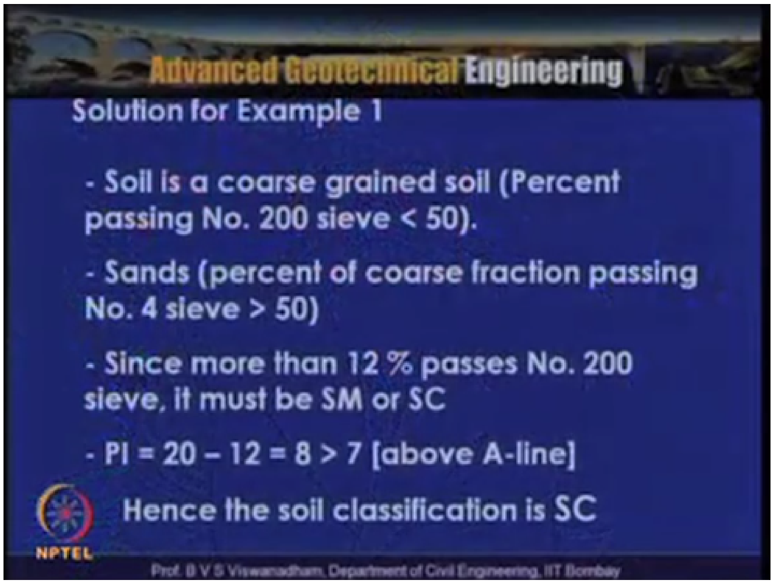

The soil is a coarse grain soil, the percent passing is less than 50% like if you look into the previous slide passing 200 sieve is less than 38%. So soil is a coarse grain soil whereas the fines are less than 50%. Sands, because percent is of coarse fraction passing number 4 sieve is greater than 50. Since more than 12% passes 200 sieve it must be SM or SC. And with the plasticity index is equal to 20-12=8.

So up to 7 we said that it can be just right below the line, so this indicates that of the given liquid limit of say, 20% and plasticity index of 8, it is slightly above A line. Hence, based by using the case of ground plasticity chart we can classify the soil and then above criteria what we discussed as SC.

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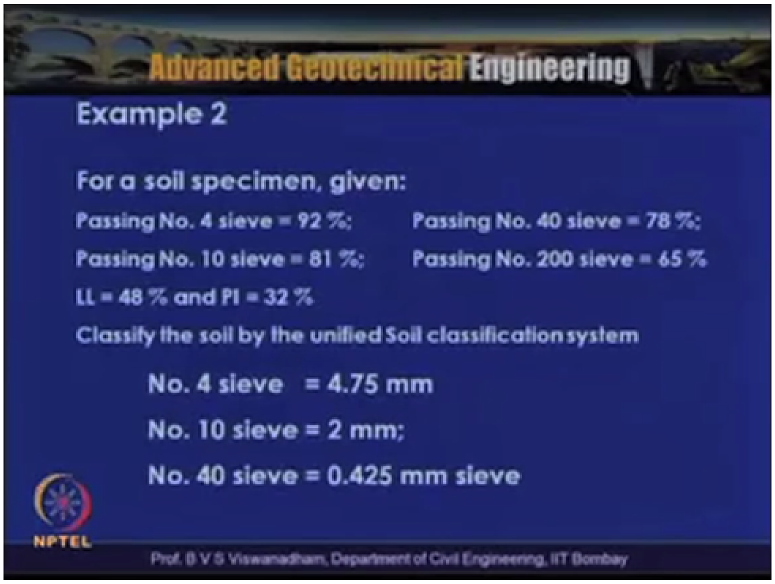

Similarly let us take another example 2, here in this soil sample passing number 4 sieve is 92% that means that number 4 sieve is the thing, but in particle sizes it is 4.75. So particles passing, the size of the particles are the fraction of the particles passing 4.75mm sieve is 92%, and passing number 40 sieve that is nothing but 0.425mm sieve is 78% and passing number 10 sieve is the thing, but the number 10 sieve is nothing but the mm size is 81%.

And 200 sieve is nothing but 65%. So you can see that the percentage finds or more than 50%. A liquid limit is 48% and plasticity index is 32%. So we need to classify the soil, according to unified soil classification system.

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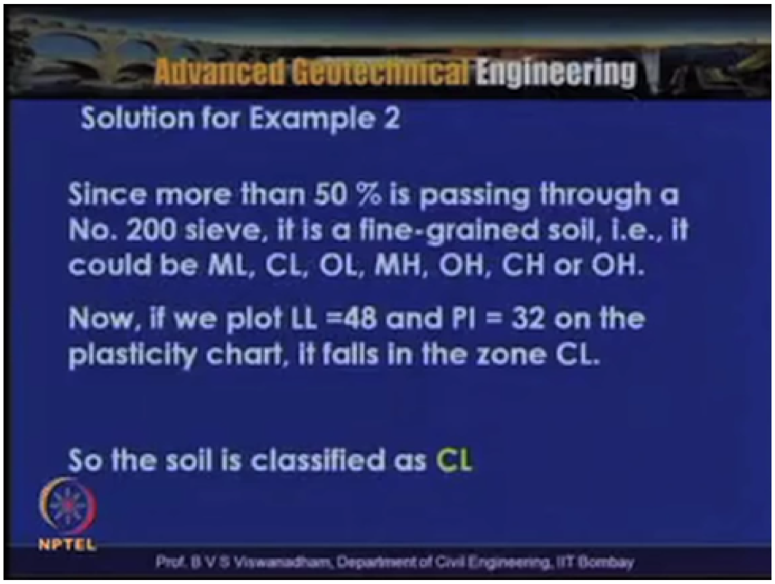

So based on the given data since more than 50% is passing through a number 200 sieve, it can be, it is a fine grain soil all over. It could be ML or CL or OL, MH, OH, CH or OH. So if you plot liquid limit 48 and plasticity index 32 on the plasticity chart, it falls in the zone of CL. So which is liquid limit greater than 30, and which is less than 50. So it is actually falls on the zone of CL. So the classification for the soil based on the given data is CL.

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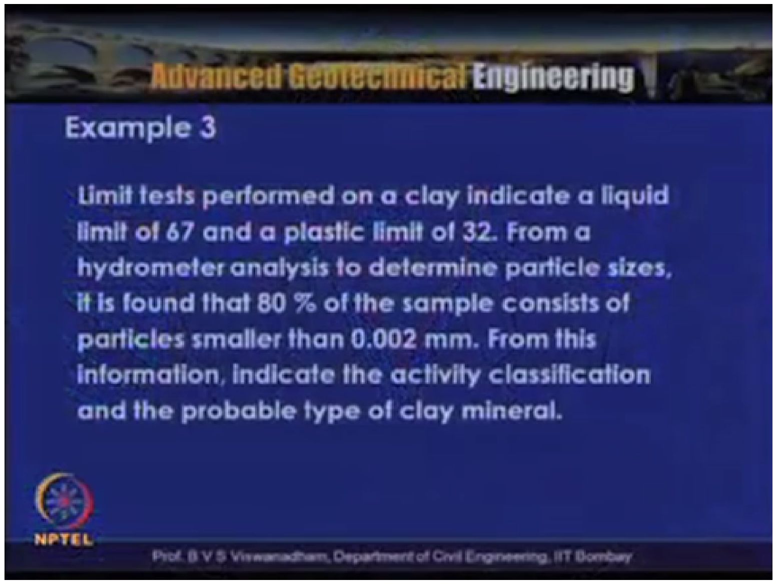

In example 3, limit is performed on a clay indicate a liquid limit of 67 and a plastic limit of 32. From a hydrometer analysis the percentage finds to determine the particle sizes, it is found that 80% of sample consist of particles smaller than 2 micron, 0.002mm. From this information we need to do, indicate the activity classification and the probable type of clay mineral. So we have been given liquid limit and plastic limit.

So we can actually get the plasticity index, and we have been given percentage clay fraction which is about 80%. So we need to indicate the activity, do the activity classification and probable type of clay mineral can be suggested.

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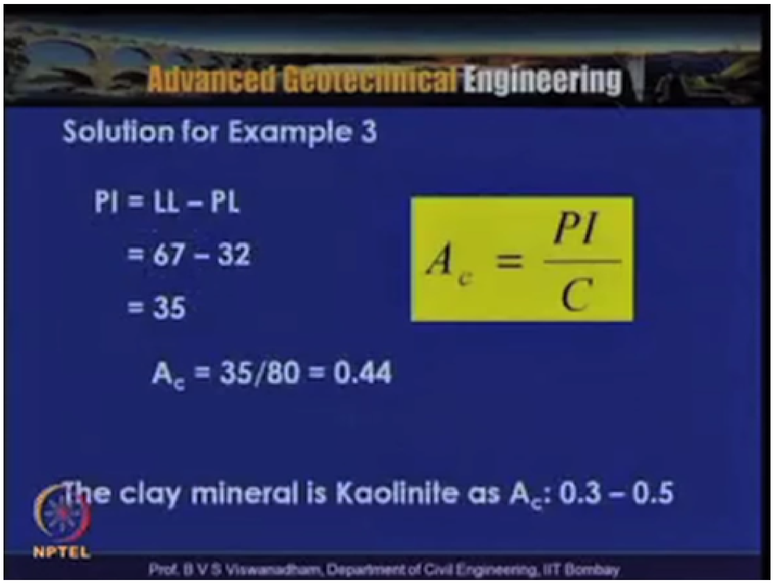

So based on the data the plasticity index is about 35 and so, the activity is calculated as 35/80 which works out to be 0.44. So the clay mineral with the activity in the range of say 0.3 to 0.5 is said to be Kaolinite. So the clay mineral can be as Kaolinite.

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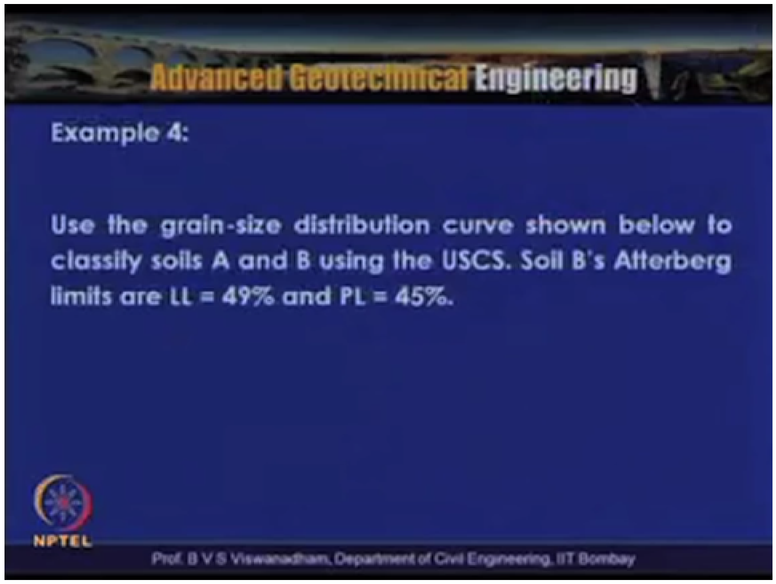

In this example by using the grain size distribution curve shown below like soil A and soil B are given and a soil B has the atterberg limits of liquid limit 49% and plastic limit of 45%. So the plasticity index is about 4% okay. So we need to classify the soil A and B using unified soil classification system.

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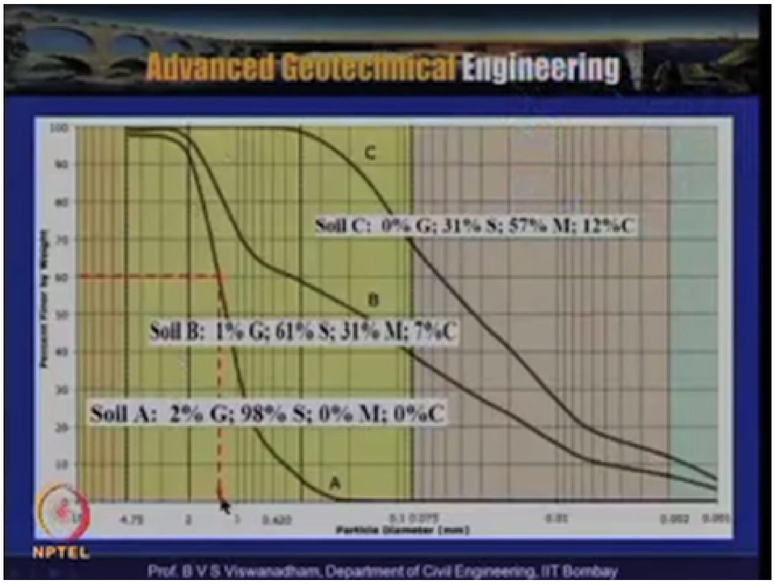

So based on the given data once we draw the grain size distribution curves soil A is mount to have 2% gravel fraction and 98% sand fraction, and 0% soil fraction and 0% clay fraction. So the soil A . That we see is this one and soil B which is actually having 1% gravel fraction and 61% sand fraction and 31% the slit fraction is indicated by M and 7% clay fraction in soil C which is for another example but however these represented here for comparison purposes soil C 0% gravel, 31% sand and 57% silt and 12% clay okay. So the gradation of soil A soil B and soil C is given in this particular slide.

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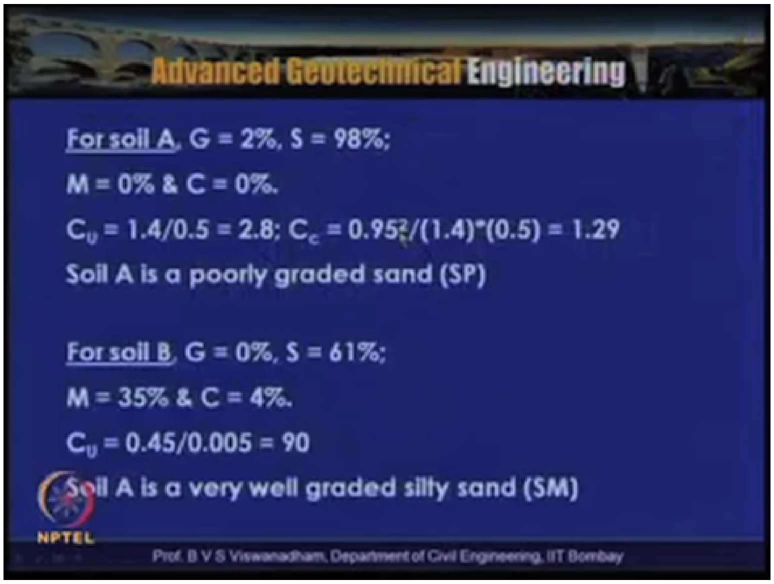

So for A as indicated in pervious slide the gravel fraction is 2%, silt a sand fraction is about 98% and slit fraction is 0% and clay fraction is 0% by calculating Cu which is nothing but D 65, D 10, which can be obtained from the chart here.

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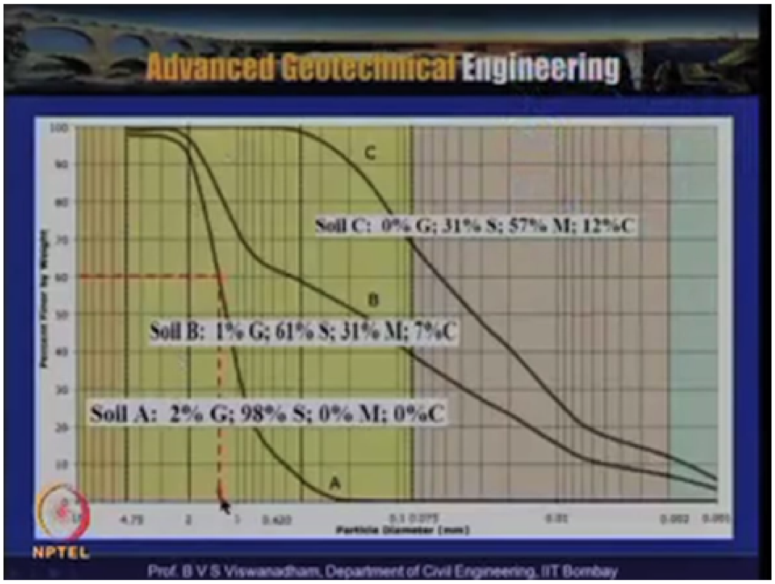

D 60 the particular size which can be referred here similarly D10 for soil A can be referred like this.

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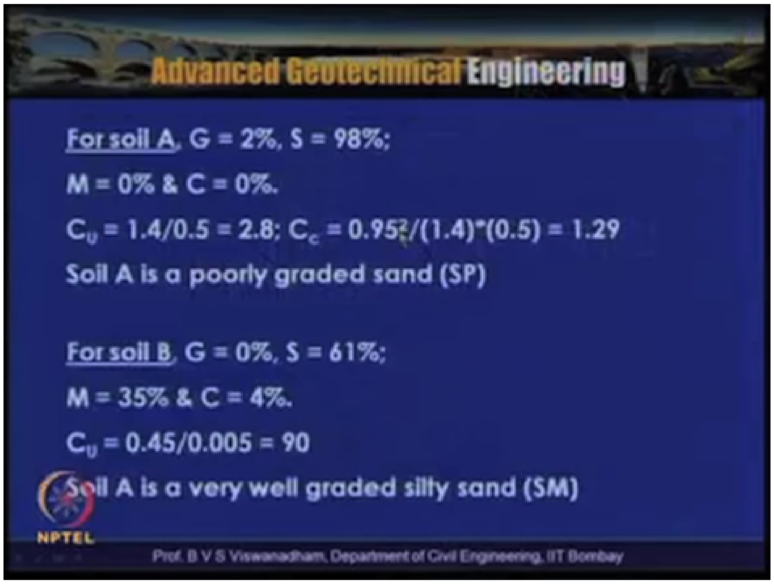

Once we obtain this we can actually calculate Cu and Cc so as can see that Cu is 2.8 and Cc 1.8 and Cc 1.29 so based on the criteria discuss the soil A is a fully graded sand or which is a also said as uniformly graded sand for soil B, G= 0%,S= 61%, and slit content is about 35% and clear fraction is 4% so with this Cu which comes to be 90 is very high so this indicates that this is a very well graded silty sand SM.

So based on liquid limit data also if you look into this the paucity index is about 4% and it is below the air line it falls actually below the line so that is why it is actually called as SM type now having you know understood about the soil calcification let us try to introduce our self to the topic of the today's lecture that is soil compaction or compaction of soils.

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The soil compaction is very important because for majority the geo structures of the structures that actually constructed on soil the soil is actually used as construction material for example highway embankments, railway embankments, earth and darns, canola bands, highway airfield pavements and backfilled trenches and for closing some landfills soil is actually used as a construction material.

So there is always a requirement in some cases it the soil compacted it soil as to give the abdicate note caring capacity in some situations the compacted soil as to act like a varies in preventing ingress of water into the encompassed waste, so when soil is used as foundation material it is desirable that in place material possess certain properties so the purpose if the compaction is to produce us soil having physical properties appropriate for a particular project.

As I said earlier so it is depending on the type of the project the purpose of the soil compaction is basically to produce a soil having physical properties appropriate for a particular project.

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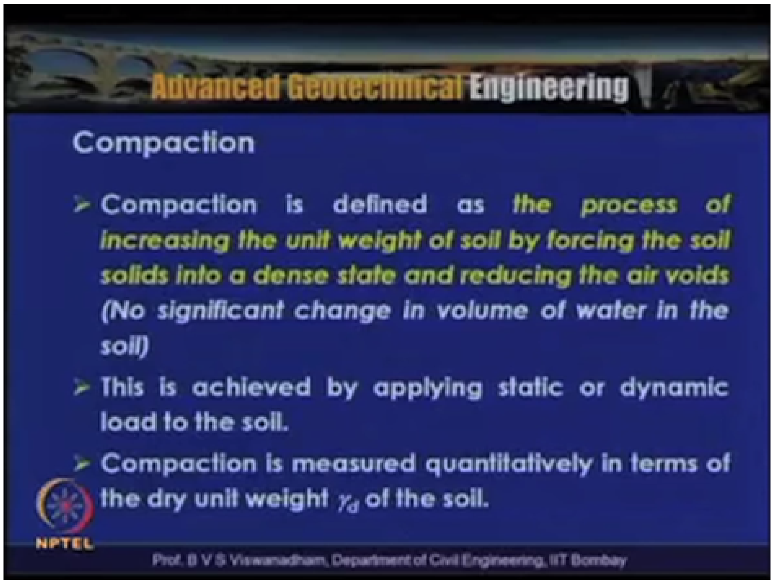

So the compaction how do you define is basically is defined as the process of increasing the unit vector soil by forcing the soil into a done state and reducing the aroids so here this is a process of increasing the unit weight or packing the soil particles into denser configuration and reducing the aired practically in these process no change in the volume of water in these soil is noted it was no significant change in the volume of water in the soil will be there and this is acquired particularly the process on the compaction can be acquired by applying the static or dynamic loads to the soil.

So compaction is measured calculative in terms of the dry unit weight of the soil so if we are able to you know achieve the desired unit weight then we can say that the soil solids is compacted to a desired degree so the compaction is nothing but the process of increasing the unit weight soil by forcing the soil solids into denser configuration and reducing the air voids so reducing the air voids means that there is a possibility of the exponent of the air takes place.

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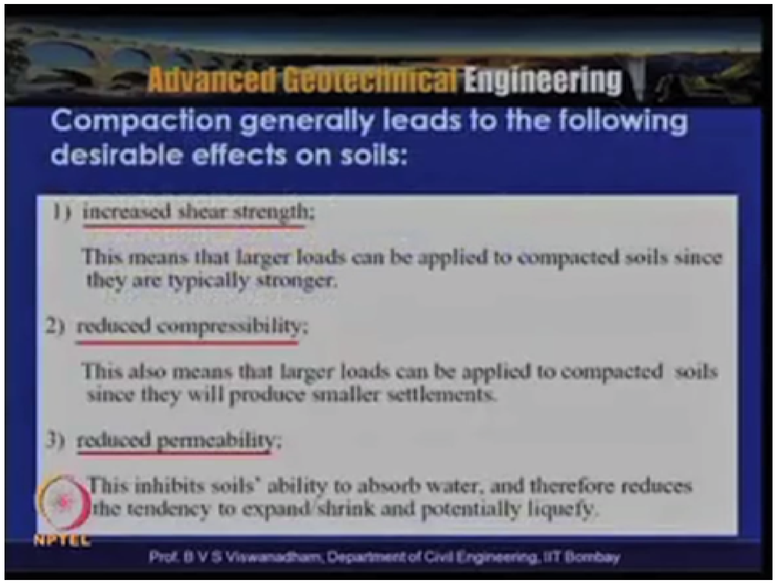

So compaction generally leads to you know it increases the shear strength this means that when you what is the soil which is compacted properly then this means that the larger loads can be applied to the compacted soil since they are typically stronger so increase in shear strength so the compaction of a soil lead to increase in shear strength and reduces compressibility this also means that.

The larger loads can be applied to compacted soils since they produce smaller means that the larger loads can be compacted soil since they produce smaller settlements and also compacted soil inhabit the in a movement of water that means the enable the soils ability to absorb water and therefore reduce the density to expand shrink and potentially liquefied so the compaction process to be soil as got several benefits one is to it reduces increases in shear strength reduces compressibility and reduces reduce in permeability.

So the reduce in permeability basically this inhabit the soils in ability to absorb water and therefore reduce the density to expand shrink and potentially liquefy at the handset of shock loading, why do we lead compaction the purpose of compaction if you look into it as you said in the previous slide maximum shear strength.

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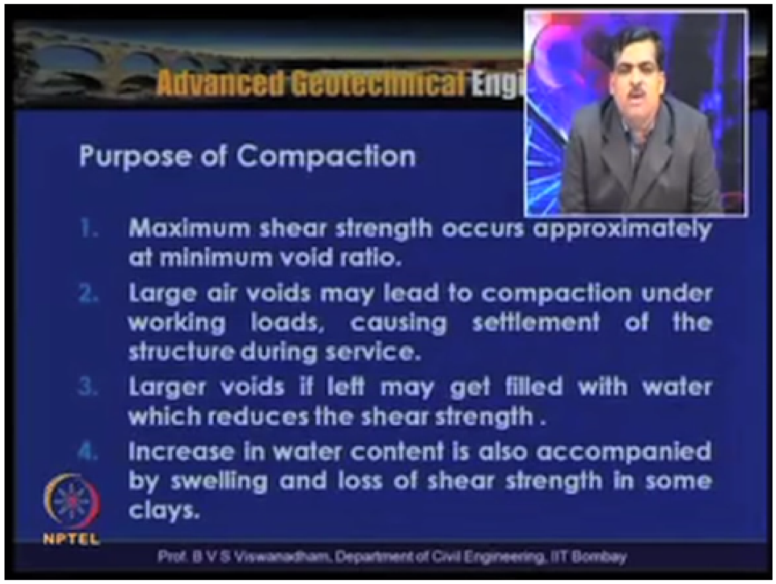

Occurs approximately at a minimum void ratio minimum void ratio is nothing but the which is actually a void ratio at which the particles are actually packed as close as possible and large air voids may lead to compaction under working loads and causing settlement of the structure during service, so under working loads you know larger air voids may lead to compaction and causing settlement of the structure.

So the larger voids if left may get filled subsequently with water band they tend to reduce the shear strength of the soil increase in water content is also accompanied by swelling and loss of shear strength in some clays so increase in water content is also accompanied by swelling and loss shear strength in some clays so when you have a compacted soil with without with large voids the it lead to increase in water content and this can lead to swelling and the loss of shear strength in some case advantages by compacting the soil we can reduce settlements or we can prevent.

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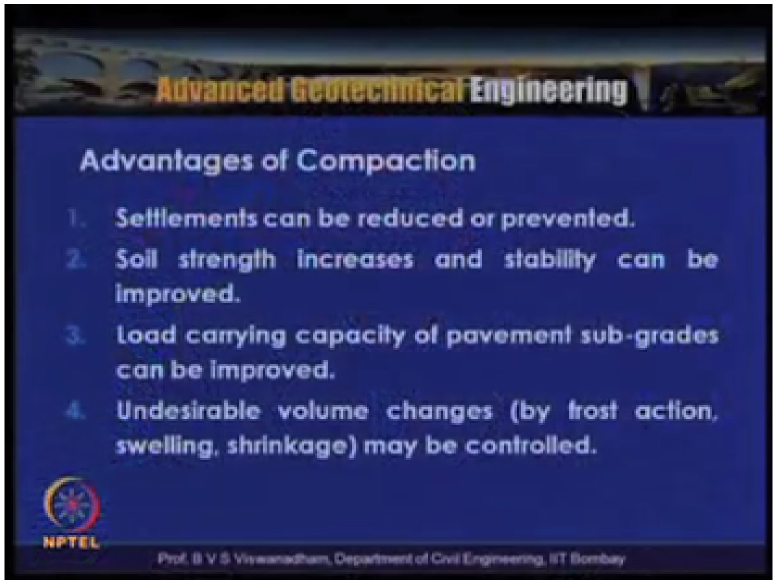

And soil strength increases and stability can be improved and load carrying capacity of the pavements sub grades especially for high way pavements or air feel pavements the sub grades can be improved, and undesirable volume changes can be avoided like frost action or swelling or shrinkage may be controlled undesirable volume changes may be controlled, so these are you know the advantages of compaction.

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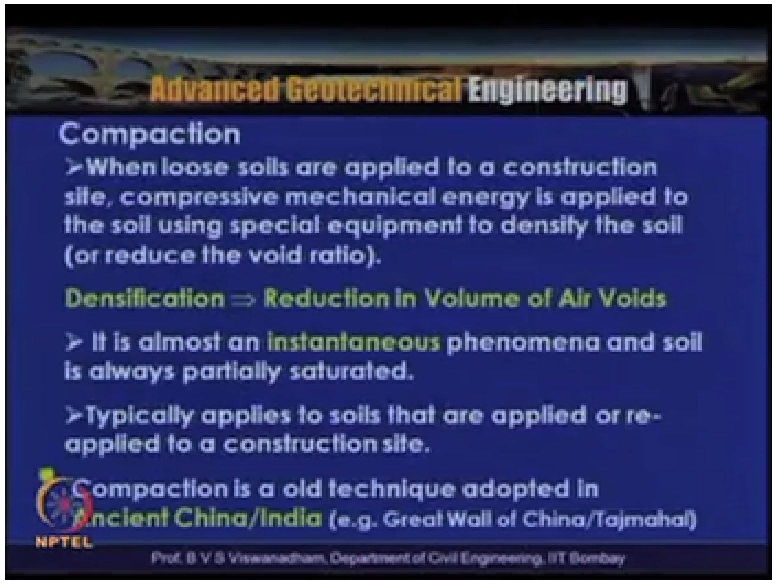

If you look the compaction as a technique as we said that is a process of densification and it leads to the reduction the volume of air voids and it is an almost instantaneous phenomenon and a soil is always demented to be partially saturated. And typically applies to all soils that I have applied or reapply to construction site, typically applies to soils that applied or reapplied to a construction site. And if you look the compaction as a technique is a old technique adopted in Ancient China and India. So compaction is a old technique adopted in Ancient China and India countries.

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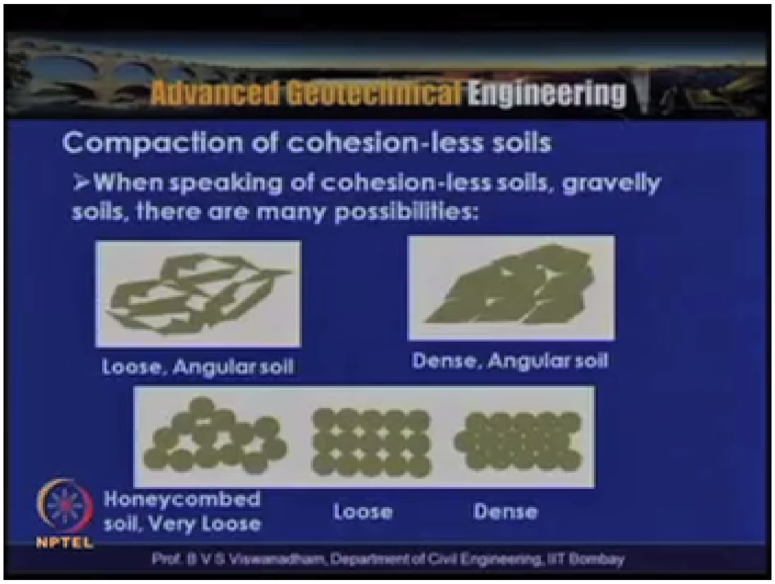

So as we discuss there are two predominantly two types of soils one is cohesion- less soils and other one is coarse soils, so if you look the process of say compaction of cohesion-less soils when I speaking of cohesion-less soils we have gravel is soil sub sandy soils, then we knew that there are different types of particle arrangements are soil fabric. So a loss angular soil may have the so called arrangement like this and when it is compacted or densified the dense angular soli will have the so called the particle arrangement.

And in certain type of sandy soils the under little moist contains conditions it will have honey combed soil and very loose in nature or we have a loose matrix of soil and then and this can actually lead to with compaction with adequate densification the possibility of arriving at densification with this particular type of soil fabric arrangement.

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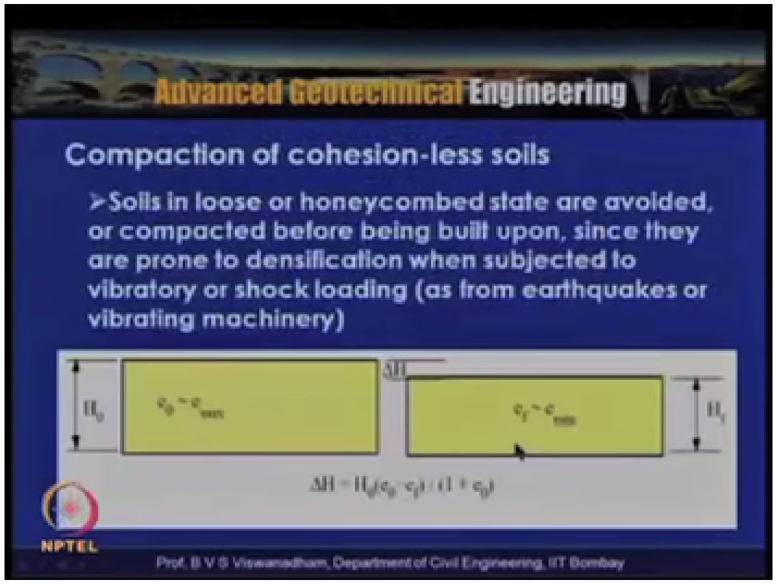

So the soils in loose or honey combed state are avoided or compacted before being build up on, since they are prone to densification when subjected to vibratory or shock loading, so as from the earthquakes or vibratory machinery. So this soils in loose or honey combed state are required to be avoided and are compacted before being build up on. So for example, if I have what a soil with H0 as the initial thickness and of up on compaction the E0 changes to Ef, it is actually closer to the approximately of emin of a given soil.

Then the Δh which is actually a reduction in the thickness is nothing but Δh is which is resulting you to the compaction process the ΔH=H0xe0-ef which is nothing but the change in void ratio from e0 to ef/1+e0 which is nothing but the original void ratio. So the thickness can be calculated by which is nothing but ΔH/H0 which is nothing but the change in length by original length to change in void ratio divide by the one place e0.

We compaction of cohesion-less soils the relative looseness of a soil in it is natural or institute state is determined by measuring a computing its relative density.

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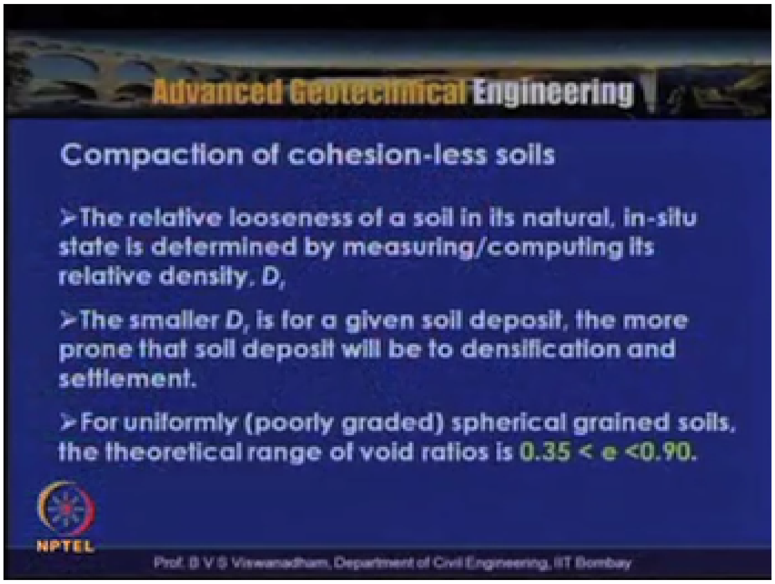

That is D_r, and this we have defined as D_r as emax-e/emax-emin, emax is nothing but the maximum void ratio in the loose state, emin is the minimum void ratio for a given soil in the denies state, e is nothing but the institute void ratio. So the smaller the relative density for a given soil deposit the more prone the soil deposit will be densification and settlement, that means that the smaller the relative density if I have given soil deposit the more prone is for the settlements. For uniformly or poorly graded spherical grained soils the theoretical range of void ratios if you see for uniformly graded soils the theoretically the range is 0.35 to 0.90. 0.35 to 0.90 is the void ratio range for the uniformly graded soils.

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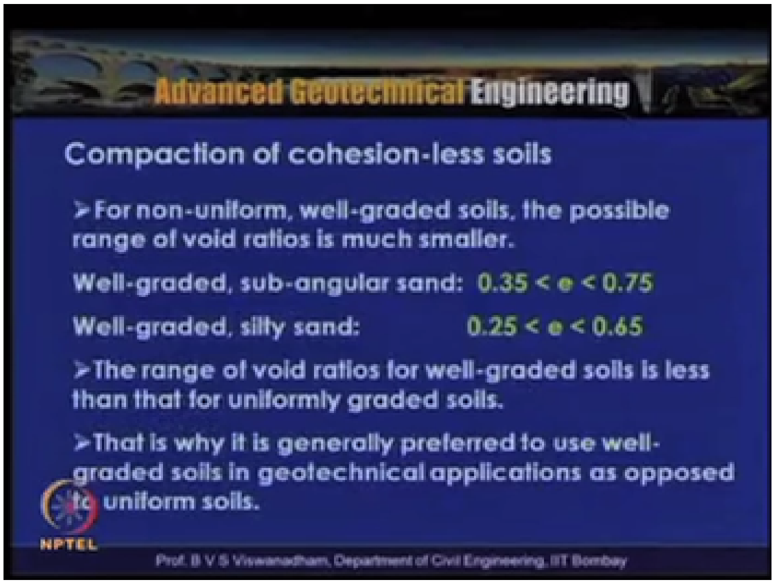

In case of say well graded soil let us sub angular sand the theoretical range of void ratios minimum and maximum is 0.35 to 0.75 and 0.25 to 0.65 for well graded slity sand, so the range of the void ratios for well graded soil is less than that for uniformly graded soils. So if you note down here the range of void ratios for well graded soils is less that that for uniformly graded soils, so that is why it is generally preferred to use well graded soils in geotechnical applications it as opposed to uniform soils.

Because here the range of void ratios for well graded soil is less than that for the uniformly graded soils, so that is why it is generally preferred to use well graded soils in geotechnical applications as opposed to uniform soils.

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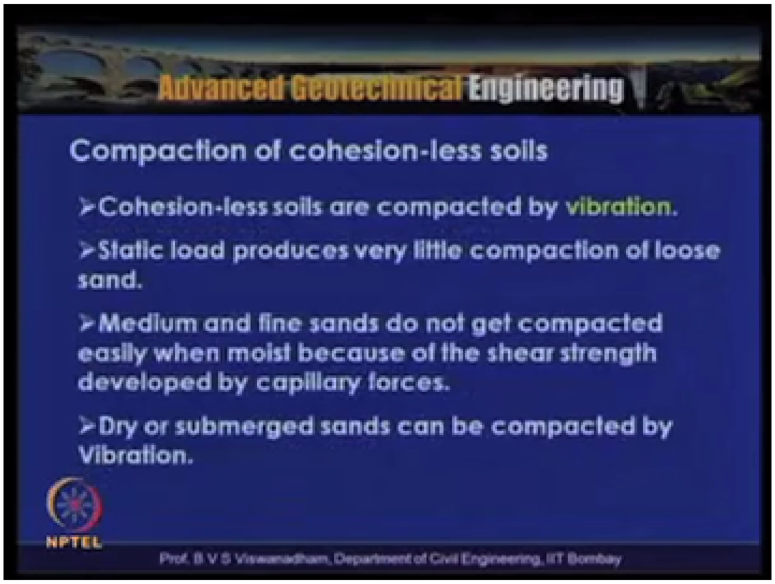

Compaction soils particularly compaction of cohesion less soils can be carried out by vibration only, and if you apply a static load it produces very little compaction to the loose sand and medium and fine sands do not get compacted easily when moist because of the shear strength developed by the capillary forces. So when you have at the medium and fine sands they do not compacted easily when they are moist because of the shear strength developed by the capillary forces.

In the, when they are, when these sands are moist in condition the water which is actually there under that moistness a develop say a thin film surrounding these particles and it prevents and it applies capillary forces and that induces actually very high strength and that makes the you know very difficulty to compact the soils particularly medium and fine sands when they are under moist conditions.

And dry or submerged sands can be compacted easily by vibration, dry sand or submerged sands water submerged sands can be compacted by vibration. So in the previous slide we have noted that cohesion-less soils can only be compacted by vibration contract to this clay soils cannot be compacted by vibration.

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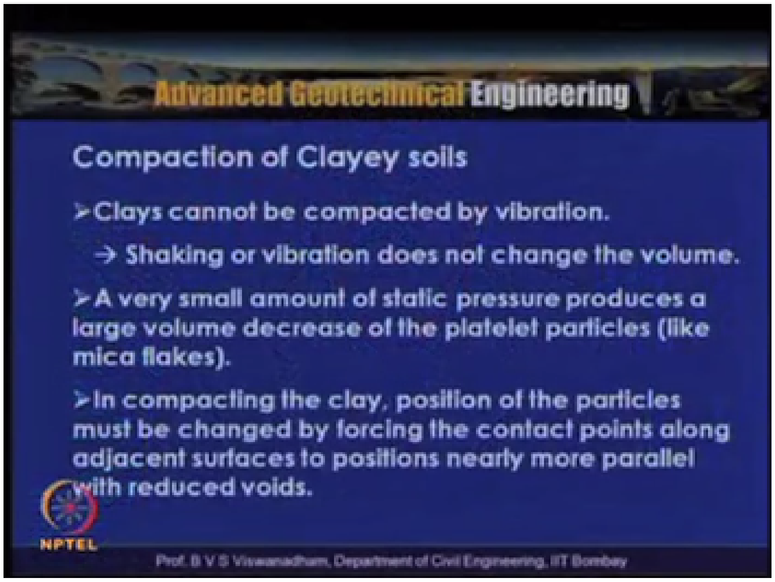

Shaking the vibration does not change you know volume, so very small amount of static pressure produces a large volume decrease of the platelet particles or if you have got mica flakes a very small amount of static pressure application induces a large volume decrease. So in compacting the clay the portion of particles must be changed by forcing the contact points along the adjacent surfaces to portions nearly parallel with the reduced voids, so in the process of compaction the clay in the clay particles undergo rotations and they actually almost take the positions of almost like parallel orientation, so the clays cannot be compacted by vibration and very small amount of static pressure is sufficient to have a you know considerable amount of decrease in the volume.

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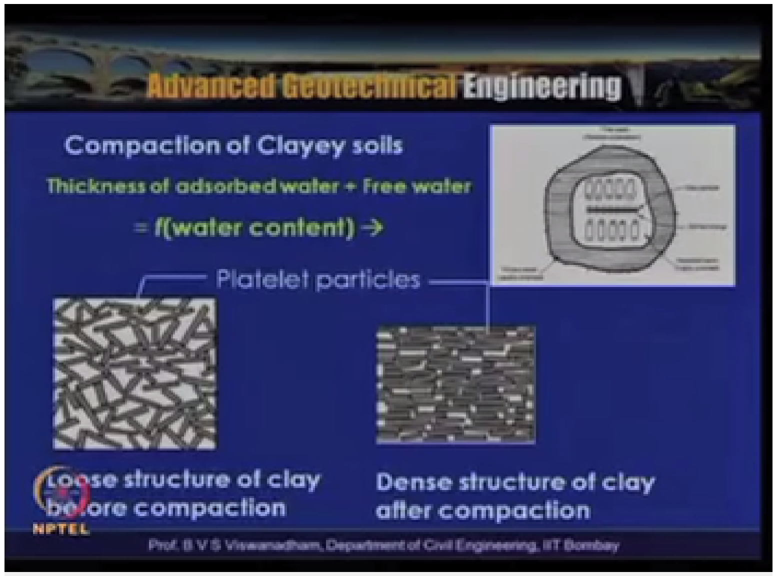

So in this slide if you looking in to this as you all know that we have lent that the clay particle is surrounded by adsorbed water which is actually with you know strong attachment of thick viscous liquid surrounding the clay particles and then it is covered by absorbed water or free water. So in this case what will happen is that the thickness of the absorber water and free water is function of water content okay.

So here in the platelet particles in the lose structure of the clay before compaction and this is the dent structure of the clay after compaction. So this can be achieved by applying or adopting appropriate compaction technique in the field.

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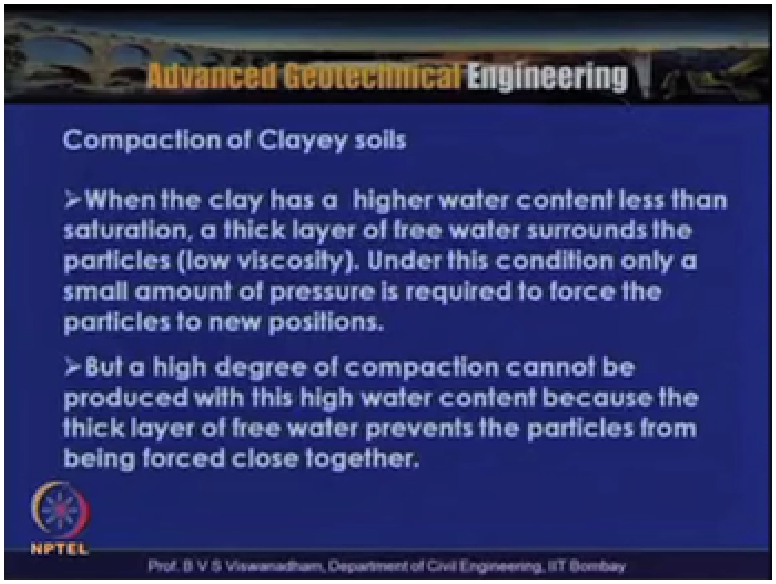

So when the clay has a high water content less than saturation let us say a thick layer of free waters surrounds the particles, so as we seen that a clay particles are surrounded by you know absorbed water so thick layer of free water surrounds the particles.

So under this condition why here a small amount of pressure is required to force the particles in to new positions but a degree of high degree of compaction cannot be produced with this high water content because this thick layer of free water prevents the particles from being force close together. So this high amount of thick layer of free water also prevents the particles from coming closer okay.

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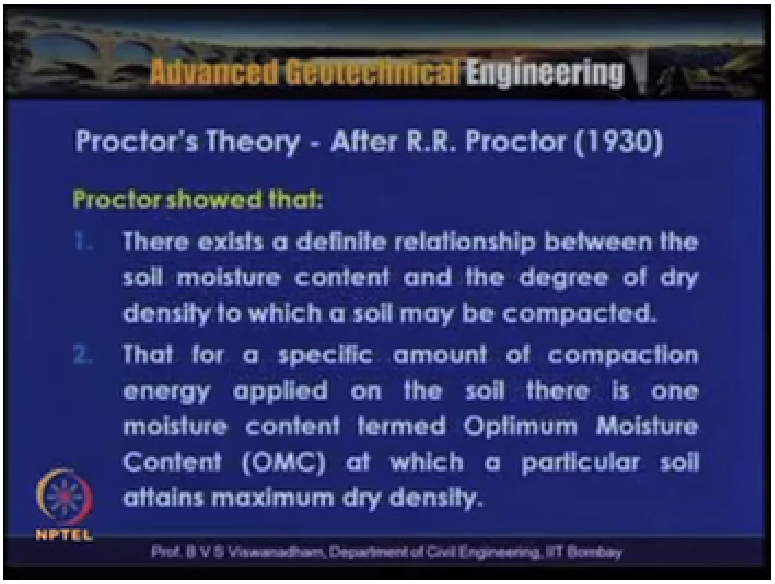

So in this process before discussing about the field compaction methods let us actually looking to you know the proctor theory were in the process of actually compaction has been define by R. R. Proctor in 1930, so Proctor showed that they are existed definite relationship between the soil moisture content and the degree of dry density or unit weight to which soil maybe compacted. And that for a specific amount of compaction energy applies to the soil there is one unique moisture content and that is referred as optimum moisture content at which a particular soil attains maximum dry unit weight.

So the Proctor prostrated that upon application of a specific amount of compaction energy plus for to this on the soil that there is a unique moisture content which is actually called as optimum moisture content at which a particular soil attains maximum dry density.

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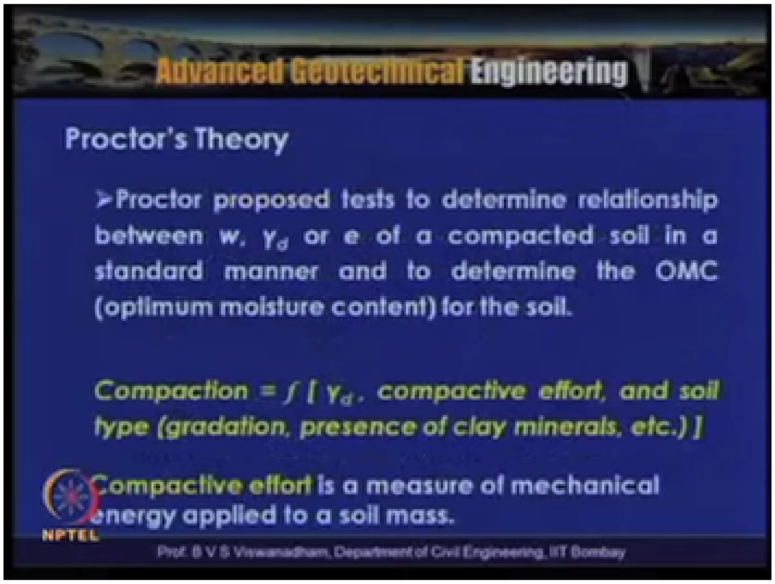

So proctor propose test to determine relationship between water content dry unit weight and wide ratio of a compacted soil in a standard manner and to determine optimum moisture content and dry unit weight of the soil So compaction is a function of dry unit weight of the soil compact to effort that is the amount of energy applies to the soil and the soil type. So if you look this soil type you knew that the gradation presents of clay minerals etc. so the compaction of a soil is found to be function of several factors and some of the factors which are actually listed down are here.

So comp active effort is a measure of mechanical energy applies to a soil so we will be using this particular technology compactive effort. So the compactive effort is defined as a is a measure of mechanical energy apply to a soil mass.

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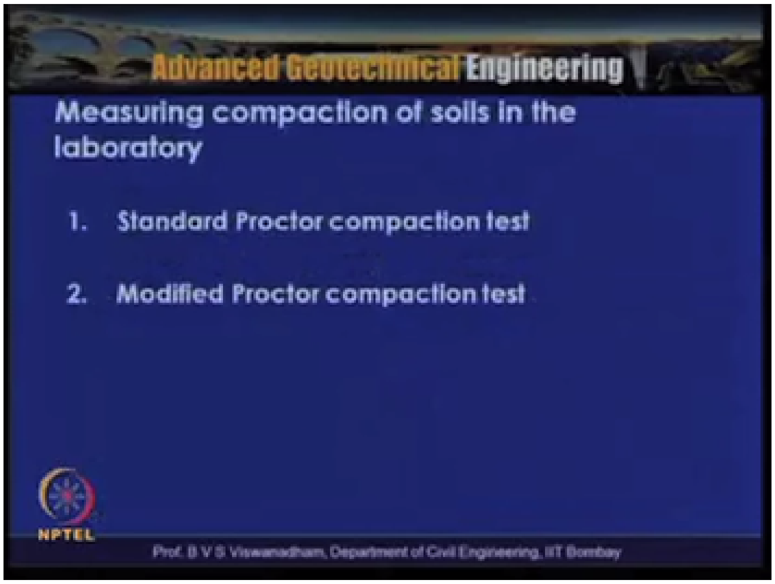

So in the laboratory the two methods have been devise one is standard proctor compaction test and modified proctor compaction test and as for the Indian code it is also called IS like compaction and modified proctor test is called as highest heavy compaction. So it has been thought that for achieving higher hidden cities at low moisture contents and this was actually thought to be possible basically for constructing highway in air field applications.

The modified proctor compaction test was actually developed, so the scope for the standard proctor test is that.

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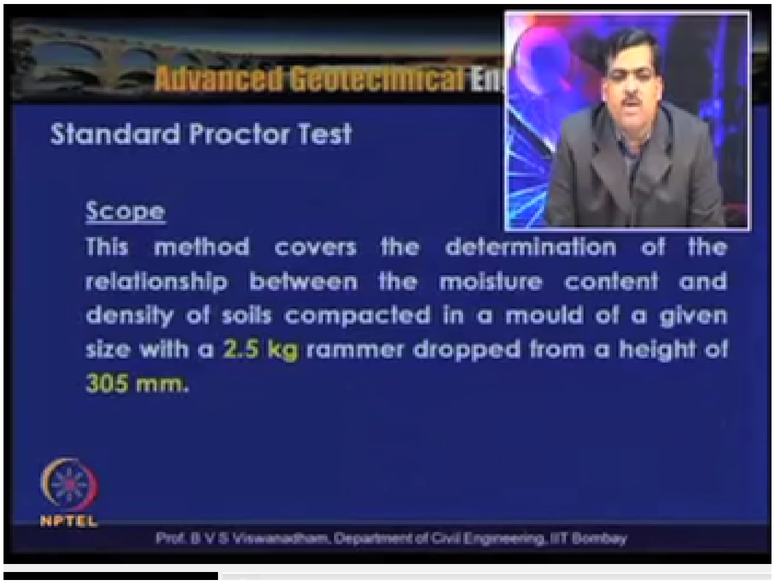

This method basically covers the determination of relationship between the moisture content and density of soils. Compacted in a mould at a given size with 2.5 kg rammer, so about 2.5 kg of rammer dropped from a height of 305mm, so here the number of layers which are actually involved in a mould of you know fixed size where three layers which are actually require to be compacted with an energy of say 2.5 kg x the drop weight of a mould 0.305 m or 305 m this is a free drop height.

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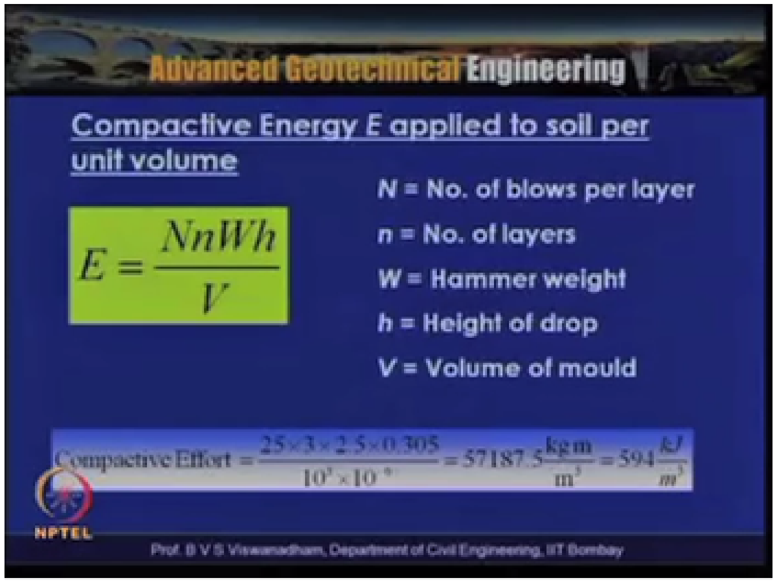

So the compactive energy can be calculated for in case of standard proctor compaction test it is like this which is compact to effort is nothing but 25 which is nothing but the number of blows three small and then nothing but the number of layers as I said that it is 3 layers and weight which is nothing but 2.5 kg that is weight of the hammer and height of drop in meters it is 0.305 / 10 3 x 10 -6 I will get about 57187. 5 kg m per m3 or 594k j per cubic 3 this is actually the energy which is applied in standard proctor compaction in the laboratory.

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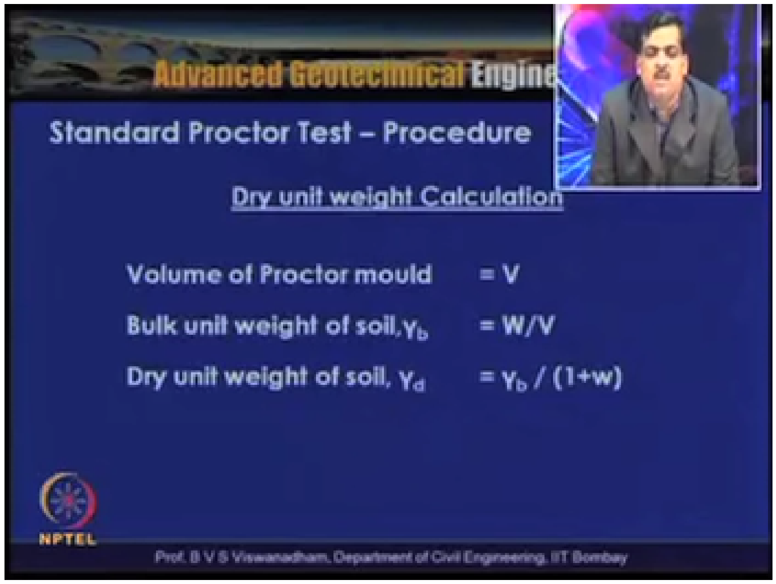

So the calculations which are actually involved is that once we know when the given soil once we take when you start increasing the water content you will actually measuring the bulk unit weight of the soil at each water content once it is compacted. So the each stage will be noting down a bulk unit weight that is weight by volume and once by determining the water content we can get the dry unit weight of the soil γ d as γ bulk / 1 + w so we will be able to calculate for a given water content what will be the different dry unit weights.

So once you plot these things you will have a normally a bulk shaped curve with a peak at a predominant point the partial way the peaking of the curve occurs that is actually on the y axis it is referred as maximum dry unit weight on the x axis it is referred as the water content that is nothing but the optimum moisture content or optimum water content.

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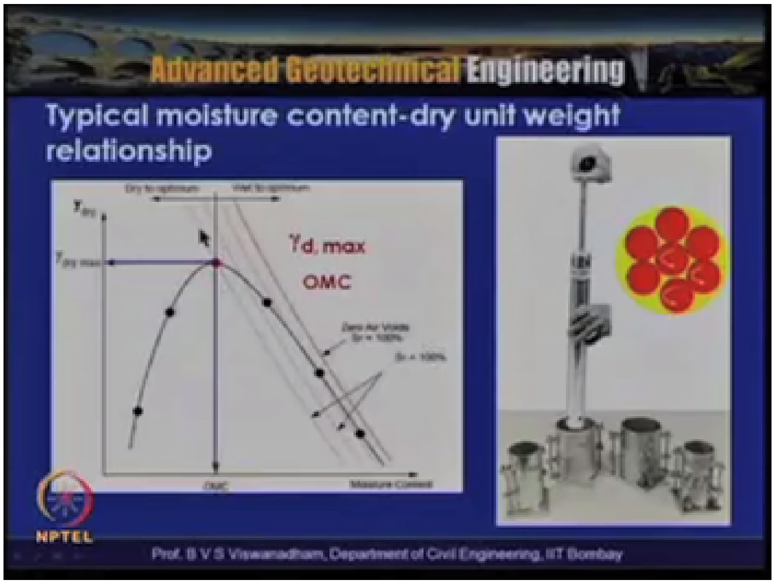

So as we discuss here in the typically for a given soil we have got γ d 1 and for that water content w 1 and a for a given water content w2 where w2 is actually more than w1 then we have got γ d 2 and then there is one particular water content at which you know the density was high the unit weight was high and then there is a decrease in the density, so if you see that you have got you know dry to the optimum so this is actually called as optimum moisture content so this is called the dry side optimum and this is called the wet side of the optimum and these are actually called as you know zero air void line so zero air void line is nothing but 100% saturation line.

So this is an hypothetical line what you can see is the hypothetical line and the downward limb of the it was the wet side of the optimum and the zero inwards line can number cooling inside because 100% you know X function of A is not possible so the soil in this case remains always in the partially saturated state only so this is the you know indefinite to compaction mole.

And the in the given area the each and every location the energy has to be supplied uniformly by dropping this 2.5 kg hammer that the drop feet up .05meter like this which is actually shown in this side so here what he actually happens is that this actually make the soil is actually compactable uniformly.

So if we looking to this there is the region where this increase in the density where the water contents actually continuous upon increase in certain water content beyond this so called optimum moisture content what we are seeing is that the same soil mass is experienced with decreased in the dry in the weight of these soil.

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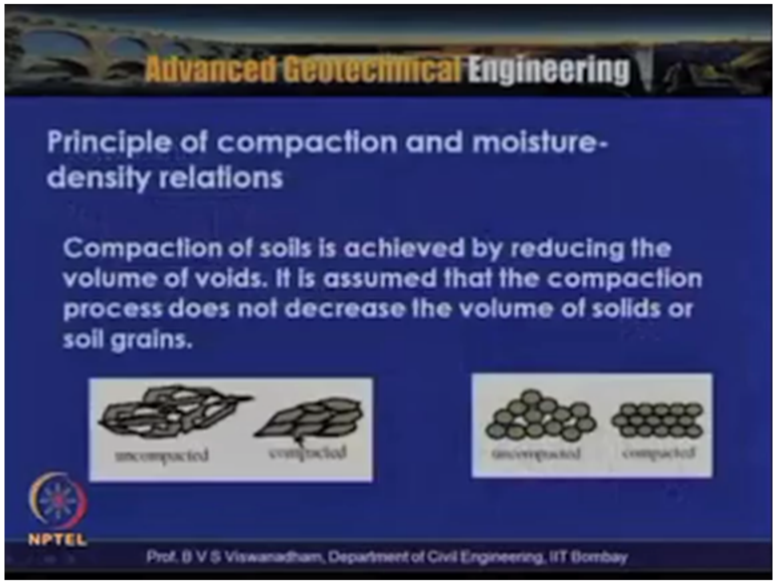

So the principle of the compaction and the moisture density relations if we looking to this compaction of soils is achieved basically by reducing the volume of voids that is what we have discussed and it is assumed that the compaction process does not decraese the volume of solids or soil grains so the compaction process does not decrease the volume of solids, volume of solids remains to be same what is actually changing is that the volume of the voids for example here this is the process of the soil which is uncomptible and this is the compacted or this is particular particle arrangement which uncomapacted and configuration which is actually shown here.

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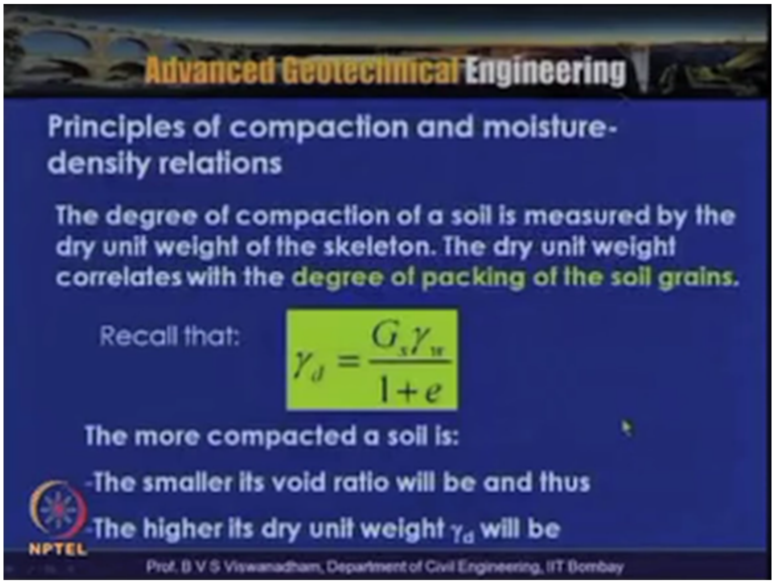

The degree of the compaction of the soil is basically measured by the dry unit weight of the soil skeleton the dry unit weight can be computed in basically because there is not that dry unit weight basically correlated the degree of packing of the soil grains so if we can recall the dry unit weight can be given by $\gamma d = G_s \gamma_w / 1+e$.

So the more compacted soil is the smaller is the void ratio will be and then higher will be dry unit weight so the smaller is the void ration and the higher will be the dry unit weight so the degree of the compaction of the soil is basically measured by the dry unit weight of the oil skeleton and the dry unit weight correlated the degree of the packing of the particles in a given volume.

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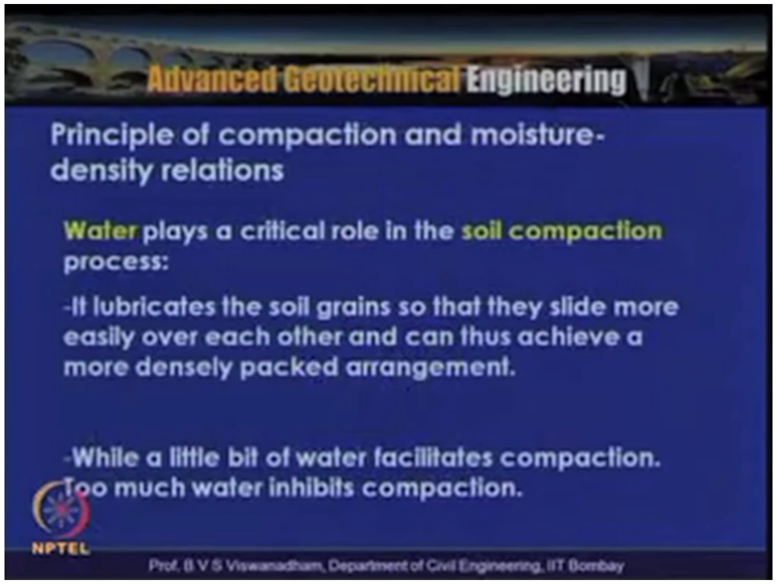

So if we look into this as we said that in the previous slides we have when we plot γd that is in the dry unit weight with water content and ask the water content, water content is added to the soil mass there is the increase in the density at a certain point there is a you know decrease in the density takes place so for a normal soils the water place a critical role in the soil compaction process.

It actually depends upon the that side so it lubricates that oil grains so that they slide more easily over each other and can thus achieve a more density packed arrangement so water which we are actually supplying in the process of increase in the water content to the given soil mass the water actually acts k lubricating the agency so make the soil grains to skip into the density conservation.

While and little bit of water facilitates compaction and too much water also inhibits compaction thus weight we have seen 0oon the wet side of the optimum towards the wet side of the optimum upon adding water we have seen that there is decrease in the density of the soil mass so what is actually the mechanism which is actually happening.

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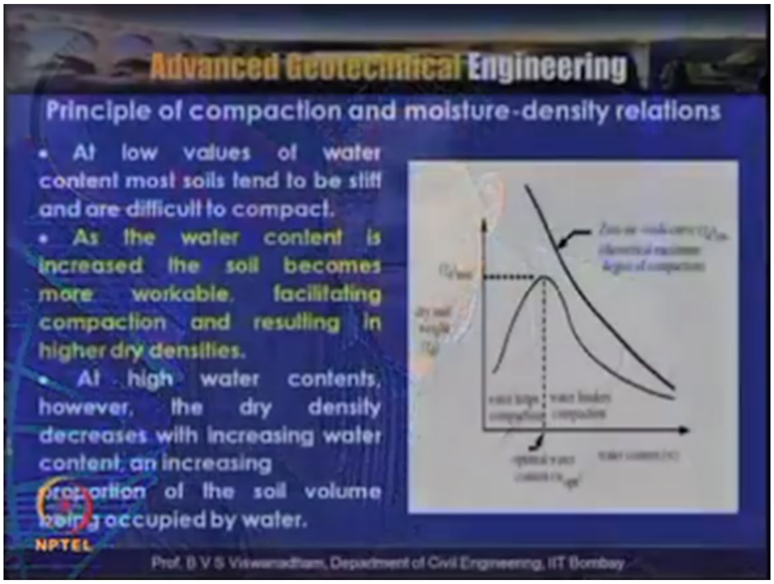

If you see here water actually helps the compaction here and water actually hindrance the compaction so this is the zero void line so theoretically this is the maximum degree of the compaction son which is also called as this is hypothetical line so here water is actually helping the compaction here water is actually hindering the compaction.

So if we look into this at low values of water content most soils actually tend to be stiff and a difficult to compact so as the water content is increased soil becomes more workable because of the lubrication actually provided buy the water facilitating the compaction and there will be in the higher densities so as the water content is increased the soil becomes more workable and facilitating the compaction and they facilitating in the higher dry densities or dry unit weights.

At higher water contents what is actually happening is that the dried is increases with increasing water content that is what actually we are seeing here on the wet side of the optimum this is the optimum water content so on the wet side of the optimum there is decrease in the dry density this is because with increase in water content and increasing proportional soil volume is now being occupied very later so as we are actually increasing the water the increase in proportion of the water is being occupied by the soil volume and increasing proportion to be the soil volume being occupied by the water so because of these as we know that ρw that is mass unit water is much, much less than ρs.

Because of that what will happen is that the density decreases so what we see is that at low volumes of water content the most soil tend to be strictly and a difficult to compact as the water content is actually increased the soil becomes more workable and facilitating for the compaction so the principle of the observe phenomenon is actually explain in this particular slide.

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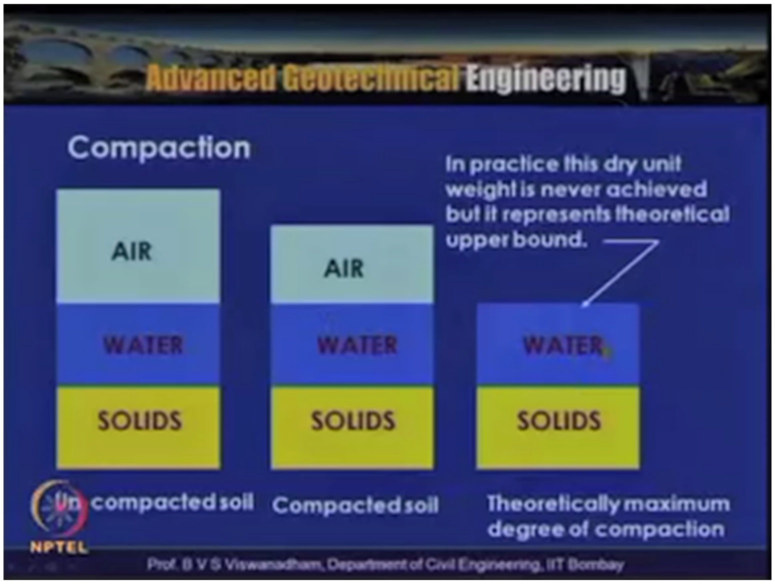

So this is you know uncomapacted soil which sir actually shown in the three phase diagram so throughout the process of compaction it actually remains in the three pause straight and this is actually impractical that dry weight is never achieved but it represents the theoretic upper bound value us complete removal of A which is actually not possible but this is theoretically maximize degree of compaction which is actually possible.

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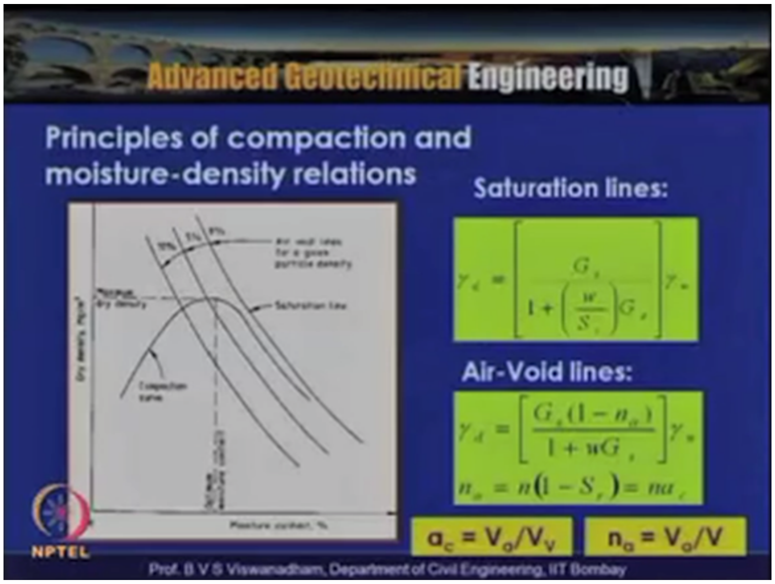

So once we get this relation of dry density or dry unit weight with water content and once have maximum dry unit weight and maximum optimum water content we can actually construct this air voids line or you know zero percent air voids line or we can also construct 100% saturation line both are same.

So this is actually possible by the saturation lines can be obtained by this relation $\gamma d==G_{s+}1_{+}W_{gs/}sr_{*}\gamma_w$ here when sr=1 that is in case of say percent saturation line then the equation for that is nothing but $\gamma d=G_s\gamma_{w/}1+wgs$ so here if you looking into this at optimum moisture content and maximum dry unit weight the soil has got 18 you know normally for 80 to 90% of the way of saturation and similarly in another terminology we can also write, we can also draw Air void lines. Air void lines is nothing but air void % air void can also be defined as volume of A in the total volume of Y, total volume of the soil mass. Air contended is nothing but volume of the air in the volume of voids. So here the γd = Gs x 1 na/ 1 + w Gs x γw.

And A = n x 1 – Sr by using this we can actually get these you know saturation lines and air void lines plotted. So this is explained once again the saturation line is a hypothetical line and points and the line below the density.
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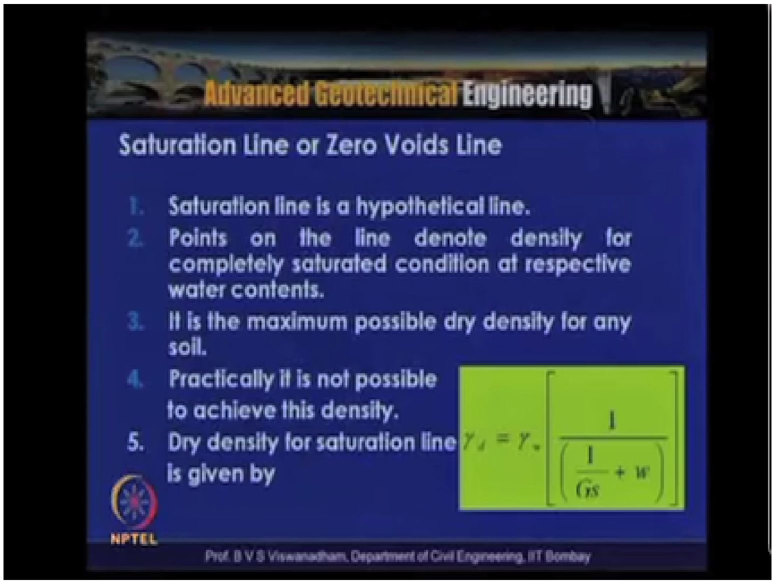

Denotes the density for completely saturated condition at respective water contents, it is basically then it is the maximum possible dry density for any soil and practically it is not possible to achieve these density. And the dry density for the saturation line can be obtained by this particular expression as we discussed already.

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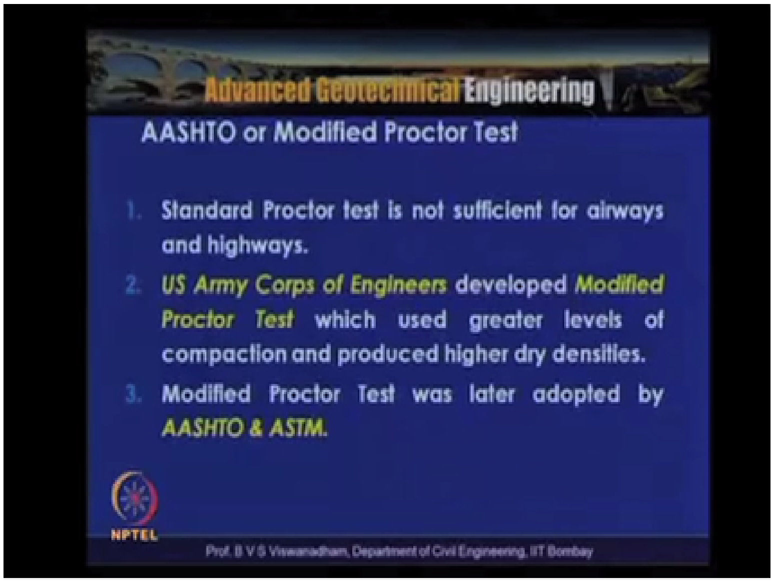

Then as we discussed that there are also another test one is that standard proctor test then for in order to achieve higher densities modified proctor test has been devised by Astor which is actually why we adopted it is developed in the US army Corps of engineers, developed the modified proctor test which used greater levels of compaction and produce the higher dry densities. So modified proctor test was later adopted by AASHTO & ASTM.

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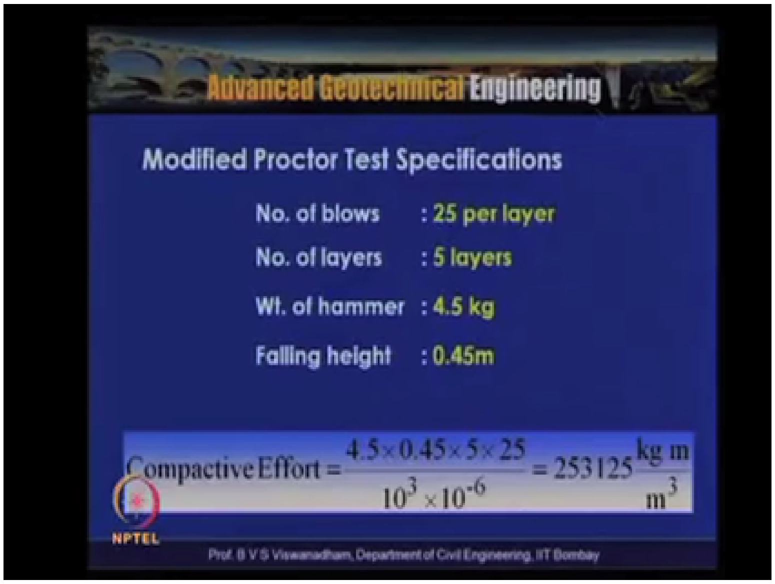

So in this modified proctor test we have number of blows that is remains constant 25 but instead of 3 layers in standard compaction test the modified proctor compaction test has got 5 layers and the weightier the hammer is 4.5kg tin comparison modified proctor compaction test it was 2.5 kg and the following height 5.4m.

So what we are actually doing is that we are actually supplying about 4.5 times the energy, so if you calculate the energy or then apply to the in the modified proctor compaction test, the compactive effort is actually about 253125 kgm/m^3. So this is actually approximately the 4.5 times the energy supplied in the standard proctor compaction test.

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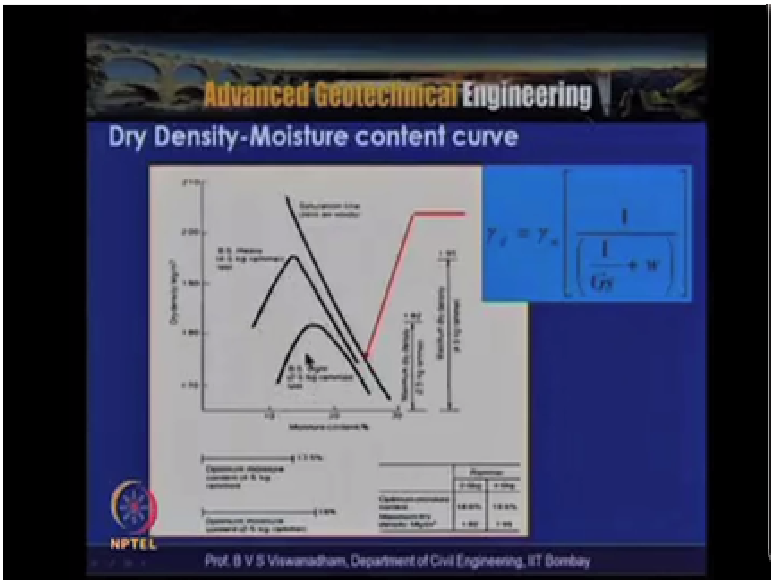

So here with increasing compactive effort this is with IS light compaction and this is with heavy compaction, so if you can see that with increasing compactive effort there is decrease in the optimum moisture content and increase in the density. So there is the possibility that with increase in the compaction for the given soil is possible for us to achieve denser configuration, that means that by applying the higher energy to the soil the possibility of achieving the denser configuration is same.

But however applying energy say to more soils or completed saturated soils can also lead to advantages and more then certain number of energy may not be decided. So the importance of the proctor test is that it gives the density that must be achieved in the field.

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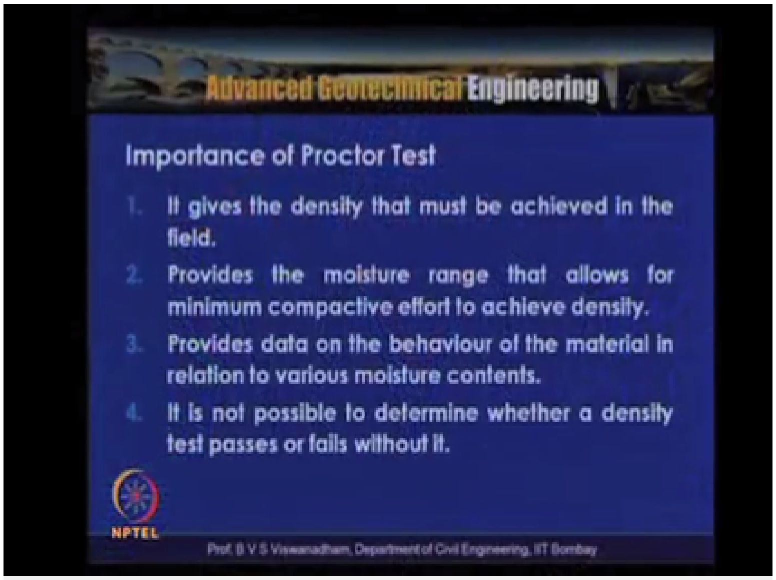

Once we have the regression soil which have been selected for the construction it gives the density that must be achieved in the atmosphere field and it provides the moisture range that allows for the minimum captivity effort to achieve the density and provides the data on behaved on material in relation to various moisture contents. And it is not possible to determine whether the density test passes or fails without it.

So once we have the data and once we verify the density achieved in the field then there is possible for us to achieve to assess the degree of the comparison which is actually achieved in the soil. Now if you list out the factors influencing the compaction there are as we discussed soil type.

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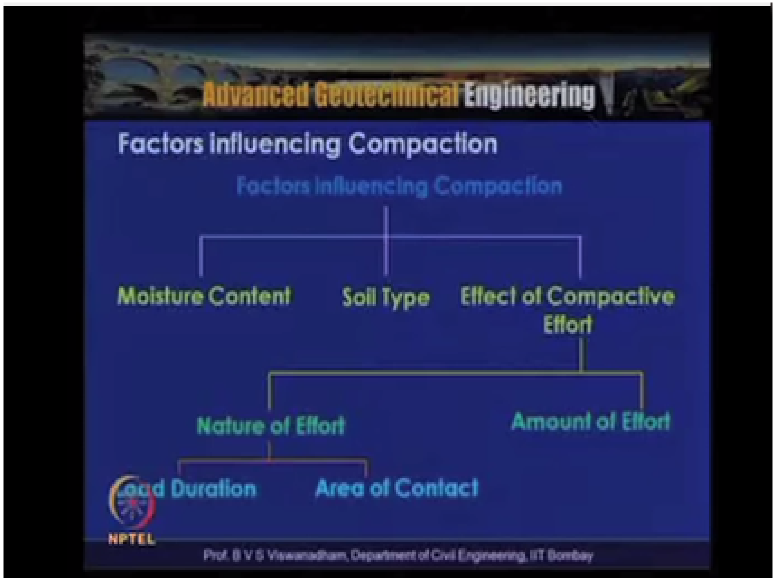

Is one of the predominate factor then moisture content suppose if you got a sandy soil and if the moist in nature it actually exhibits a certain phenomenon and upon the increasing the moisture content you know it behavior changes. Similarly when you have got soil type then whether it is the CL type of soil, there is the possibility the influence on the compaction.

We have just now discussed with that increasing compaction energy reduce optimization content because what is actually happening is that the apply energy makes the particles to adjust in the denser configuration so it facilitates with particle rearrangement and at low moisture contents itself and the effect of the compactor effect is again sub divided as the nature of the effort like in the area of contact.

So sometimes the some soils the area of the contact play a very crucial role and effect of the compactive effort is nothing but the amount of effort. How much is being applied to the soil? So soil type which is again grain size shape of the soil is grain amount and types of mineral clays present and that GS of the soils.

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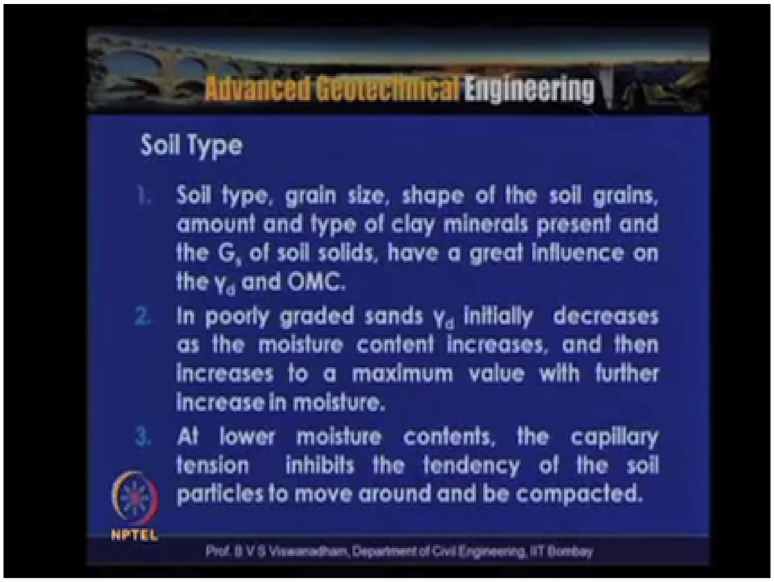

Greater influence on the dry unit weight and the clay moisture content, suppose you have got poorly graded sand, that is say the uniform graded sand usually there is the decrease in the moisture content and then increase to a maximum value with further increases moisture content. So if you see at low moisture contents them is the possibility of capillary tension which actually inhibits the tendency of the soil particles to move around and compacted.

So what will happen is that at low moisture contents the soil density decreases and upon increase in the moisture content what will happen is that the soil fillings which are actually surround, the water filling which are actually surrounding the grains get washed or diminish. So taht5 makes the soil particles to again rearrange into the denser configuration. So this particular phenomenon is actually happens on sandy soils. And this is actually the capillary phenomenon, so here in this particular slide.

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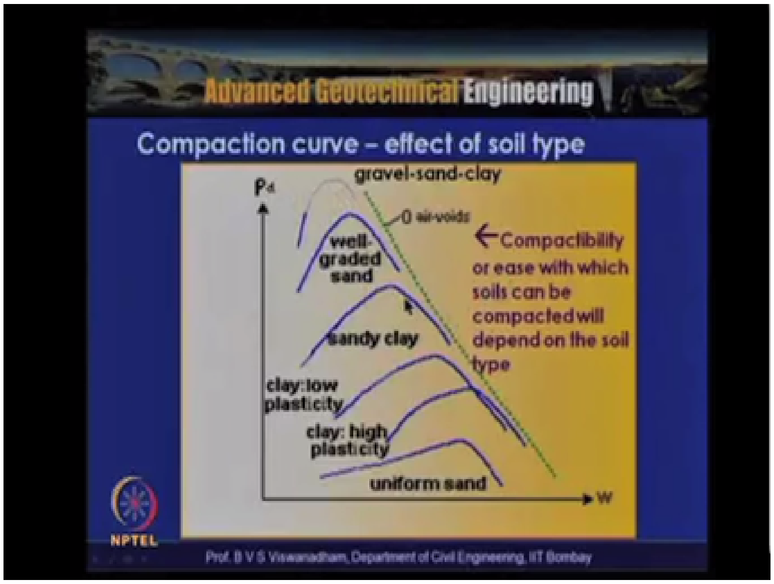

If you can see that the compaction curves for with different soil types are shown here what you see is for this is for uniform sand, infact for a sand there will be a decrease and then increase so what you are seeing is for the uniform sand and if you see here the clay of high plasticity and then clay of low plasticity. So clay of low plasticity can actually get a higher density and low moisture contents and clay of high plasticity have low density.

Similarly sandy clay and well graded sand, well graded sand have higher and lower optimizer content, similarly gravel sand clay mixtures you can actually place it somewhere here, so the compatibility or ease with which the soils can be compatible basically depends upon the type of soil so if you know in the previous slide at given moisture contained it clay with low plasticity will be stronger than heavy.

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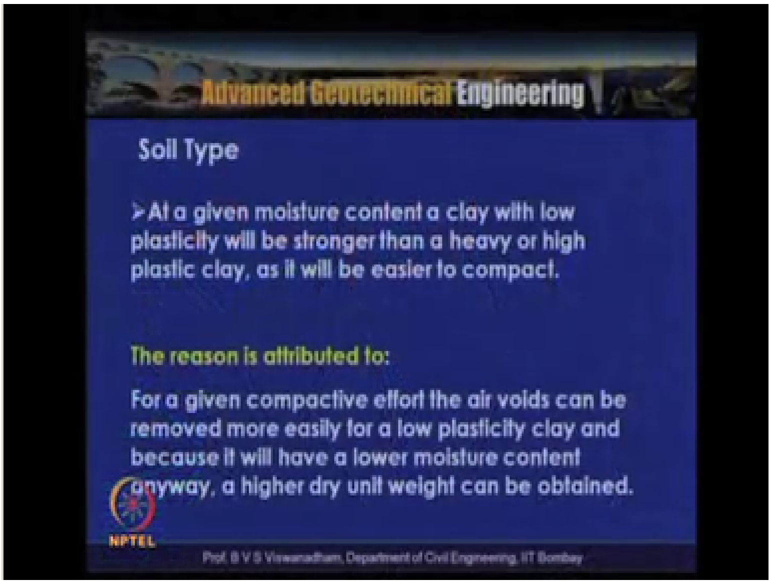

High plasticity clay as it will be easier to compare the basic reason is to attributed line is for a given comparability effort the air voice can be moved more easily for low plasticity clay and because it will have low measure content anyway higher drive unit weight can be ensured so this is you know the major reason what we actually have seen.

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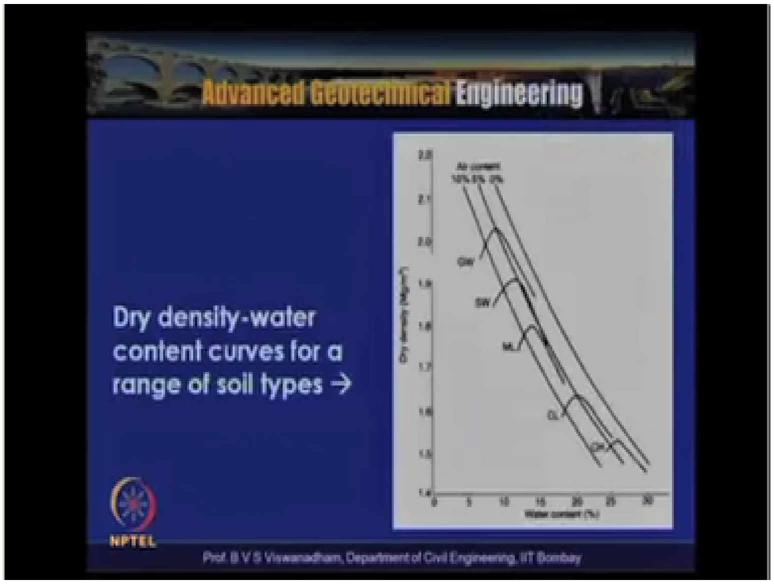

So in this particular curve once second it is shown here a SCH type of soil and SCL type of soil and this is for ML type of soil and SW well grated sand well grated gravel so you can see here that these are the you know degree of this is air content lines 0% 5% and 10% lines from the fundamental definition the 05 air content line are the 5% air content line and the corresponding degree of saturation line they are different.

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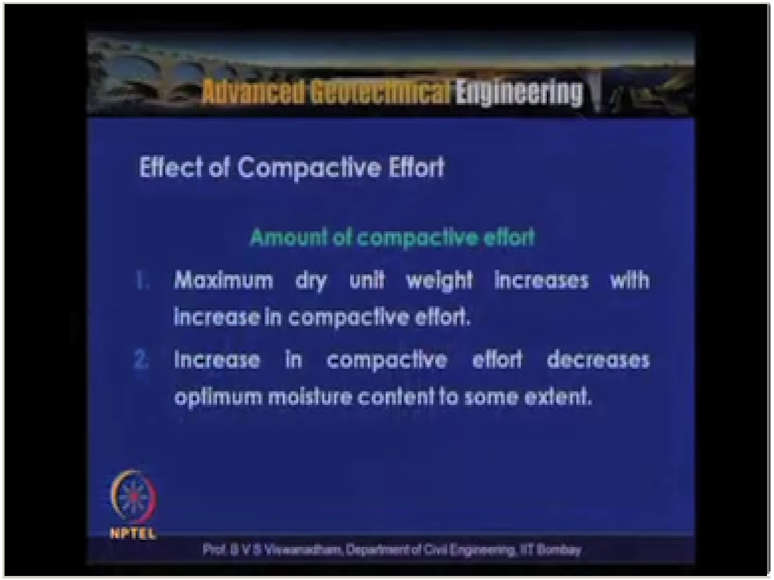

So the effect of comparative effect if you look into you know amount of comparative effect maximum dry unit increases with increase in comp active effort and the increase in comparative effort decreases optimum moisture content to some extend that is what actually we have seen that increase the comparative effort decreases the auto moisture content to the some extend.

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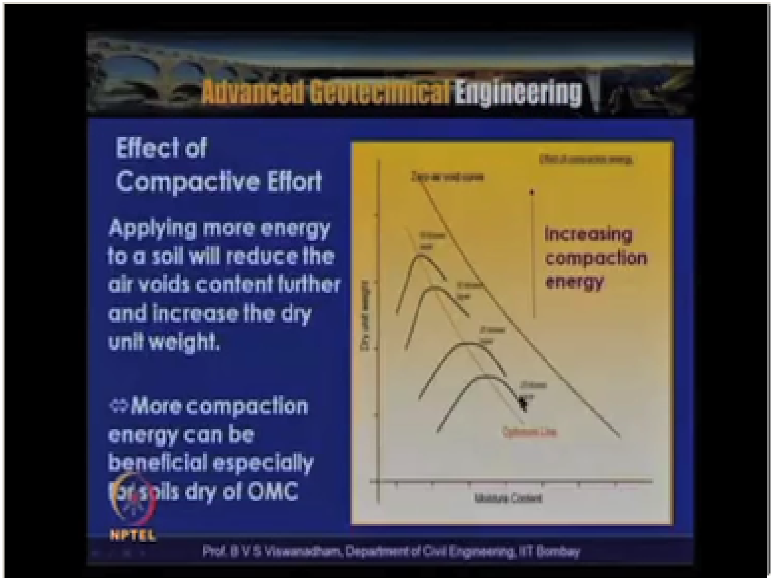

So here when you increase the compaction energy like from 20 blows 25 blows or 30 blows or 50 blows then there is a possibility that so this particular you know as you can see with increase in compaction energy there is a shift in the you know the comparison curves towards left hand side with increase in dry densities increase in compaction energy leads to decrease in the optimal moisture content so the line joining the maximum dry unit weights and onto moisture content is called as line of optimal.

So this is so called line of optimum so it is also referred for some certain applications like no comparison so in the is no comparison what we do is that in order to stimulate the pure comparison condition we apply you know low 15 numbers of blows only and the standard 25 number of blows and modified comparison means sometimes even 50 number of blows so applying more energy soil will reduce the air voice content and further increase the dry weight and more comparison can be beneficial as specially for soils which are actually dry set of optimum and wet side optimum if it is not possible because that can actually lead to the increase in the pour water pressures.

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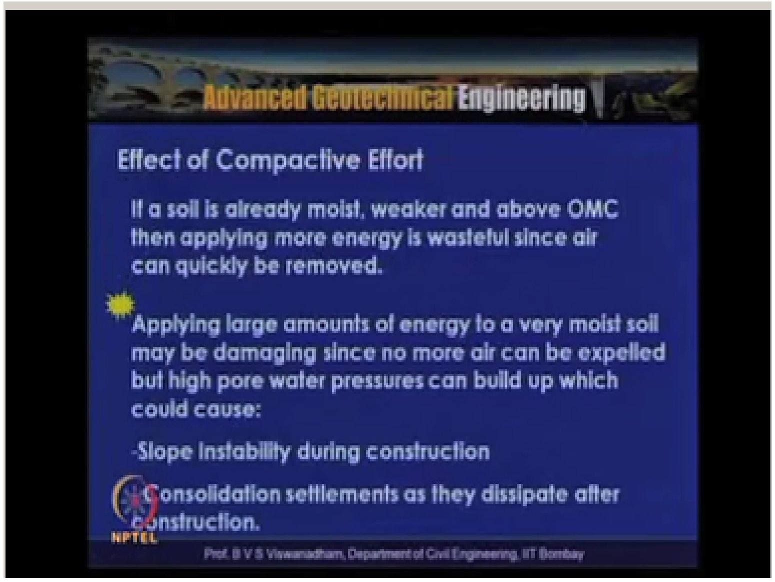

So if a soil is already moisture weaker and above moisture optimal moisture content then applying more energy is wasteful as because air can quickly be removed and applying large amount of energy to a very moisture soil may be damaging since no more air can be expelled but high pour water pressure can build up which could cause so these build up high pour water pressure can actu8ally locked and can lead to the slope instability during constructions and also can lead to the consolidation settlements as they pour order pressure which is actually locked inside can dispute and this settlement can be resulted.

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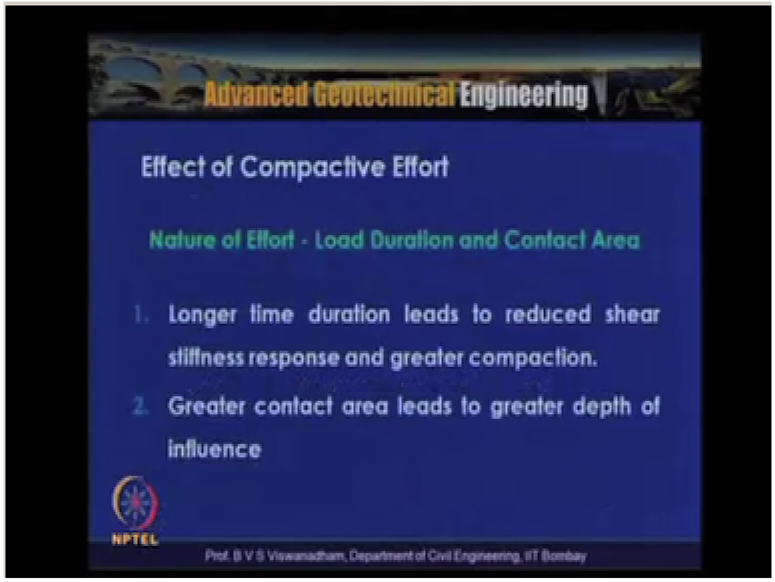

So the effect of the comparative effort means nature of effort the low duration and contact area so longer duration leads to reduces shear stiffness response and greater component greater compaction and greater contact area leads to the greater depth of influence so that is also what we said is that effect of the comparative effect is also the nature of the effort the load duration and contact area also is so degree of compaction energy degree of compaction general increase to increasing comp active effort that we have discussed already.

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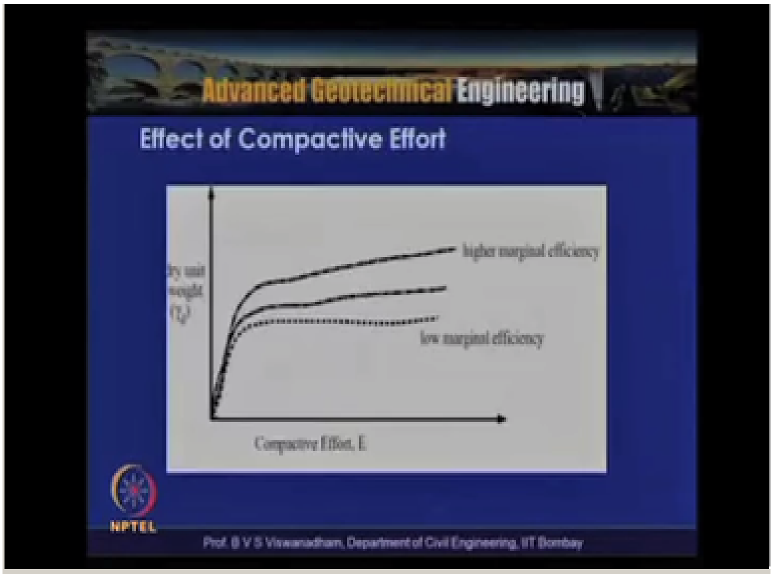

So here if you look into this the applying more comp active efforts to the soil is also not much beneficial if we can noted it here the increase in the dry way to this marginal.

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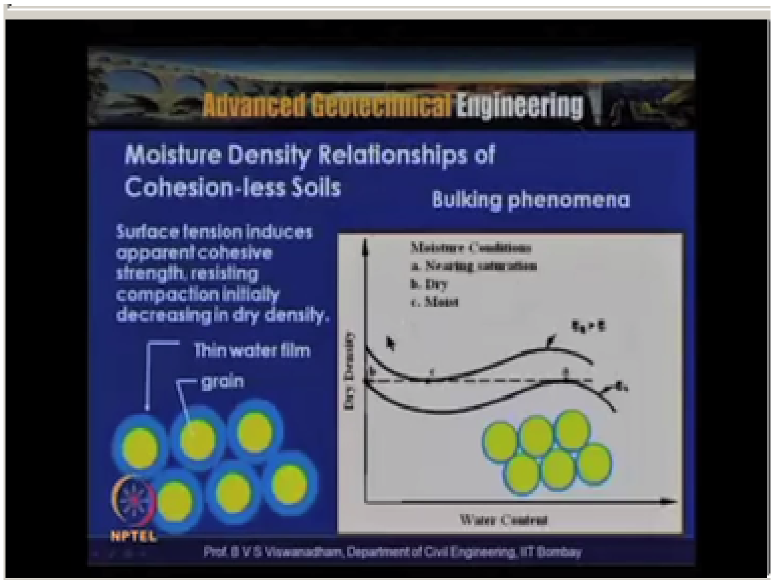

So this is actually moisture density relationship of the cohesion less soil as shown so this is actually what actually at point c what is actually is happening is that these water films which will actually prevent the particles to come into the denser configuration and because of this things water films it actually has got the low density.

But upon adding more water to this same soil the thinning of the film takes place that makes are we know the density increase here so that is the reason why here there is a decrease in the density and then increase in the density that this particular phenomenon is actually described in this slide so this surface tension forces a induces this effective apparent cohesion the resistance compassion is usually decreasing the dry density.

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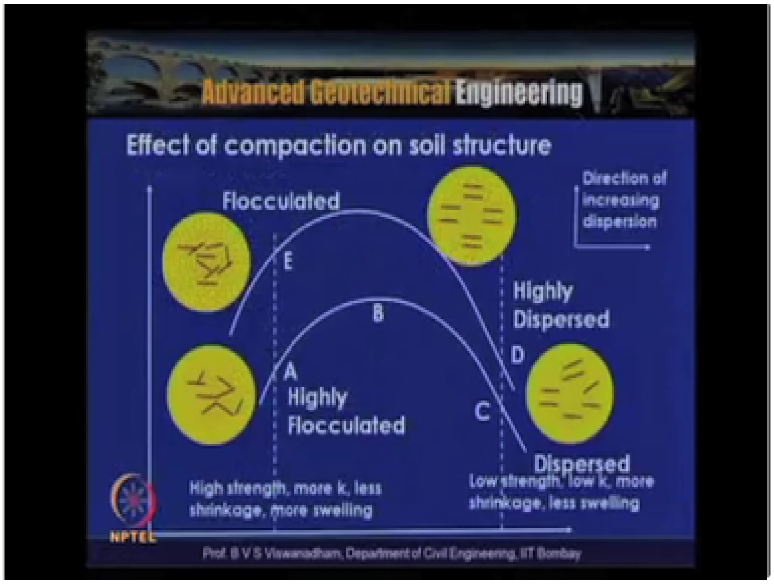

And if you look into the effect of comparisons of the soil structure so here if you look here there are A at point A the soil is actually highly flocculated and that point A this soil is in a dispersed state so upon the increase in water contain if you see the particles are actually undergoing the clay particles are undergoing degree of rotation it I said that this clay particles under go about you know 60% rotation so at optimum here if you see these soil will actually have partially flocculated and partially dispersed and here because of this it is something the flocculated nature the stunt of the soil is high and this is the possibility of the higher perambulate and lesser shrinkage and more swelling.

Because and then here the low strength because of the high water content and because of this disposal nature there is a low probity more shrinkage and less swelling so in this lecture what we try to understand is that some example problems we actually solved for based on the classifications of the soils what we discussed in the previous lecture and then we introduce ourselves to soil comparison and we have discussed that the methods of the principle of the comparison.

And also the factors effecting the compassion of the soils and further we will try to understand about the comparison methods and how the comparison can be assemble in the field and then some issues which are actually levied with the influence of the bulk particles on the guidance's extra in the next lecture.

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