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NATIONAL PROGRAMME ON TECHNOLOGY ENHANCED LEARNING

CDEEP
IIT BOMBAY

ADVANCED GEOTECHNICAL ENGINEERING

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Lecture No. 03

Module-1

Particle sizes, shapes and Arrangement

Welcome to lecture three of module one. In the previous lecture we have discussed about phase relations and phase properties, and we also solved some example problem one in module one. Now in this lecture before addressing the particle shapes and their arrangement, and soil structure we are going to discuss about one problem which belong to the previous discussion. And then we have one practice problem set in this module M1, it is named as M1A.

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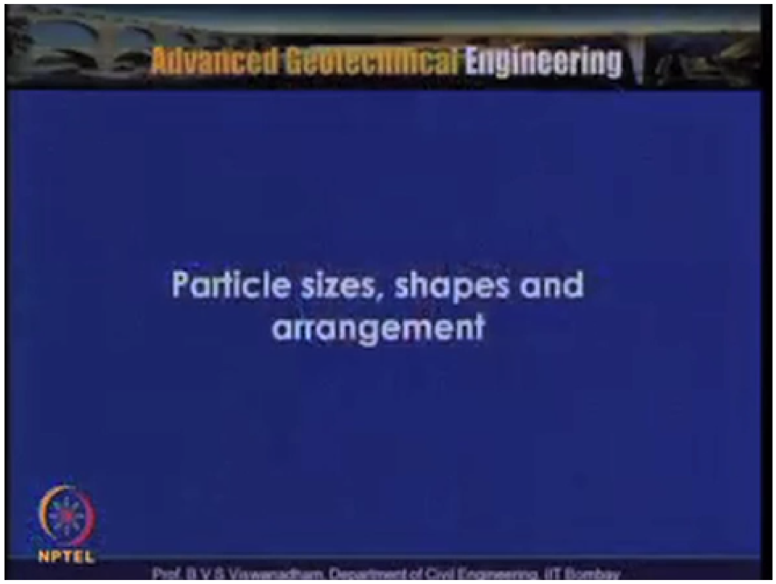

So in this lecture we are going to discuss about particle sizes, shapes and arrangement. And about the recent trends we are going to discuss further in subsequent lectures.

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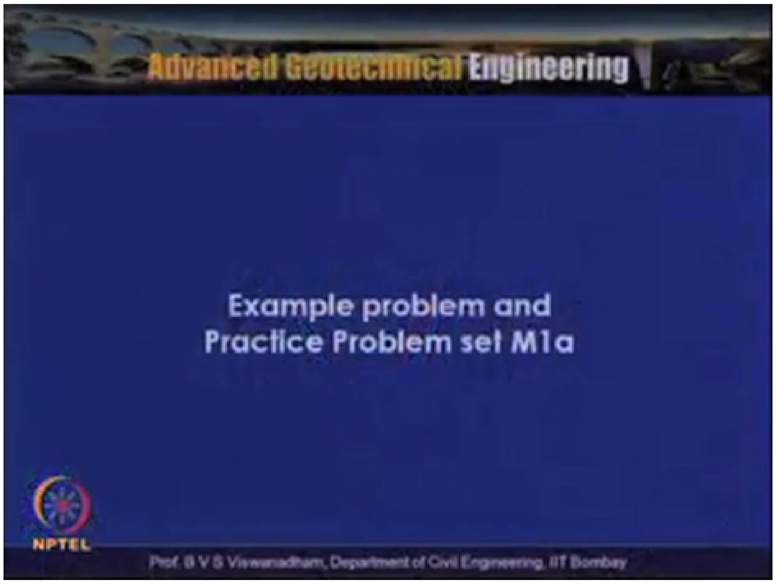

Before going to this particular lecture topic let us try to address the example problem and practice problem set M1A.

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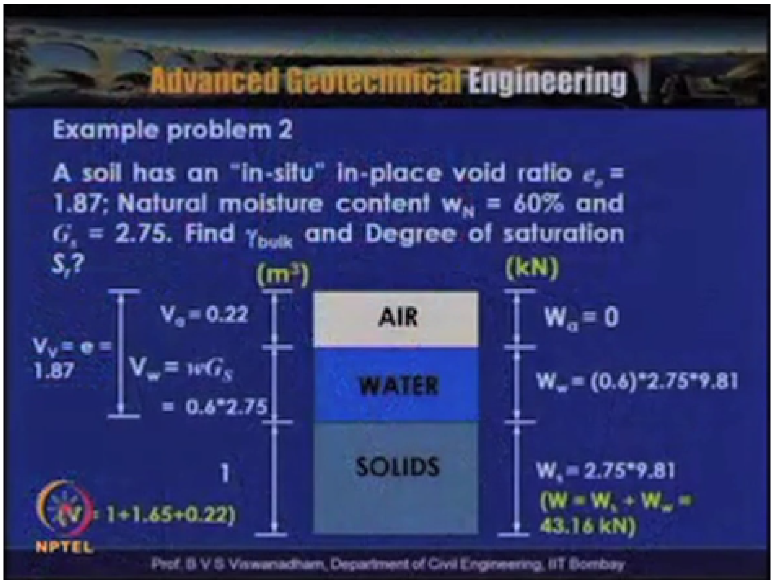

In this example problem 2, here a soil has an institute in place void ratio E0=1.87, natural moisture content W suffix n is given as 60%. And the specific gravity of the solids is given as 2.75. We need to find out what is the bulk unit weight and degree of saturation of the soil deposit. So as we discuss this particular problem can be solved by drawing a phase diagram. So if you draw the phase diagram this is a basically a partially saturated soil.

So this is nothing but a three phase diagram, so you have air, water, solids. Now we let us adopt the specific volume approach where volume of the solids is set as one or unit meter cube. Now with this if you set the volume of the solids as 1, now the volume of voids will be equivalent to 1.87, now from the definition of void ratio volume of voids to volume of solids which is actually given as E0=1.87.

If you take this implies that the volume of the voids is equal to 1.87. So the total volume is nothing but 1+1.87 that is $2.87 m^3$ is the total volume. Now here we were actually given the water content, natural water content that is 60%. Now by using this definition of the specific gravity of the solids GS = γS/γW and by taking γW = 9.81 kilo Newton/m^3 we can write WS = GS VS γW and VS = 1with that what will happen you have WS = 2.75x9.81.

So this is nothing but the weight of solids from the definition of water content, water content is defined as weight of water to weight of solids. So weight of water is nothing but 0.6 times 2.75x9.81which is nothing but weight of solids. So weight of water is equal to 0.6x2.75x9.81 and weight of air being zero, so the total weight is W = WS + WW which is equivalent to 43.16 kilo Newton.

By knowing the weight of water we can actually obtain by dividing by my γW we get the volume of water. So volume of water is equal to WGS which is nothing but 0.6x2.75. So by knowing volume of voids and we can actually now obtain volume of air which is there in the volume of voids, which is nothing but in the present problem it is volume of air is equal to 0.22. Now we have all parameters defined.

So in this case now if we wanted to obtain the bulk unit weight you need to use the definition weight of solid, weight of water plus weight of solids divided by the total volume you should get the bulk unit weight. And if you want they say dry unit weight of the soil, the weight of the solids divided by the total volume you are able to get the weight of the dry unit weight of soil.

If you want dry unit weight of the soil solids and that is the thing but which is given by weight of solids divided by volume of the solids which is actually 1in this present problem.

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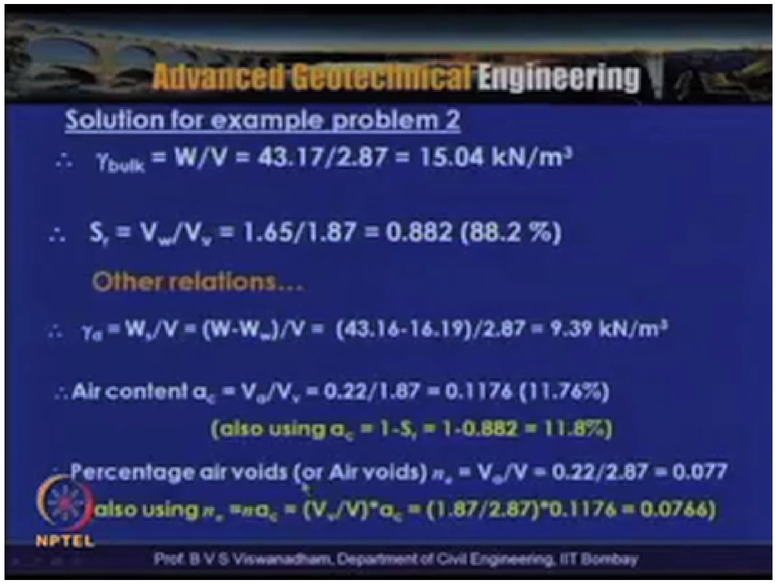

So now what we discuss here the γ bulk or bulk unit weight is nothing but W /V so weight which is actually given our what is obtained as 43.17/2.87 you get 15.04 Newton/m^3. From the definition of degree of saturation we can actually get SR is equal to volume of water to volume of voids which is nothing but 1.65/1.87 you get 0.882 which is expressed in percentage 88.2%.

By having all these we can deduce other relations also like γD WS/V which is nothing but weight that is total weight minus weight of water which is nothing but the weight of solids divided by total volume you will get the dry unit weight of the soil mass. Air content in the soil mass can be obtained by volume of the air divided by volume of voids that is nothing but 0.22/1.87.

And we all know that we are by using AC = 1-SR you also get 1-0.882 that is nothing but 11.8%. So the air content can also be obtained from degree of saturation or air content can also be obtained from the definition of volume of air to volume of voids. The percentage air voids are air voids n suffix A which is nothing but the volume of air in the total volume. So which is nothing but 0.22/2.87 = 0.077 that is which is nothing but 0.077.

So also by using the definition like NA=NxAC or Nx1-SR with that we can actually get, we can also get the similar value which is nothing but 0.076. So like this we can actually employ these phase diagrams for the respective state which is actually given in the problem, you can actually solve the problems. Particularly when the soil is actually excavated and the place, then there will be changes in the void ratios. So this allows us to estimate the actual volumes which are changes which takes place.

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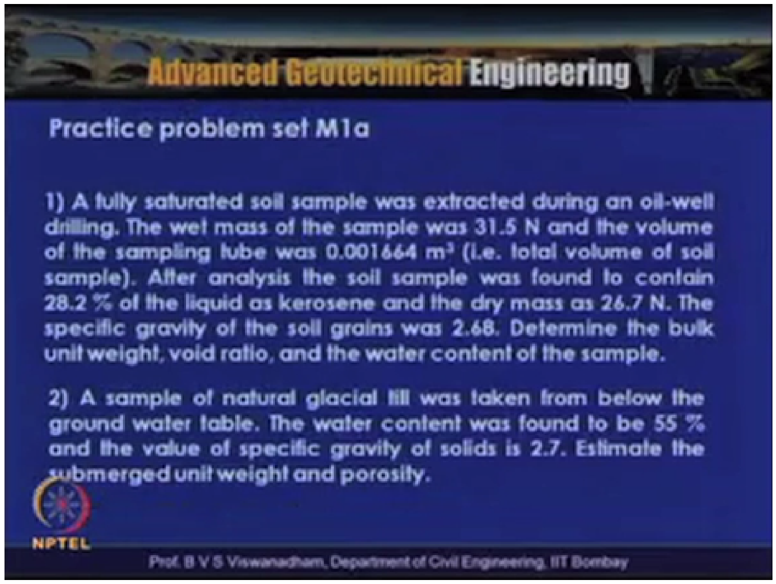

So based on the discussion I suggest you all to have a look at these problems which are actually given in the practice problem set M1A. The first problem reads like this, a fully saturated soil sample was extracted during an oil-well drilling, that means that the offshore investigation. The wet mass of the soil sample was, the wet mass of the sample was 31.5 Newtons and the volume of the sampling tube was $0.001664m^3$ that is total volume of soil sample.

After the analysis of the soil sample was found to contain 28.2% of the liquid as kerosene and the end the dry mass as 26.7 Newtons. The specific gravity of the soil grains was 2.68, determine the bulk unit weight, void ratio and the water content of the sample. So this will be an interesting problem to solve based on the discussions we had in the previous lecture. In the second problem a sample of natural glacial till was taken from below the groundwater table.

So the water content was found to be 55% and the volume of this specific layer to the solids is 2.7. Estimate the submerged unit weight and porosity, the submerged unit weight is nothing but $\gamma sat - \gamma W$, γsat is nothing but the saturated named weight of the soil mass, γW is nothing but the unit weight of water.

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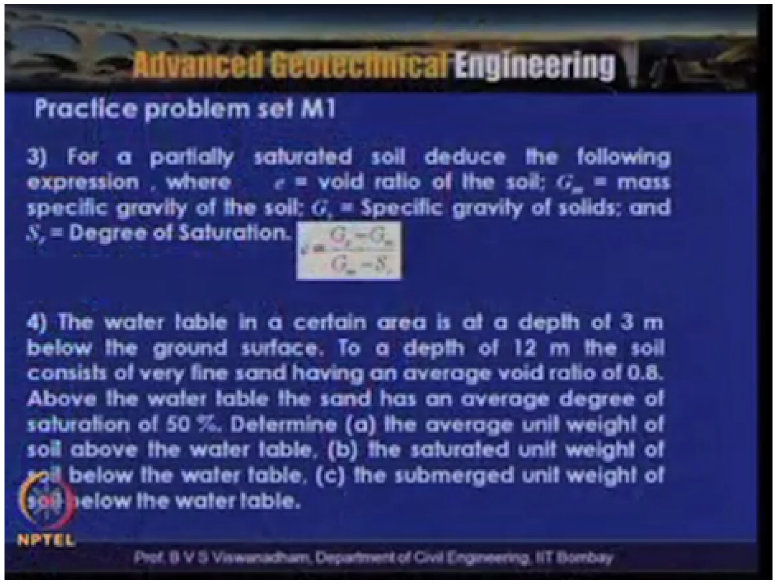

In the third problem this is a derivation for a partially saturated soil deduce the following expression way E is equal to the void ratio of the soil GM is nothing but the mass specific gravity of this file, GS is nothing but the specific gravity of the solids. And SR is nothing but the degree of saturation. So based on the, for the given phase diagram are the partially saturated state of the soil you need to express the void ratio as GS – GM/GM - SR.

In the fourth problem the water table is in certain area is at a depth of three meter below the ground surface. To a depth of 12 meter the soil consists of very fine sand and having an average void ratio of point 8. Above the water table the sand has an average degree of saturation of 50% what you need to determine here is A, the average unit weight of the soil above the water table, B the saturated unit weight of the soil below the water table, and C the submerged unit weight of the soil below the water table.

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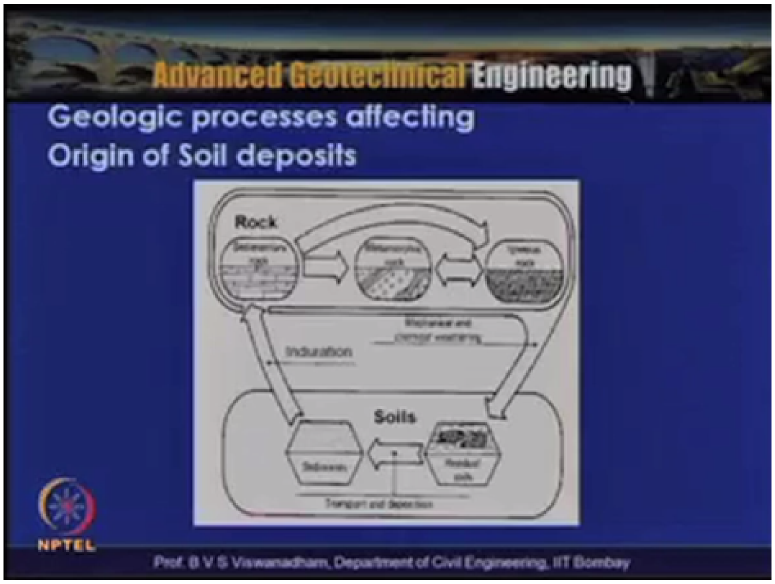

So now let us come to the present you know topic of this lecture 3 where particle shapes and the their arrangements. Before discussing that let us revise once again or let us review once again how the origin of the soil deposits occur. In this particular slide as it is shown here the origin of the soil occurs from rocks predominantly igneous rock, metamorphic rock and sedimentary rock.

Some soils particularly the residual soils when they go with some agencies or they get transported with agencies and then deposited they form sediments. When the sub sediments when they undergo subjected to a process of hardening for a period of time then they can actually get converted into a sedimentary rock, that means that the sediments because of the process of induration there is a possibility that they can get converted into rocks that is sedimentary rocks.

And sedimentary rocks can get transformed into metamorphic rocks or sedimentary rock can get transformed into igneous rocks, or the mechanical weathering of these rocks can also lead to the particularly formation of these soils.

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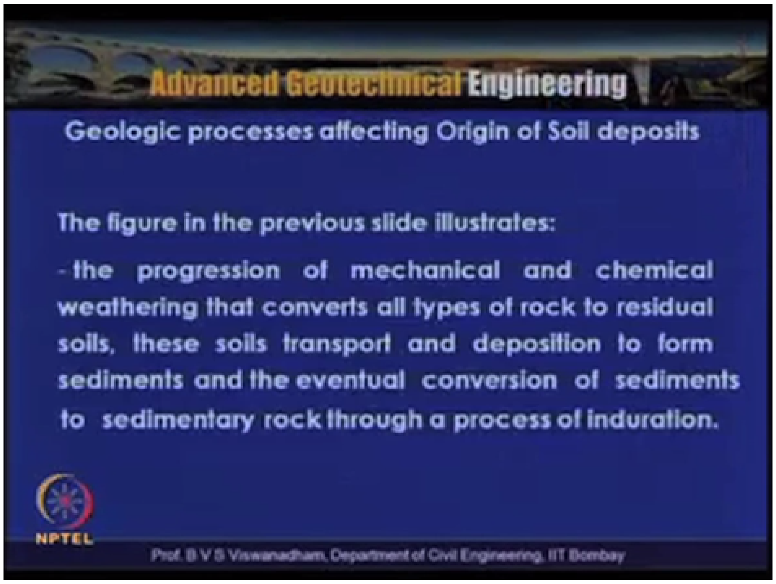

So the geological process affecting the original soil deposits which was actually discussed in the previous line reads like this. The progression of mechanical and chemical weathering that converts all types of rock to residuals soils and these soils transport and deposition to form sediments and deposition to form sediments. And eventually conversion of sediments to sedimentary rock through a process of induration.

That is what actually we have discussed in the previous slide about the how the origin of these soils can take place. So as we have discussed the different types of soils are possible like we have predominantly coarse-grained soils and fine-grained soils. And the coarse grained soils basically they are large in size and incase of fine grained soils there are actually very, very you know small in size.

And the residual soil profiles or the soils where they after formation they are deposited at the place of origin and they resemble the properties of the original or parent rock from where it has been deduce.

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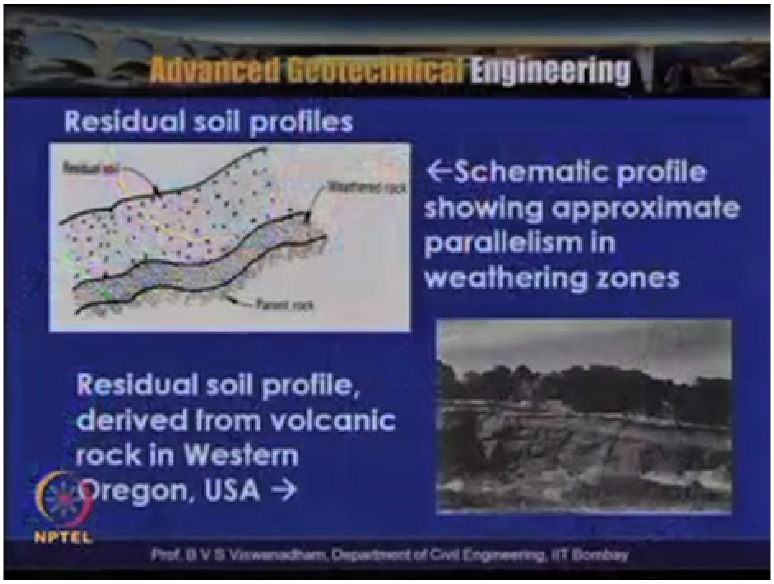

So in this slide a schematic of the profile showing approximate parallelism in the weathering zones is shown. And here an actual residual soil profile which is observed is actually shown here.

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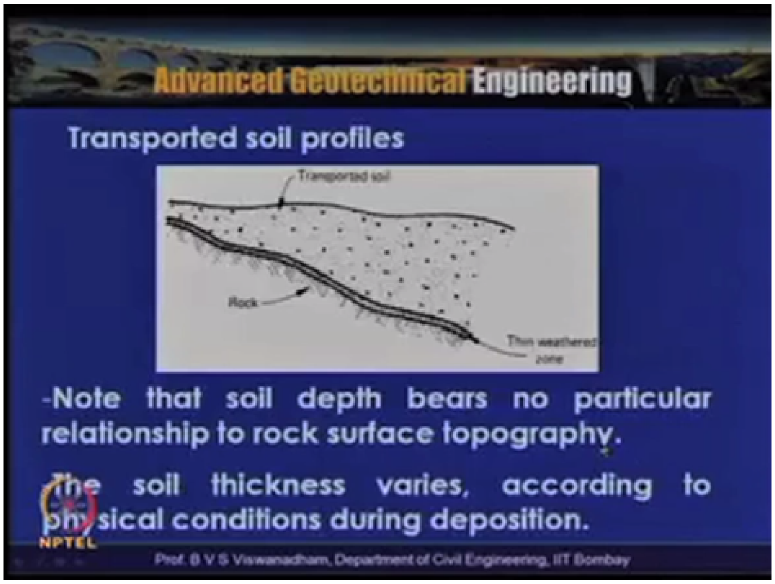

The transported soil profile is nothing but the soil depth builds no particular relationship to the rock surface. And the soil thickness varies according to the physical conditions during deposition, their particular soil is transported by the different agencies like air, water and other modes of agencies.

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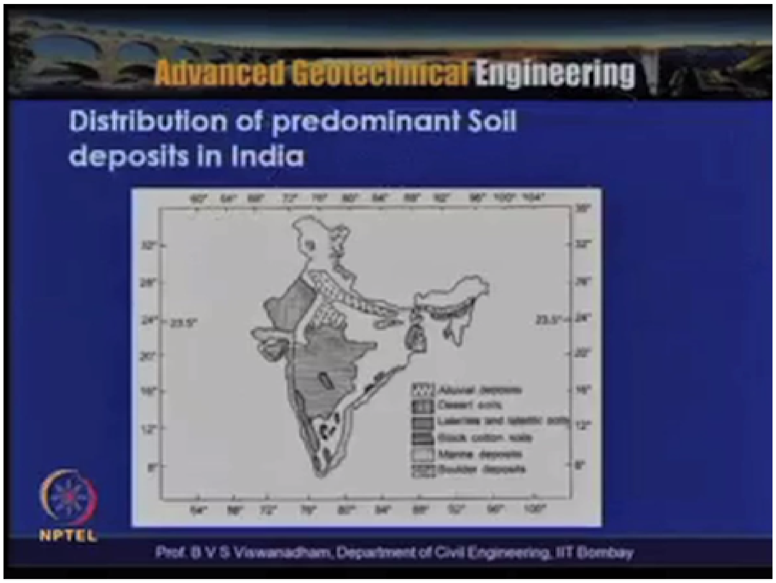

If you look into the Indian context we have different sets of, you know soils like we have alluvial deposits, and we have desert soils particularly towards the this particular portion. And we have a major portion is the black cotton soil deposits, and along the coastal zone we have the marine deposits, and the hilly regions we have the boulder deposits. So if you look into this the particular in reference to the Indian map our Indian context we have the very nature of soils.

Alluvial deposits where there is a possibility of the silt clay, or sand silt clay layers of status. The desert soils predominantly there sandy soils, and in some part of the portion of the western portion where you have the laterites and laterite soils, and the black cotton soils which are also called as expensive soils and which are actually has a large predominance in India and other countries also.

And then we have the marine deposits which are basically soft in nature and the foundation constructions are required to be done with utmost care.

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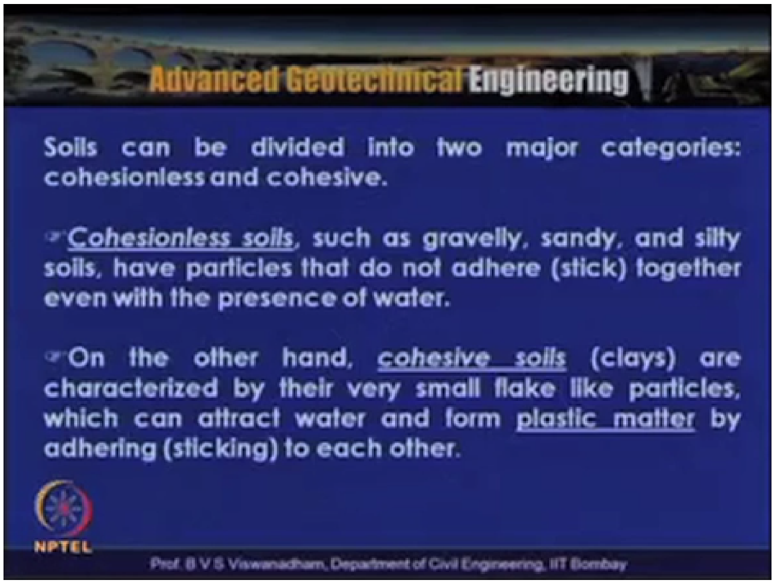

So as we discuss the soils can be divided into two major categories the cohesionless and cohesion. What is this cohesionless and cohesion? Cohesionless soils such as gravelly means that the soils which are particles are large in size sand comparatively smaller in size, and the silty soils have particles that do not adhere or stick together even with the presence of water.

So cohesionless soils such as gravelly, sandy and silty soils have particles that do not adhere or stick together even with the presence of water, but in some silty soils presence of the carbonates make them to how a true cohesion in them. On the other hand cohesion soils predominantly called as clays are characterized by their very small flake like particles that means that they resemble the sheets of the book which can attract water and form the plastic matter by adhering or sticking to each other.

That means that this clay say soils exhibit a sort of plasticity and they have a tendency of sticking in the presence of water. So this is predominantly two sets of soils one is called cohesionless soils other one is cohesion soils which we will be discussing in length in the process of this advance of geotechnical engineering course modules. Now what is the grain shape, what does what is the shape of the grain, how the shape of the grain looks like is it rounded or is it has got a square shape, or has got any specific shape.

We all know that the soils are formed by nature, so they have there is no possibility of having a particular shape.

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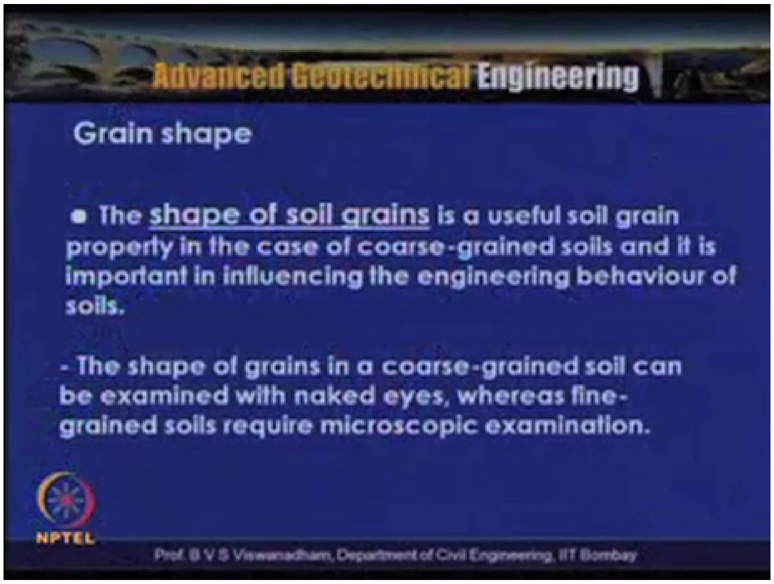

So the shape of soil grains is useful is useful soil grain property in the case of coarse grain soils, and it is important in influencing the engineering behaviour of soils. So the shape of the soil grains basically is useful particularly in case of coarse grain soils and it is important in influencing the engineering behaviour of soils. The shape of grains in a coarse grained soil can be examined with naked eye, whereas the fine-grained soils require microscopic examination.

If it is said, you can actually see the shape of the coarse-grained soil clearly, but if you wanted to see the fine grained soil shape you actually need to resort to adopting an option of microscopic examination.

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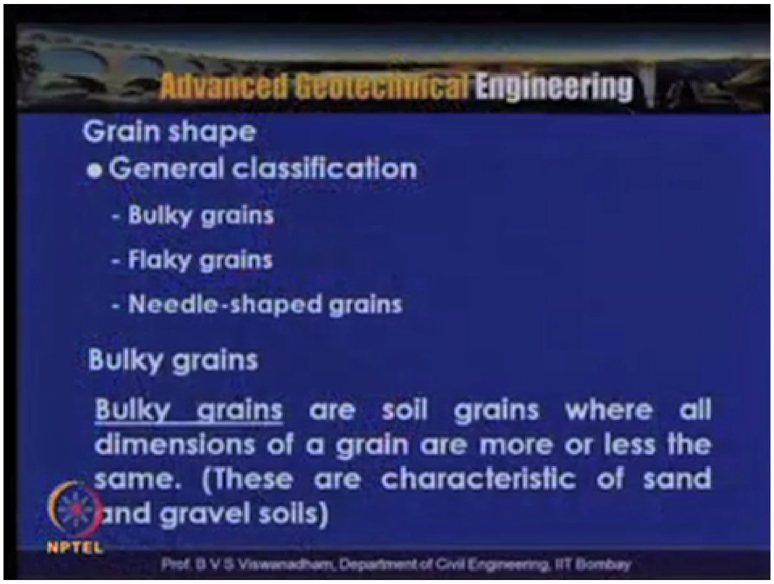

So the grains basically they are based on their sizes, they are divided into classified into three types one is bulky grains and the flaky grains and needle shaped grains. The bulky grains are small grains or bulky grains are soil grains where all dimensions of grain are more or less the same and these are characteristic of sand and gravel soils. So basically the bulky grains are large in size and they are the soil grains where all dimensions of grain are more or less the same. And these are the characteristics of the sands and gravels.

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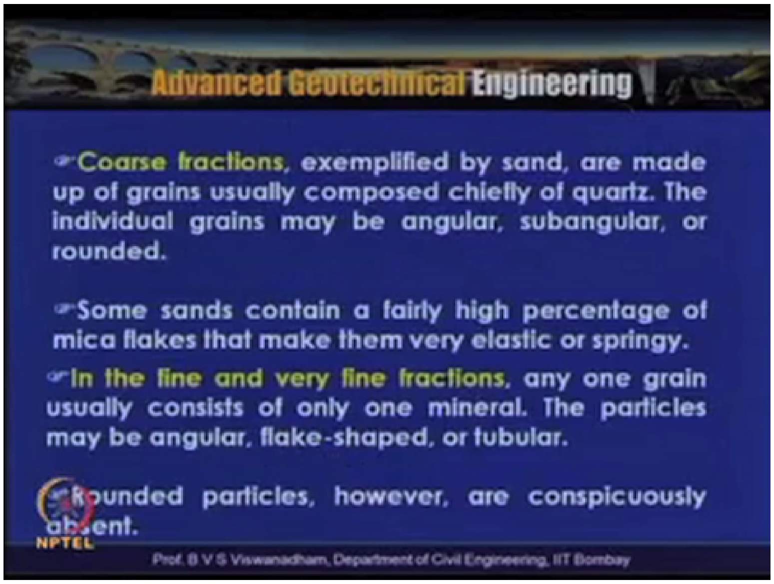

Coarse fractions exemplified by sand are made up of grains usually composed of chiefly of quartz. The individual grains may be angular, subangular or rounded. That means that these grain shapes can be angular or subangular because of the some process of weathering, or if they are on the riverbed they can get actually a rounded shape. The coarse fractions of these grains exemplified by sand made up of grains usually composed chiefly of quartz and the individual grains may be angular subangular or rounded.

Some sands contain fairly high percentage of mica flakes that make them very elastic and springy. In the fine and very fine fractions only one grain usually consists of one mineral the other particles may be angular, flake shaped or tubular. So wrong particles however consciously absent. So wrong particles are not generally presented.

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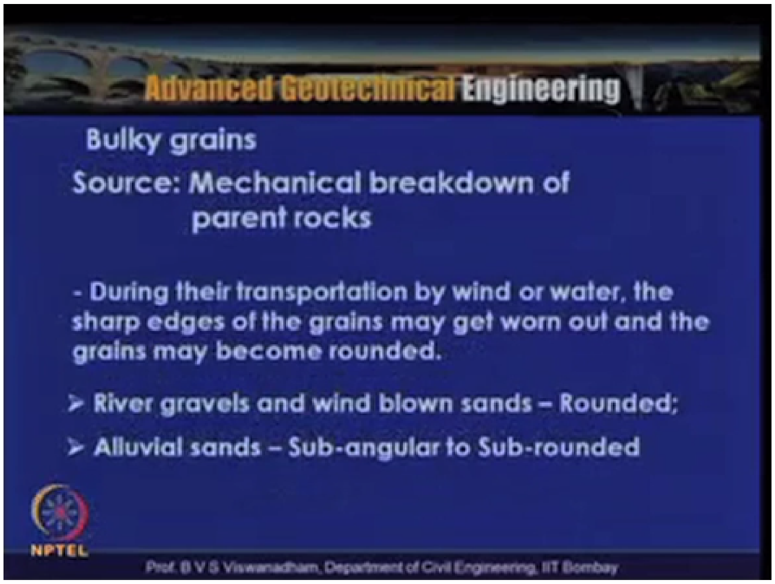

See bulky grains the source how then what is the source of these bulky grades, the mechanical breakdown of the parent rocks. So during their transportation by wind or water the sharp edges of the grains may get worn out and the grains may become rounded. So river gravels and wind blown sands basically they are rounded. Alluvial sands, they get actually subangular to some rounded shape.

Suppose if you have alluvial deposit and if that the predominant soil is a sandy soil the grain shape is approximately ranges to subangular to surrounded. A river gravels and wind blown sands, they have a round shape.

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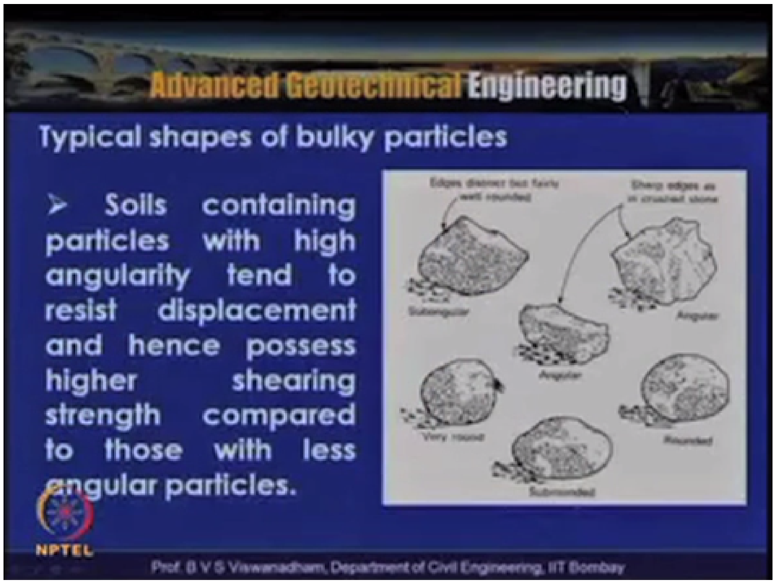

Now in this slide here a very rounded aggregate is shown, typically a very rounded aggregate is shown schematically. And here a sub rounded aggregate is shown, and here the rounded aggregate is shown angular and where sharp edges in the crusher stone, but here this is actually is most possible where you have got sharp edges in the crustal stone, and this is said to be angular. And here edges are slightly rounded so that is if the edges are in a particularly crystal stone or practical crushed particle if there are some angular.

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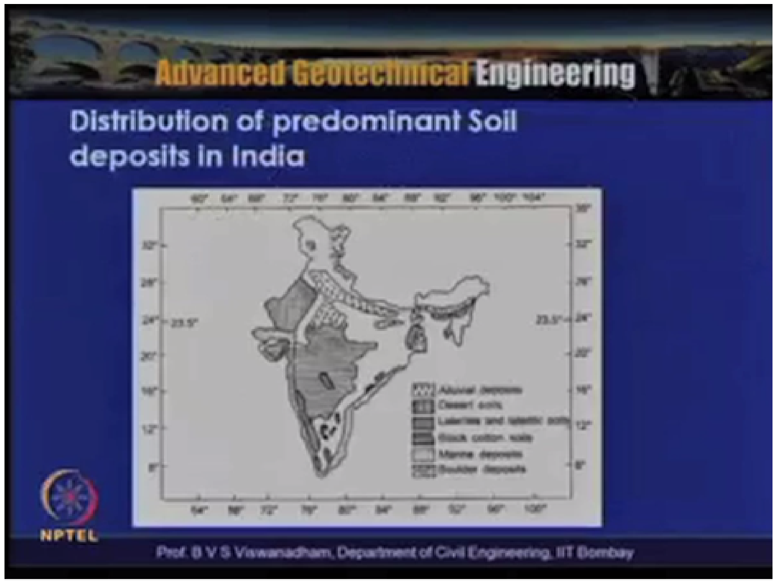

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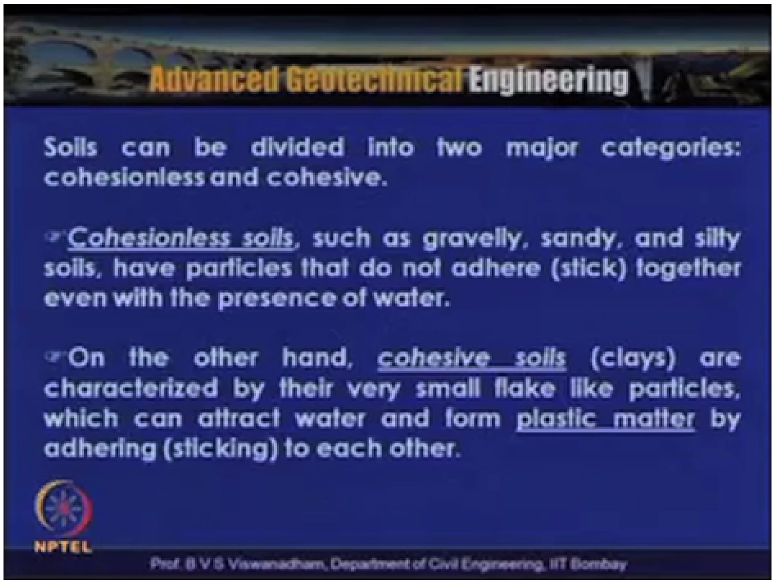

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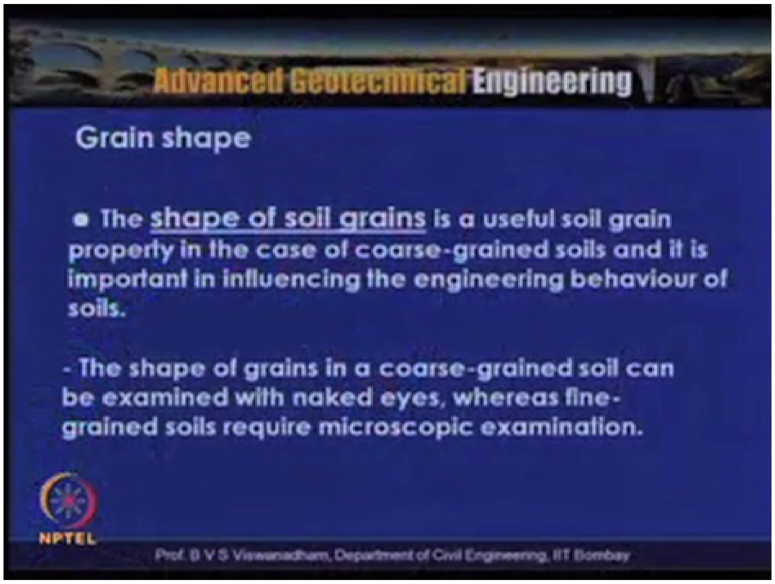

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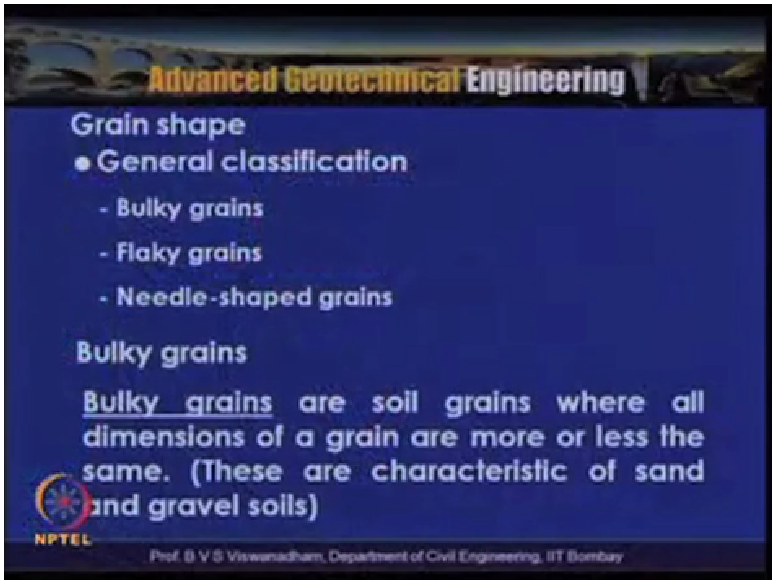

The bulky grains are small grains or the bulky grains are soil grains, where all dimensions of grain are more or less the same and these are characteristic of sand and gravel soils. So basically the bulky grains are large in size, and they are the soil grains where all dimensions of grain are more or less the same. And these are the characteristics of the sands and gravels.

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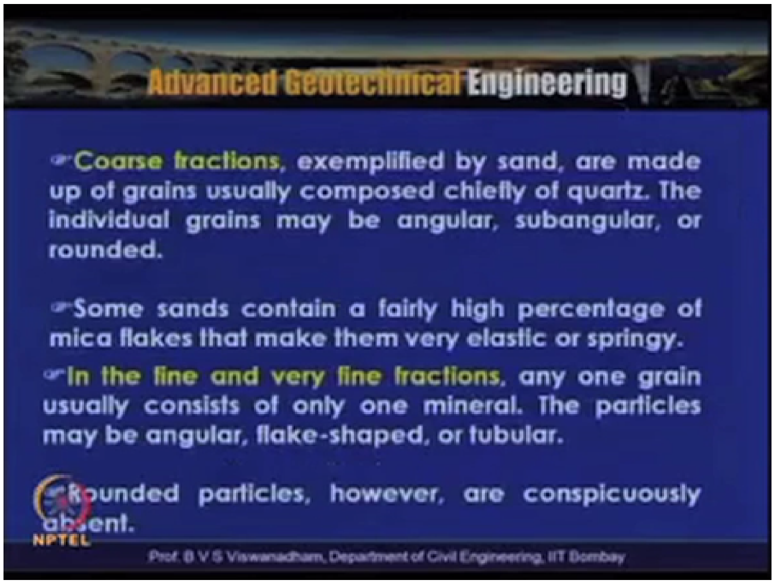

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Some sands contain fairly high percentage of mica flakes that make them very elastic and springy. In the fine and very fine fractions only one grain usually consists of one mineral, the other particles may be angular, flake shaped or tubular. So round particles however consciously absent, so rounded particles are not generally presented.

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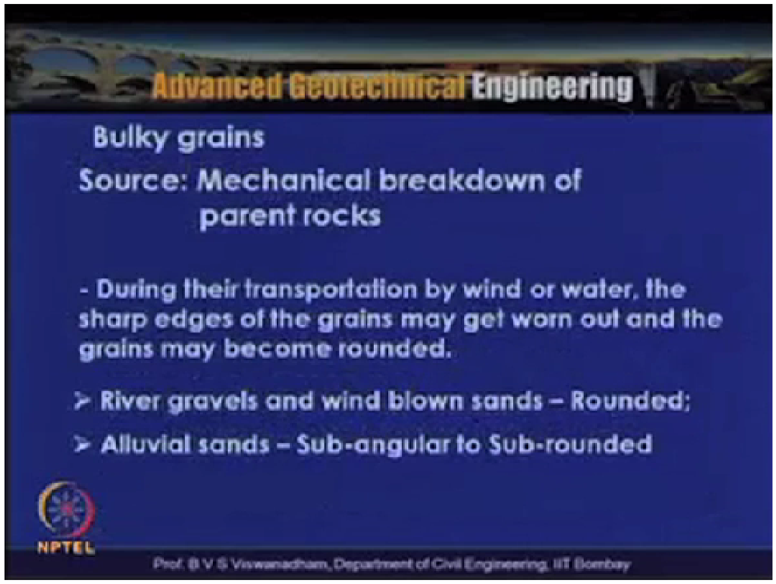

See bulky grains, the source however what is the source of these bulky grains, the mechanical break down of parent rocks. So during their transportation by wind or water the sharp edges of the grains may get worn out at the grains may become rounded. So river gravels and wind blown sands basically they are rounded. Alluvial sands they get actually subangular to sub rounded shape.

Suppose, if you have a alluvial deposit and if that the predominant soil is a sandy soil the grain shape is approximately ranges to subangular to sub rounded. River gravels and wind blown sands they have a round shape.

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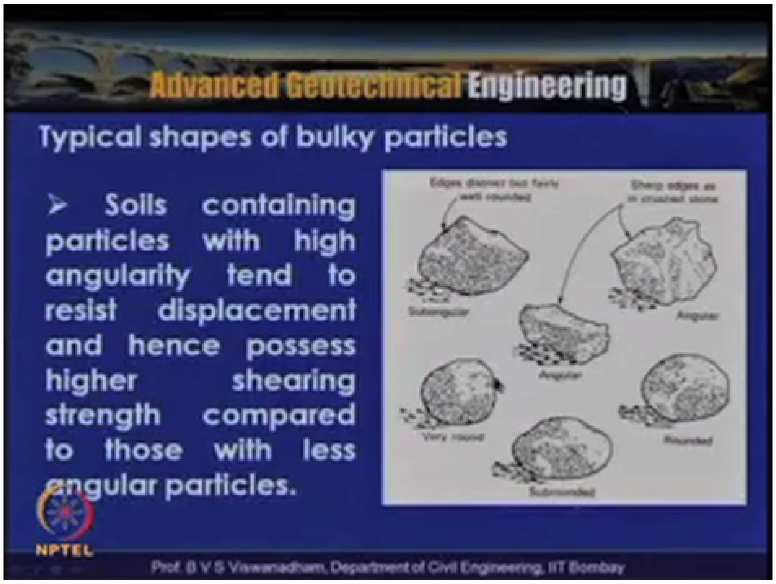

Now in this slide here very rounded aggregate is shown typically a very rounded aggregate is shown schematically. And here a sub rounded aggregate is shown and here the rounded aggregate is shown, angular and where sharp edges in the crusher stone, but here this is actually is most possible where you have got sharp edges in the crustal stone, and this is said to be angular.

And here edges are slightly rounded so that is, if the edges are in a particularly crystal stone or particular particle, if there are sub angular and if they are rounded, then that is actually called as subangular. So the difference between angular and subangular is that the edges are slightly rounded. So soils containing particles with high angular T tend to resist displacement and supposes high shearing strength compared to those with the less angular particles.

So because of these sharp edges they offer very high shear resistance that is the reason why we use for construction where the load bearing is important you need to actually use the angular particles which are actually having sharp edges.

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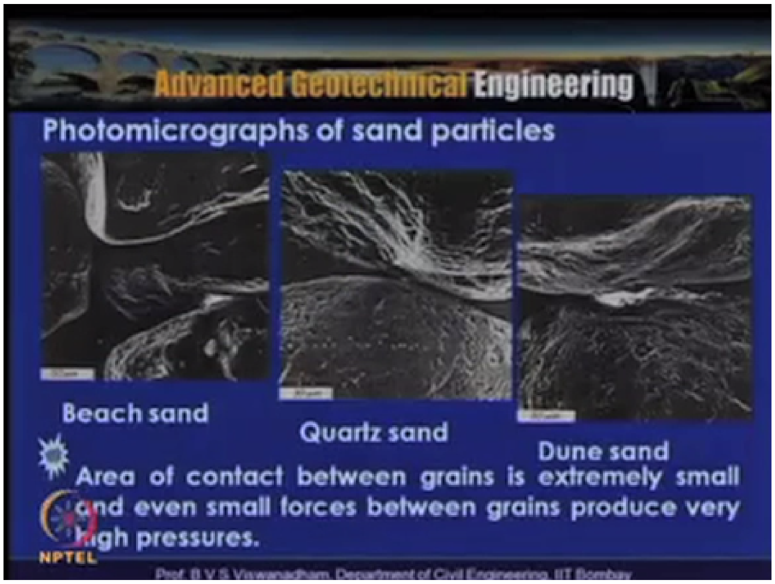

So in this slide if a typical photo micrographs of sand particles is shown here. So here there are three types of the sands which are actually collected by different depositions is shown. One is beach and other one is quartz sand, other one is Dune sand. So if you see here the particles they have angular to sub rounded edges, and the area of the contact between each grains is extremely small and even small forces between the grains produce very high pressure.

That means that the contact areas between these grains are very small and these when the contact areas are very small and because of this the application of the load they produce very high contact stresses and these contact stresses if they were come or if they become larger than the crushing strength of the particles then the particles can lead to the crushing.

And that indicates that the entire soil mass also can, in can experience settlements because of the large crushing takes in place because of the increase in contact stresses.

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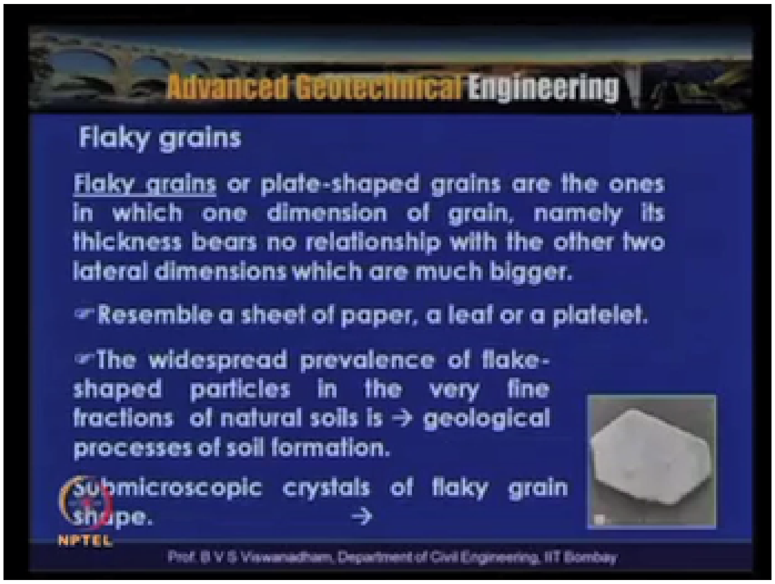

The other type of the grain other than the bulky grain what we said is called flaky grains our plate super grains these are the ones which one dimension of the grain namely its thickness bears no relationship with the other lateral dimensions which are much bigger so the lateral dimensions of these grains are much bigger so resemble a sheet of paper or a leaf or a platelet so that is the reason why these are predominantly occur in clay type of soils or soils which are actually exhibiting coefficient.

So flaky grains our plate shaped grains are those ones in which one direction of the grain namely it is thickness bears no relationship with the other two lateral dimensions which are much bigger so as I said they resemble a sheet of the paper in a book or in a leaf or a platelet the weights the white spirit approval of the plague ship particles in the very fine fractions of the natural soil is attributed to geological process of formation.

So the void spread prevalence of the flagship particles in the very fine fractions of natural soils is attributed to the process of soil formation here in this slide a micro-graphic photograph of a crystal with a flaky grain is shown so it can be seen that the particle is very small having but large surface area so this is of the point of interest which actually we should know that the particles which are actually have smaller sizes they have large surface area.

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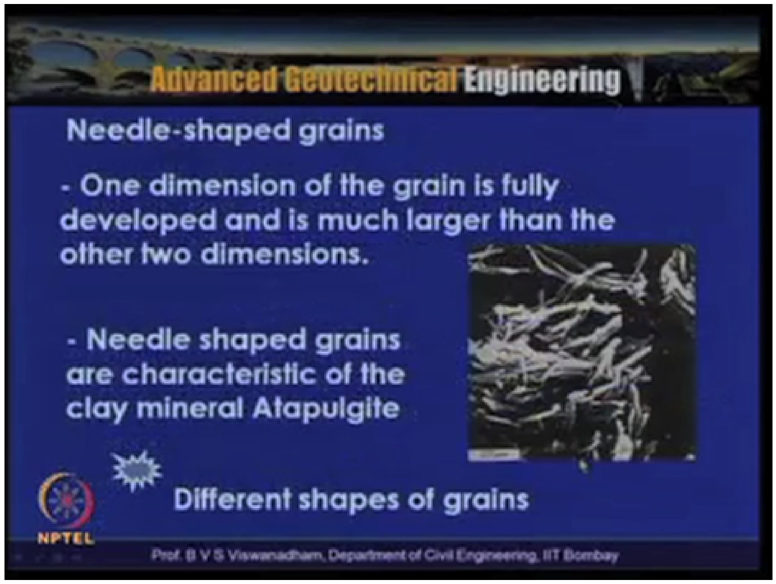

Another type of the shape of the grain is called needle shaped grains one dimension of the grain is fully developed and is much larger than the other two dimensions needle shaped grains are characteristics of the clay mineral Atapulgite so particularly we are going to discuss of the different clay minerals here I named him mineral previous class.

We also named some three minerals kaolinite, illite, montmorillonite and another mineral which is actually called as at Atapulgite particularly the specialty of this mineral is that the grains actually have got tube shaped tube shape or full ship full tube or off cube the one dimension the grain is fully developed in its much larger than the other terminal.

So what we have seen is that we have got different shapes of the grains one is bulky grain other one is we have seen the flaky grain other one is the needle shaped grains so here a schematic of the how a micrograph which is actually showing a tube grains can be there is shown here in the soil mass.

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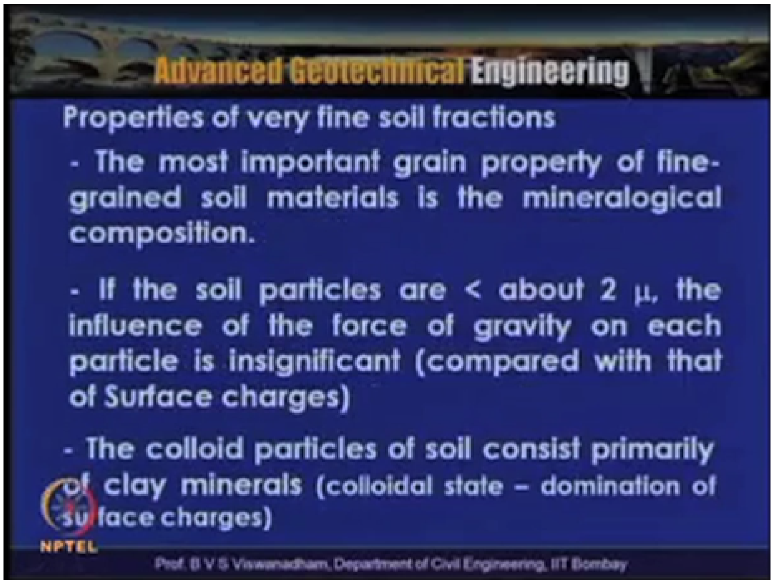

So properties of very fine soil fractions the most important grain fact property of fine grain soil is the mineralogical composition what type of mineral the soil as if the soil particles are less than two micron that is 0.002mm the influence of the force of gravity on each particle is insignificant so just we have discussed that if the particle is small it exhibits the large surface area and the shape of the grain is called platelet particle or flaky shape if the soil particles are less than two micron the influence of the force of gravity and each of the particle is insignificant compared with that of the surface charges.

The piston if you compare surface charges and gravity forces the surface forces predominate if the particles are small the colloidal particle of soils consisting of plane minerals the colloidal state is nothing but a way the domination of surface charges takes place so let us come to what is a soil structure and how it is actually defined.

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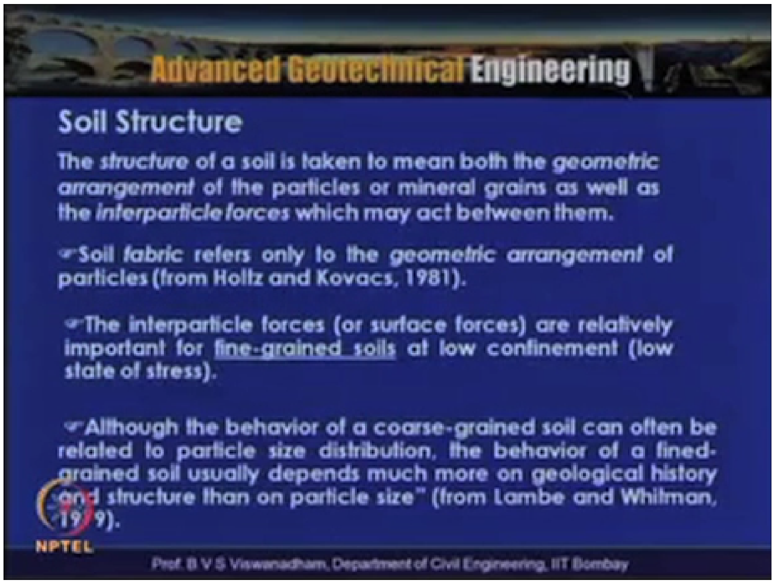

The soil structure or soil fabric which is nothing but the structure of a soil is taken to mean both the geometric arrangement of the particles or mineral grains as well as the inter particle forces which may act between them so soil fabric refers to only geometric arrangement of the particles but the soil structure of a soil is taken to mean both geometric arrangement of the particles or mineral grains as well as the inter particle forces which may act between them the inter particle forces are surface forces are relatively important for fine-grained soils at low confinement or low state of stress.

That means that if you have got a fine-grained soils under the low confining stresses or at the surface of the soil strata the inter particle forces are relatively important if they are at the high confining stresses let us say that deeper depths then the dominance of the effect of the confinement comes into the picture although the behavior of the coarse-grained soil can often be related to particle as distribution the behavior of the fine-grained soil usually depends much more on geological stream and a structure than on the particle size this is after Lambe and Whitman 1979.

So we have now said that on a soil particle there can be a gravity force or they can be a surface force so let us discuss about the particle forces and behavior and how they influence in forming different soil structures.

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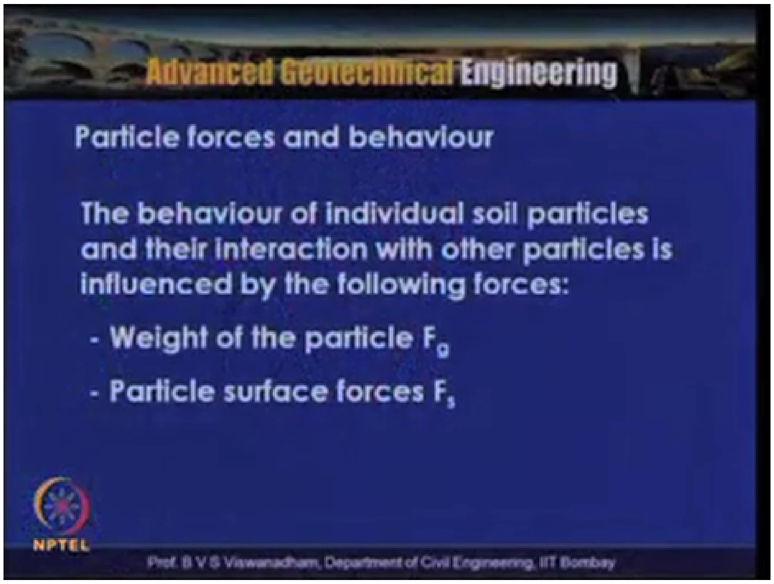

The behavior of the individual soil particles and their interaction with other particles is influenced by the following forces weight of the particle which is indicated here as F_g particle surface forces which is indicated here as F_s.

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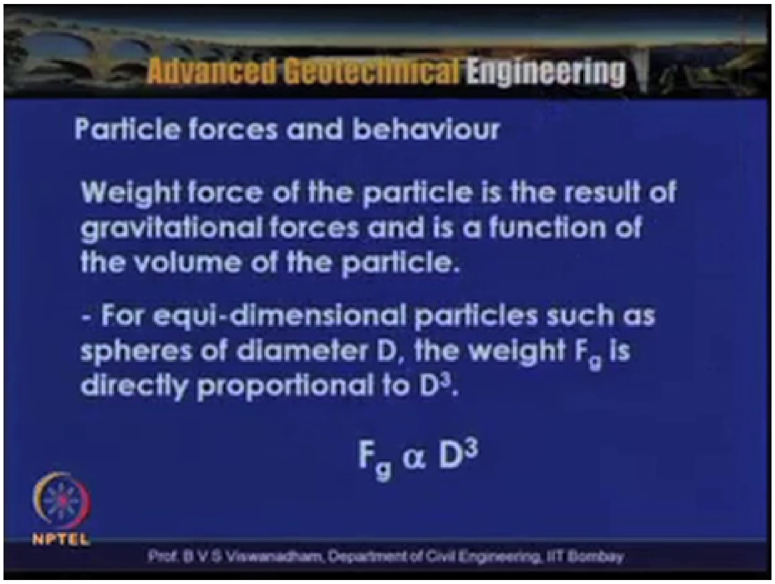

The particle forces and behavior weighted weight force of the particle is the result of the gravitational forces and is a function of the volume of the particle so larger the particle larger will be the weight force the for equi-dimensional particles such as spheres of diameter D the weight F_g is directly $\propto$diameter of the particle that is $F_g \propto D^{3.}$

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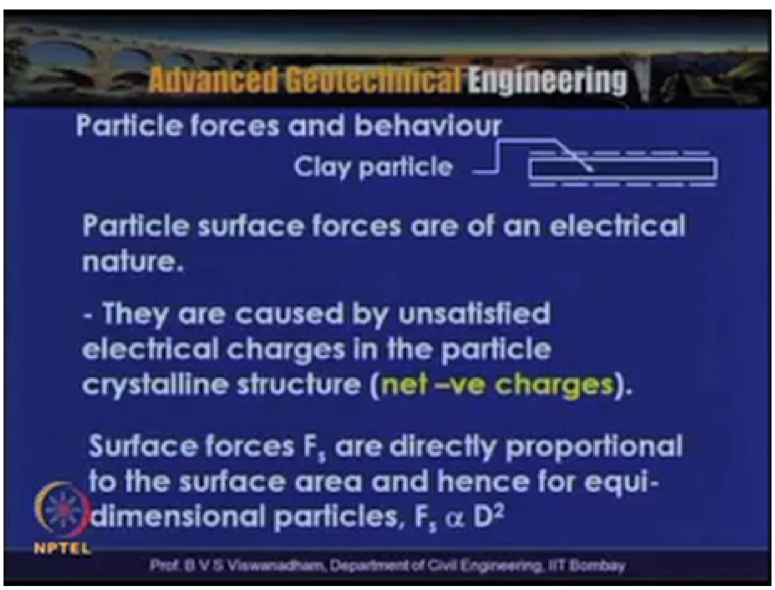

In case of say a fine-grained soil say clay particle and we said that it is a thin platelet a particle so if you assume that this is the typical cross-section of a clay particle and these are the net negative charges which are unsatisfied net negative charge which are actually available and if this is considered the particle surface forces are of an electrical nature so easy if you take a particular clay particle the we say that the surface forces of an electrical nature and they are caused by an unsatisfied electrical charges in the particle crystalline structure.

So there will be always a net negative charges on the clay particles so surface force F_S are directly $\propto$the surface area hence for equivalent dimensional particles equi- dimensional particles the surface area suppose if it is D/ D then $F_S \propto D^2$ so surface forces F_S are directly $\propto$the surface area hence for equal dimensional particles $F_S \propto D^2$
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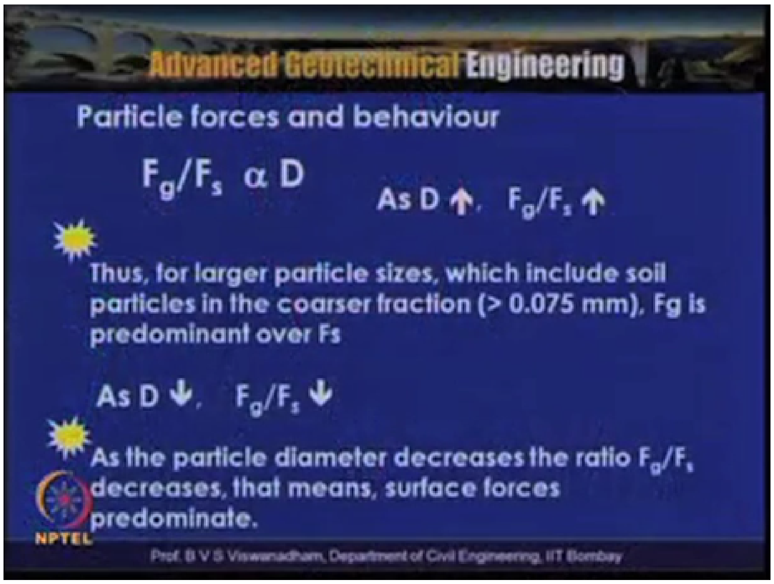

So if you take the ratio of F_g / F_s previously we said that $F_g \propto D^3$ and if you take $F_s \propto D^2$ if you see that the ratio of gravity forces and surface forces is $\propto$ D0 now as the D increases you F_g / F_s increases thus for largest particle sizes which includes soil particles in the coarser fraction > 0.075 mm F_g is predominant over F_s if as the D decreases you have F_g F_s decreases that means that the dominance of the surface forces comes into the picture as the particle diameter decreases the ratio of F_g / F_s decreases that means that the surface forces predominate.

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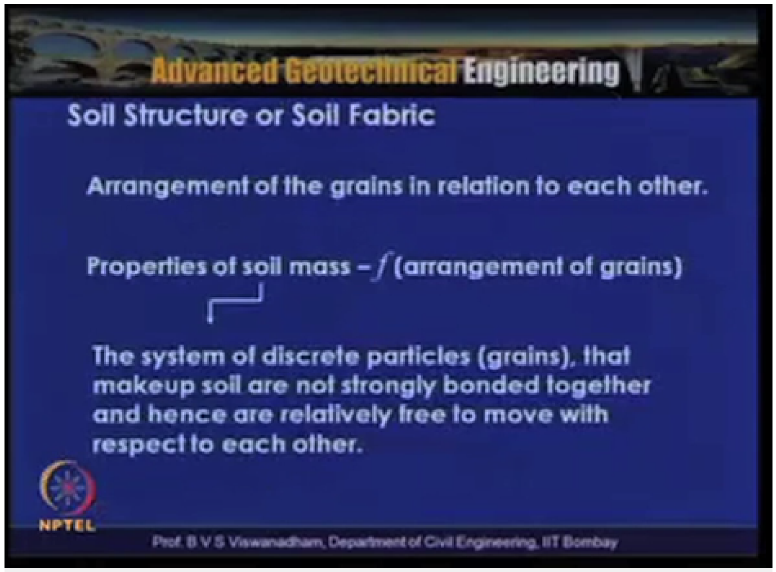

So soil structure or soil fabric let us once again discuss where the properties of soil mass is nothing but a function of arrangement of the grains the system of discrete particles are grains that makeup soils are not strongly bonded to then hence are relatively free to move with respect to each other.

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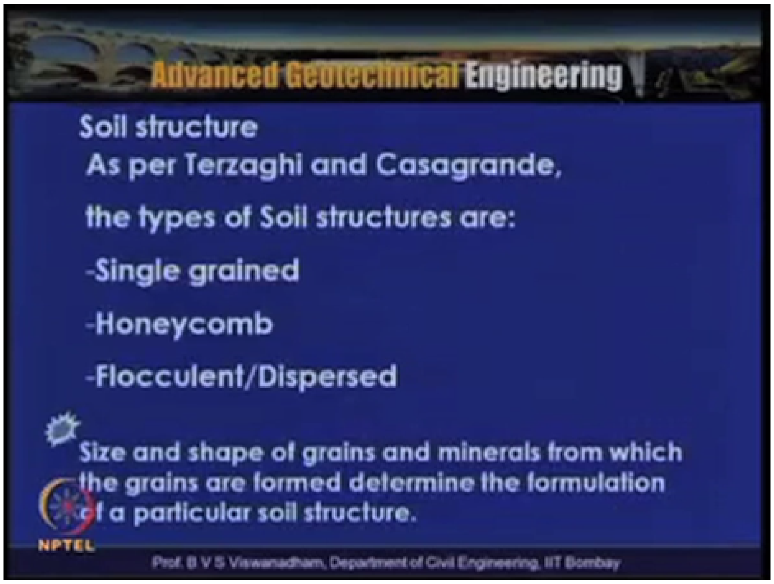

So if you divide or if you classify the soil structure or the particle arrangement according to da soggy and a ca sagandy it is said a single grained honey combed or flocculent and disperse the size and shape of the grains and minerals from which the grains are formed determine in the formulation of the a particular soil structure so how are the what environment these soil masses are soil deposits are they that also governs.

So size and shape of grains and minerals from which the grains are formed determine the formulation of particular soil structure, so let us discuss about the single grain structure the structural arrangement is positive this particular structure arrangement is possible because of the bulky particles.

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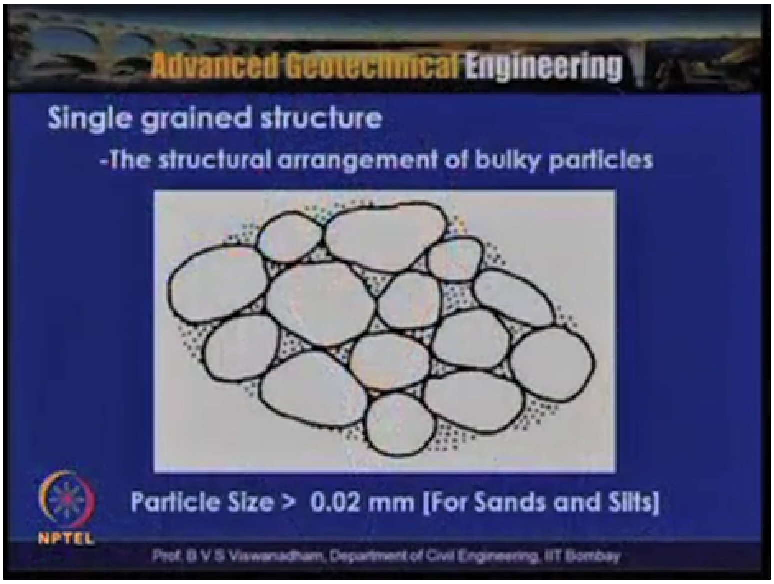

Particles having size is more than 0.02 mm that is for actually sands and silts where you can actually have large particles.

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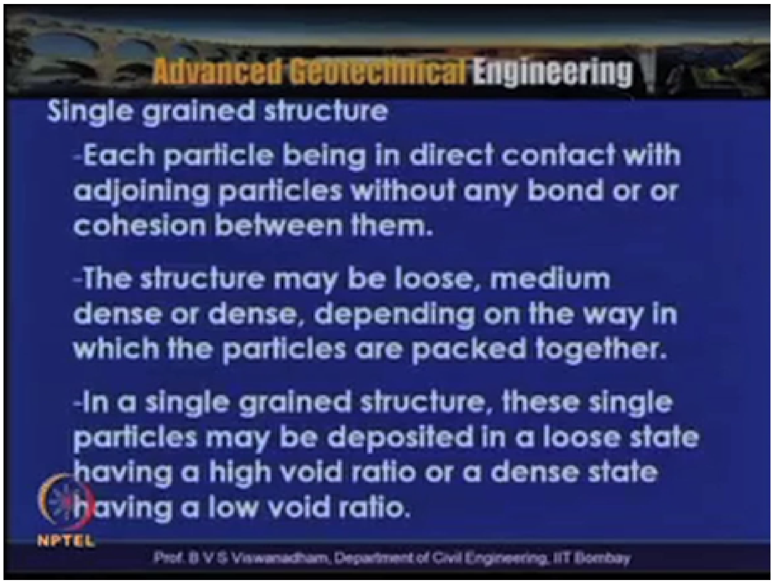

And then these are actually called as single grain structure and each particle being indirect contact with the adjoining particles without any bond and cohesion between them and the structure may be loose so if you look into this there is a possibility that the single grain structure can be loose or intermediate or medium dense are complete very highly having high dense the denseness that is very dense depending upon the way in which the particles are packed in a given volume of soil mass.

So the structure may be loose medium dense or dense depending on the way in which the particles are packet to them in a single grain structure the single particles may be deposited in a loose state having high void ratio in dense state and in low void ratio, so in a single grained structure if there is a loose deposit there is a possibility of high void ratio that means that the particle to particle contact is minimum and the particles are actually arranged in a such a way that they exhibit high void ratio. In case of a dense state the particles are closely packed and they exhibit very low void ratio.

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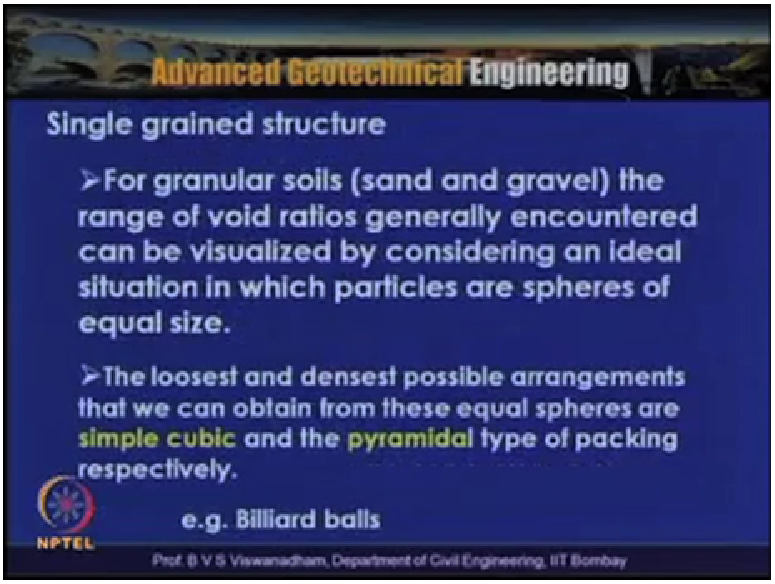

So for granular soils particularly sand and gravel the range of void ratio generally encountered can be visualized by considering the ideal situation in which particles are Spears of equal size if it is assumed that the particles are approximately this particle shape is approximated as a spear of diameter D then we can actually come out something like the loosest and densest possible arrangement.

So the loosest and densest possible arrangement that we can obtain from these equal spheres can be said as simple cubic where you have a loose arrangement and the pyramidal type of packing where for example if you consider billiard balls and if they a replaced in a simple cubic then it actually represents the loosest configuration and if they are actually butting the pyramidal type of packing and it actually gives the densest possible.

So we can actually determine theoretically what will be the void ratio under the loosest configuration and densest configuration so here in the single grain structure which is shown here.

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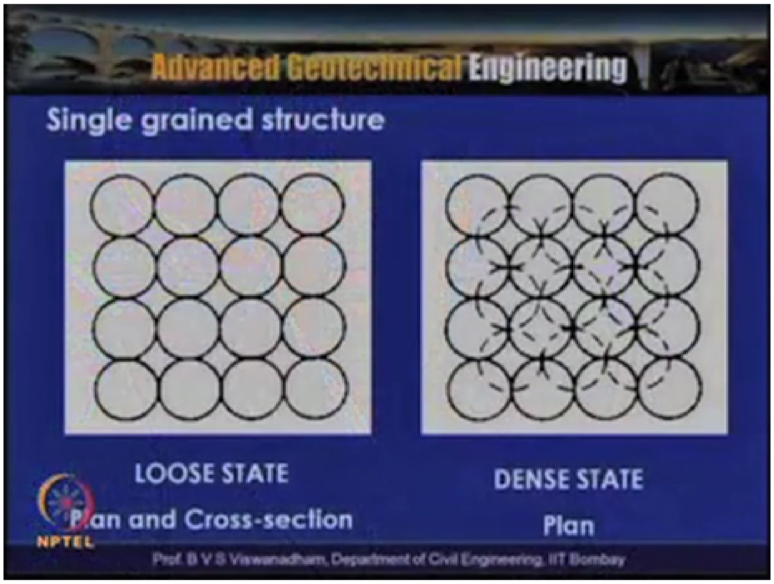

The plan view and cross-section of a cubic arrangement let us assume that you have got a each particle is visualized as a billiard ball and then you have got number of particles and this is actually a loose state where in your what use chunk of voids which are actually between these particles and in the that state you actually have this is the plan where all the voids actually filled with the edges and particles.

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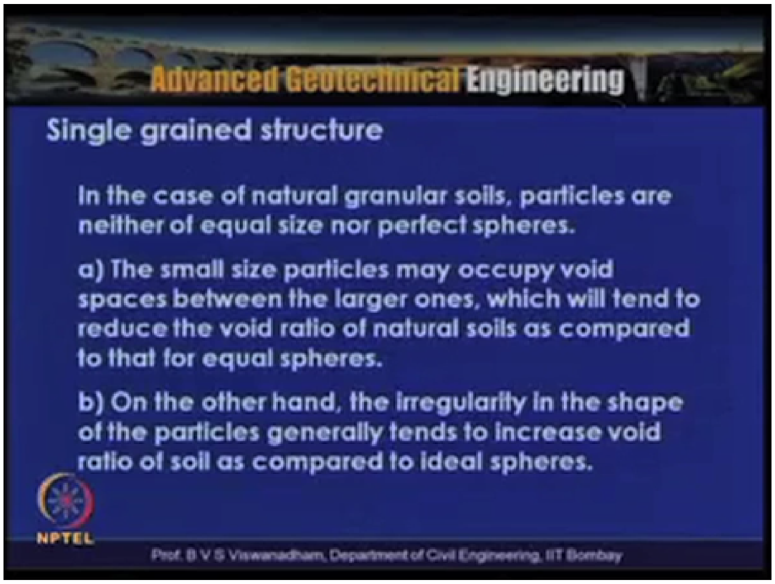

So in the single grain structure in the case of in the case of natural roller soils the particles are neither equal size nor perfect spheres we know that though we have actually said that the particles are you know equal dimensional but they are not there the neither equal size are not perfect spheres however these small sizes particles may occupy the void spaces between the large ones and which will tend to reduce the void ratio of the natural soils as come right to that equals spheres.

So on the other hand the regularity of the shape of the pair of particles generally tend to increase the void ratio as compared to ideal spheres.

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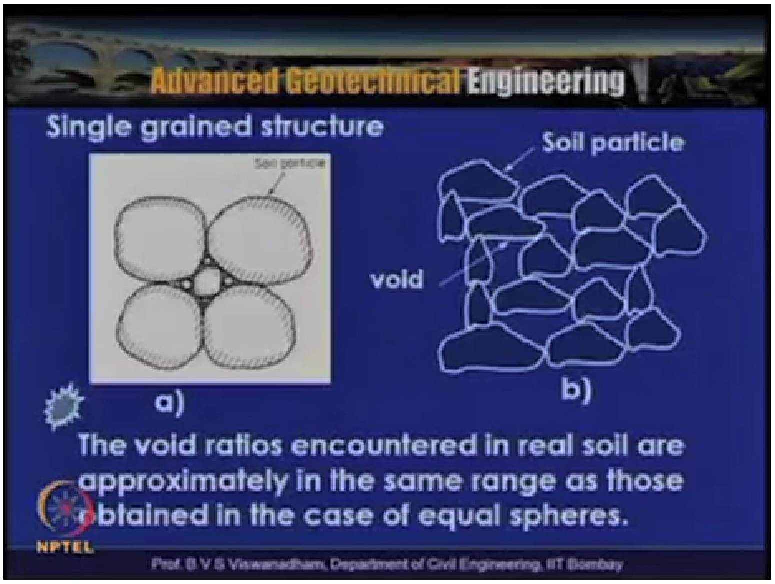

So that means that this idealization which what we assume is that with loosest and densest configuration somewhat holds go the violations encountered in real solid approximates the same range as those obtained in the case of equals spheres because of the when you have a single grain structure when the when you have what fine particles occupying the void spaces between the large particles they actually give the densest configuration when you have got the soil particles which are actually with the larger void spaces that actually can so-called close to the approximation what we actually said with the equal spheres.

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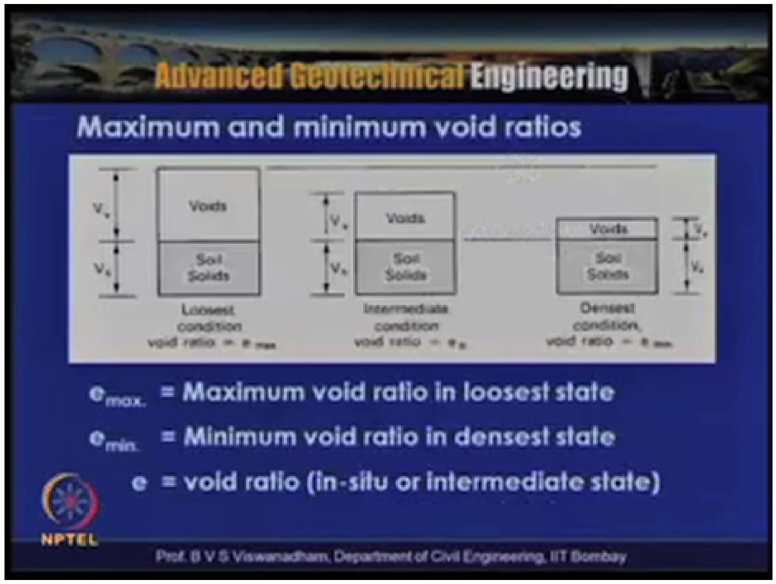

So here in this particular slide what are these Maxima minimum void ratios suppose if you assume the soil is in dry state then we have here two phases one is the volume of voids and volume of solids so in the loose state you have got the very high proportion of the volume of voids compared to the volume of solids in case of densest possible state what you see is that the volume of voids is very less compared to the what we observed in the loosest condition.

So here the loosest condition the void ratio e max is nothing but the volume of voids to volume of solids where the volume of solids is very high in the case of densest condition void ratio is indicated the minimum where the volume of voids is very minimum because of the densest packing so this type of arrangements are possible sometimes the soil deposits are losing state and if you have a structure which is required to be constructed on a looser deposit or if they are on the saturated state there is a possibility of endangering with liquefaction.

Hence there is a need for you know strengthening these soil deposits so it is always pure you know good to estimate these particular values of maximum will be minimum void ratios and these are actually unique for the given soil type and suppose let us assume that we are trying to compact a soil with a particular type of sandy soil then this is actually used to achieve what compaction can be done so that these soil is actually closed to the densest condition.

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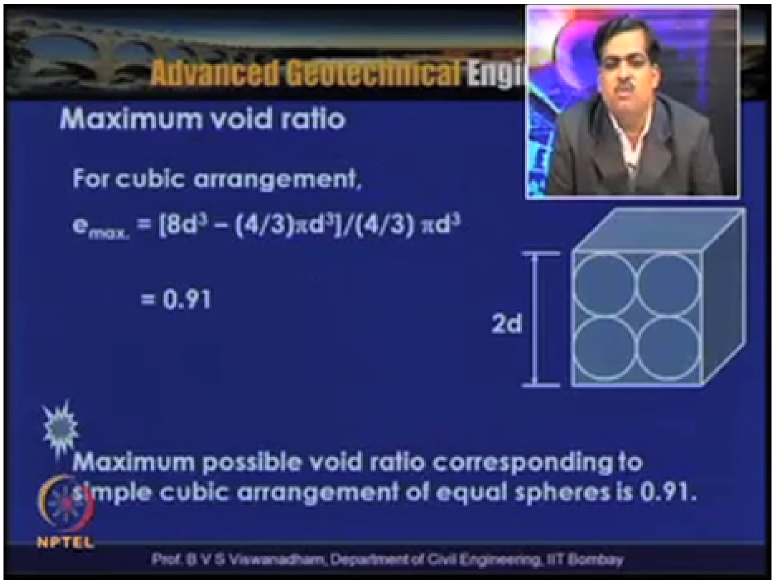

So if you idealize a cubic arrangement if d is the diameter of the particle so if you take a cube of having to d a face length here and then the total volume is nothing but $8d^3$ so the maximum void ratio what we said is that nothing but the volume of voids to volume of solids so here volume of the solids is 4 /3 πd^3 into 8 particles that means that here 4/3 π $d/2^3$ into 8 particles when it gets simplified you get as 4 / $3\pi^3$.

Now in order to get the volume of voids total volume of the this cubic arrangement works out to be $8d^3$ - this volume of solids is nothing but the volume of voids so if you simplify this it is nothing but there 6 - π / πe which is nothing but 0.91 that means that if you have the maximum possible void ratio is of this order whenever it is in gradient soil or this width is idealization it comes out to be about 0.91, so maximum positive void ratio corresponding to the simple cubic arrangement which actually gives the loosest state is said to be 0.91.

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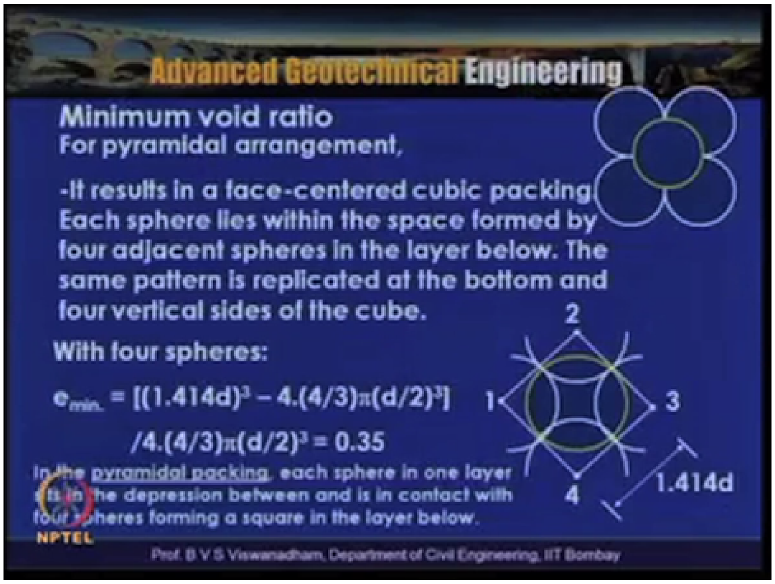

Contrary to this if you have got a densest configuration that means that you have got a soil particle which is actually resting on the four equal dimensions spheres that means that in the primordial packing each sphere in one layer sits on the depression between and is in contact with the four sphere forming a square in the layer below so it is the result of this what we get is that in the pyramidal packing there is a possibility of you get the minimum void ratio.

So it results in a face centric cubic packing each sphere lies within the spaces formed with the four here formula resistance spheres in the layer below the same pattern is replicated at bottom and for vertical sides of the cube so the idealization which is actually shown here which is nothing but the route to d, so that is nothing but the total volume that is volume of voids is here is nothing but 1 .41 d^3 -4 into 4/3π $d/2^3$/ the volume of the soils in their particular layer which is works out to be about 0.35.

Now if you see here the densest possibility you have got a void ratio of which is about 0.35 in the case of loosest possibility you actually have got a void ratio of about 0.91 now let us define one more parameter which is very useful parameter as far as the compaction of the coarse-grained soils which are actually not having fines more than 10% that means that the size of the particles is not more than 10% of the 10 to 12 % of the particles not more than 75 finer than 75 micron.

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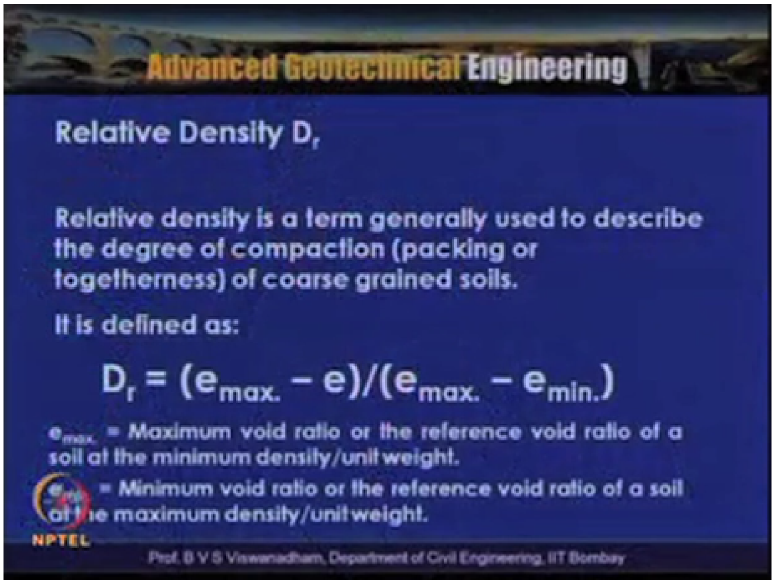

That is 0.075 mm really to density is a 10 generally used to describe the degree of compaction packing or to the Ness of the coarse grained soils and which is indicated by D_r = e – e max - e/ e max - e minimum minima e is nothing but the in-situ void ratio or the void ratio which is actually achieved if the soil deposit is say done manually so E max is nothing but the maximum void ratio or the reference world ratio of a soil at the minimum density per unit weight a minimum is nothing but minimum void ratio or the reference void ratio of soil at the maximum density per unit weight maximum density unit weight.

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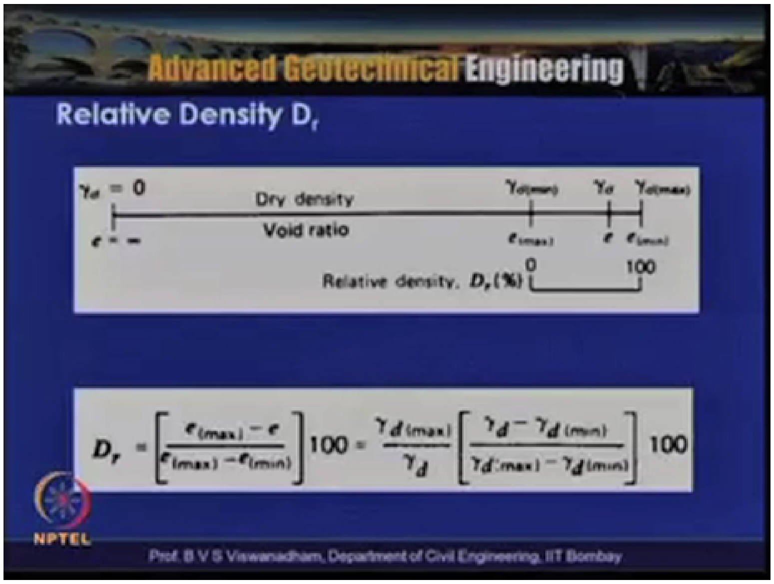

So here in this particular slide the relative density which is indicated as D_r is given as it actually has got two boundaries when suppose if the void ratio instead of void ratio is say close to e minimum that means the relative density is about 100% if it is say close to e max that means that the γ and a minimum the relative density of a soil mass is 0 but e which is actually between these two upper bound possibility and lower bound possibility of the void ratios and that is actually exhibits a certain amount of relative density.

So if you want say a loose deposit then you if you encounter with the loose deposit you have the soil relative density values close to the e max and if you have got denser deposits then you have what the relative density values close to this area so by using the if you assume that e = Gs γ W/ γd - 1 and if you substitute these with respect to densities are unit weights you will get here d_r = e max –e or e max - minimum which is if you simplify this you will get γ d-max / γ d into γ d -γ d minimum / γ d max- γ d minimum so in 200.

So the relative density is actually expressed as hundred so by determining you know the by knowing for a particular type of soil what is the maximum dry unit weight of soil and minimum dry unit weight of soil which is possible by measuring the in situ unit weight of soil we can actually assess the inductive density in the field which is actually a very useful parameter in identifying the soil deposits.

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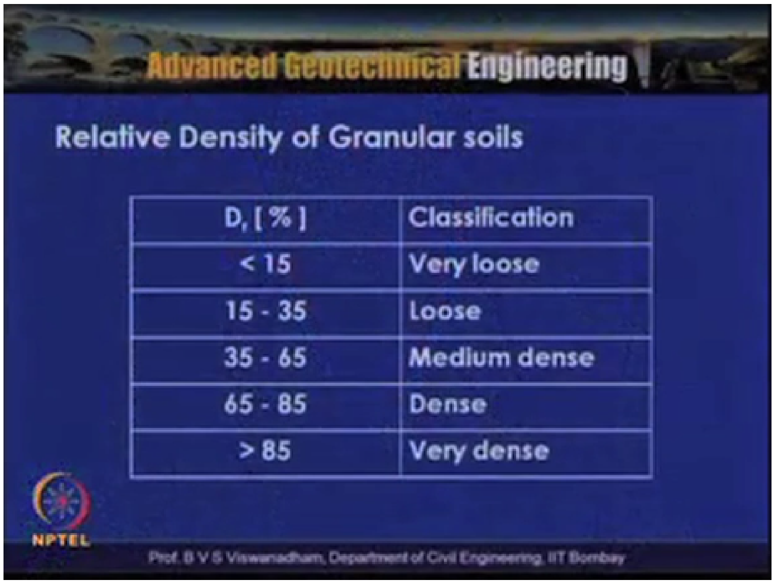

So here in this slide typical range or a classification of the relative density of the granular soils is shown here where the relative densities say if it is less than 15% very loose 15 to 35 indicates lose the deposits 35 to 65 means medium dense 65 to 85 is dense and greater than 85 indicates that very dense soil deposit.

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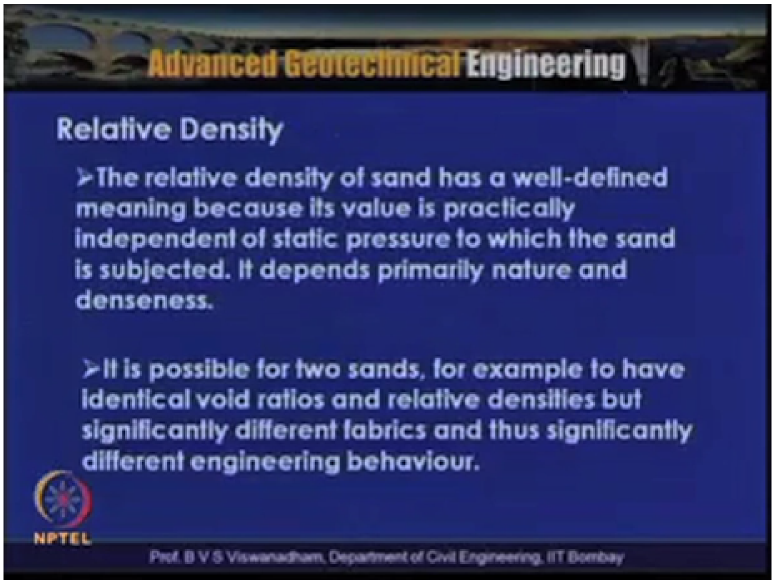

The relative density of sand has a well-defined meaning because it is values practically independent of the static pressure to which the sand is subjected it depends primarily in nature and denseness it is possible for two sands for example have got two identical void ratios to have identical void ratios and relative densities but significantly different soil fabric arrangement thus significantly different engineering behavior it is possible that for example to have identical void ratios and relative densities but significantly different particle rearrangement the significantly different engineering behavior.

So it is very typical as far as the soil behavior is concerned possible but the two sides for example to have identical void ratios and relative densities but significant different fabrics and significant different engineering behavior.

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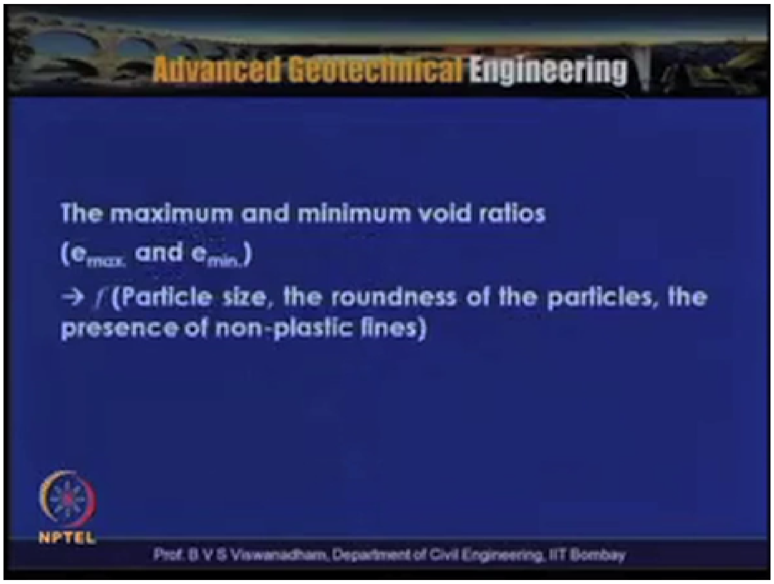

Now the maximum and minimum void ratios are found to depend upon the particle size the dullness of the particles and the presence of the non plastic files it has been found that with the recent research the presence of the non plastic finds influences significantly the maximum minimum void ratios of the particular soil deposit and the roundness of the particles whether their angular sub-angular are surrounded around it and particle sizes.

So this will be discussing at the end of the module along with the other parameters once we introduced coming to the another possible type of the particle arrangement which is actually called as Hana common structure and these are actually occur there is possible if you have got a silt smaller than 0.02mm and larger than 0.02mm.

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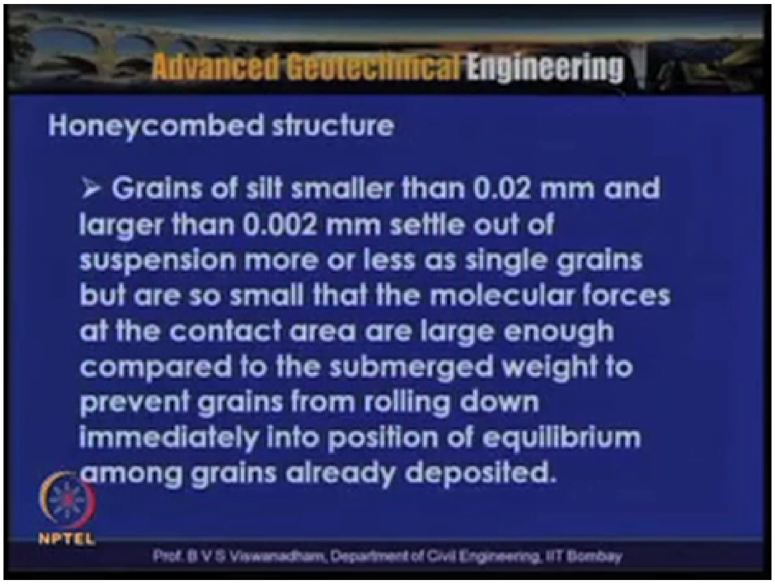

And basically this occurs because of the intermolecular forces and this actually can come if you actually have you know some silt particles so grains of silt smaller than 0.02 mm and larger than 0.02mm settle out suspension more or less and single grains but are small that molecular forces at the contact area are large enough compared to the submerged weight to prevent grains from rolling down immediately to the position of the equilibrium among the grains already deposited.

So here in the honeycomb structure when you have at a particles smaller than 0.02mm and larger than 0.02 mm 0.002 mm there is a possibility that it actually forms the honeycomb structure and even in case of some fine science because of the presence of some contact moisture there is a possibility that you actually come across this honeycomb or something like a mat type appearance when you have when you see you know partially or a moist side.

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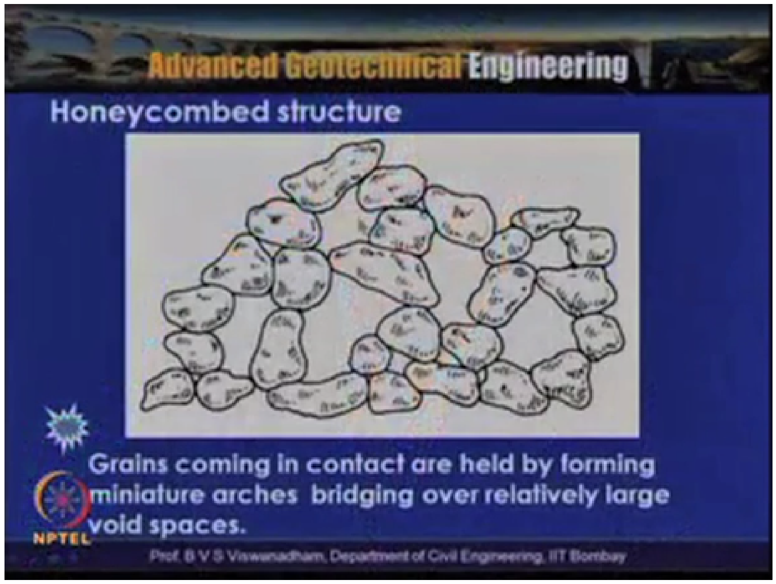

So in this slide the typical honeycomb structure is shown here wearing you actually have got the particles which are bridged because of the inter particle forces and the grains coming in contact held by forming a mineral arches bridging or relatively large spaces so once you know it comes in contact with water once these intermolecular forces you know vanish it actually converts into a bulky grain structure or a single grain structure.

So it is possible that the honeycomb structure which is actually shown here if in contact with in the vendor then these molecular forces vanish it actually forms something called the again gets converted into a single grain structure.

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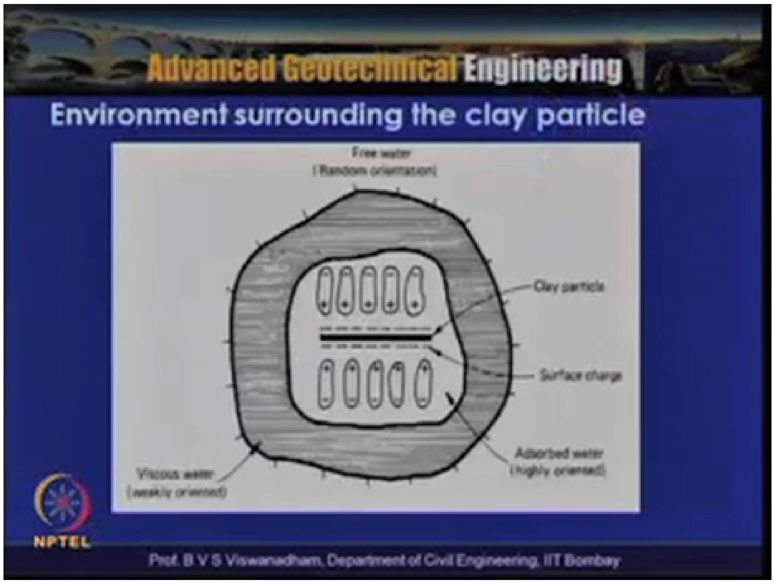

So in the next lecture we discuss about the environment surrounding the clay particles particularly here what we discussed in this class is that the clay particle is a plate platelet shape particle which is part of predominantly negative charge and then there you have a water particles which are actually close to the part clay particle size and then you have a free water which is actually surrounding this particle so we will try to discuss about this particular behavior and this part this part of the water which is called free water which is actually has got low viscosity compared to this zone.

And this zone which is actually called adsorbed water we which actually has highly oriented and has got very high viscosity and which is actually headed very close to the surface of the particle and so in the in this particular lecture what we try to discuss is about the particle shapes and what are the different particle shapes and what are the different possible particle arrangement which are actually possible.

And we actually said that there is a possibility of a single grain structure and then we said that honeycomb structure then when it comes to clay particles we need to actually discuss about two types of the structures which are actually called flocculent structure and dispersed structure and that can be introduced only once we understand about environment surrounding the clay particle.

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