Geology and Soil Mechanics
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Lecture - 02
Index Properties of Soil

Welcome to the course Geology and Soil Mechanics. So, in the last lecture we have seen the rock formation, different types of rocks, classification of rocks, and the disintegration of the weathering process of rocks and then formation of soil and different deposits across the country. So now we are really moving to the actual soil mechanics. So before that we need to know different index properties of soil.

So, today's lecture will be dedicated to define or to understand different index properties of soil. Now how basically you categorise different types of soil. Now first of all we need to discuss about the phase diagram. So, any soil if you consider that is basically the 3-phase system. So, soil basically consist of soil solids, water, and air. This is the general scenario in any kind of soil. So that is why soil is known as 3-phase system.

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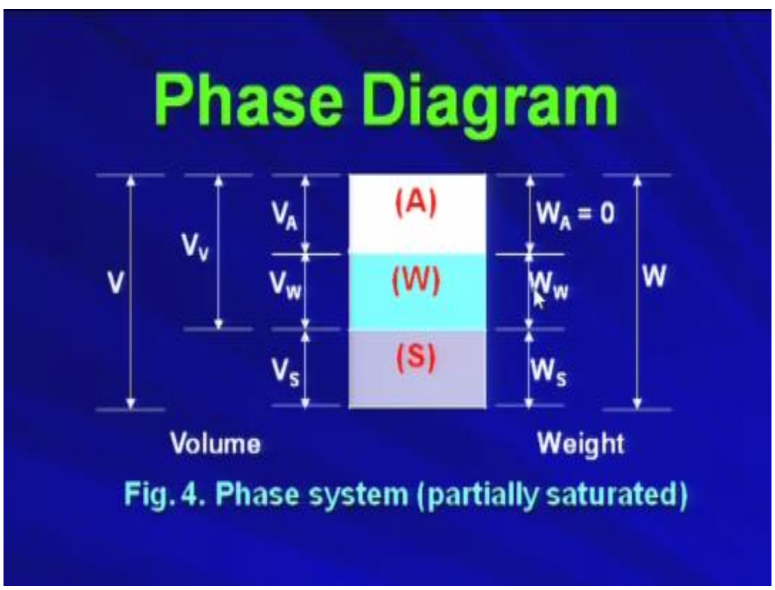

So, if you look at this figure, so basically if I consider this is the whole soil matrix then part of that will be covered by soil solids and then water and then air and on the right-hand side basically we are having the weight scale where W S is the weight of soil solids, W W is the weight of water, and W A, which is nothing but the weight of air and eventually that is becoming or that is that can be considered as 0.

Whereas on the left-hand side we have the volume scale. So total volume of the matrix is a capital V whereas V S is the volume of soil solids that means this much of volume will be occupied by the soil solid particles. Then V W is the volume of water that will be occupied by water and V A is the volume of air. So that means please try to remember that W A is 0 but V A is not 0. So please do not make any mistake there in your consideration.

So, the total weight of the matrix is capital W which is W S plus W W whereas total volume V of the matrix is V S plus V W plus V A. Now where this water as well as air is getting occupied? Now of course when you are considering the soil if you if you think about any soil matrix basically there is soil there are soil solids and there will be some pore space or the void space which will be occupied by air or water or both.

Now basically this volume, this V A plus V W I mean this V A plus V W together will be conforming or will be forming the total volume of voids that is V V. So, total volume again is V V plus V S that means volume of voids plus volume of soil solids. So, if you understand this thing properly then rest of the things will be very simply understandable.

So, this is the phase system for partially saturated. Why it is partially saturated? That means if soil is fully saturated or completely saturated then what is happening? Soil is getting saturated by the water. So, if I say soil is fully saturated then you do not have any air. You are you have only soil solids and water. So, I am considering the partially saturated which is pretty common which is generally common in the field so you have all the 3 components present in the soil.

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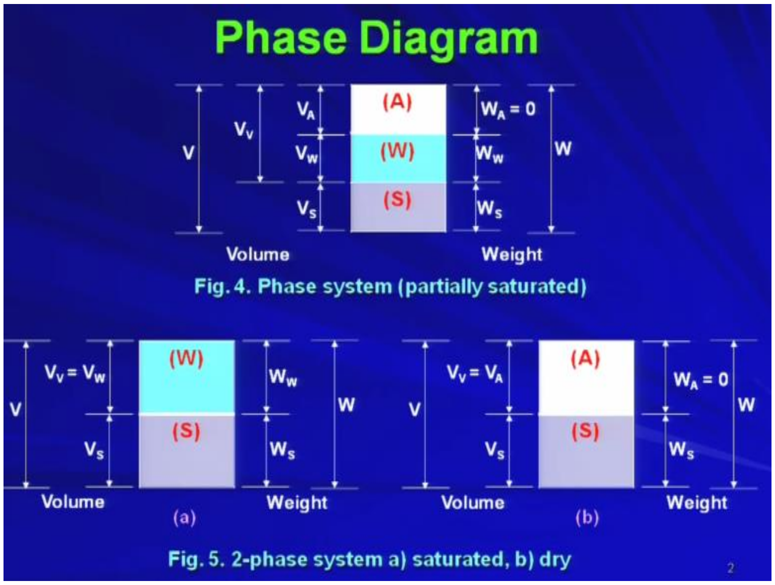

Now coming to some special case where we are considering completely saturated soil as I told you have only soil solids and water whereas you can have also completely dry soil. That means there is no water at all in the matrix. That means you have soil solids and air. So, if you consider the saturated soil then it becomes, the 3-phase system becomes eventually the 2-phase system where you have soil solids and water and the total weight W is getting occupied by the weight of solids W S and weight of water W W whereas the total volume of the matrix capital V is basically getting occupied by the volume of solids V S and volume of water V W.

Now if you look at completely saturated situation, now what is your volume of voids? Volume of voids is simply equal to your volume of water because it is completely saturated all the pore spaces or that is void spaces will be getting occupied by the water. So, there is no air at all. So V V will be just equal to your V W.

Similarly if you come back to this completely dry situation you have 2-phase system again, the soil, soil solids, and air. Again, your total weight capital W will be consisting of only weight of solids. So, because we have currently considered that there is no weight of air. Similarly, if you consider the volume of total matrix then V capital V will be consisting of V S that is volume of soil solids and V A that is volume of air. Together it will form the total volume of the matrix.

Again, the void space that is all pore spaces will be occupied by air because there is no water at all in this completely dry situation. So V V again will be equal to V A. So, if you understand this phase diagram then we will be calculating different things to find out different properties as well as different say definition which will be required to understand the soil behaviour. Now coming to some simple definitions. So, these are very much required to understand the soil mechanics and to quantify different properties of the soil basically you need these definitions.

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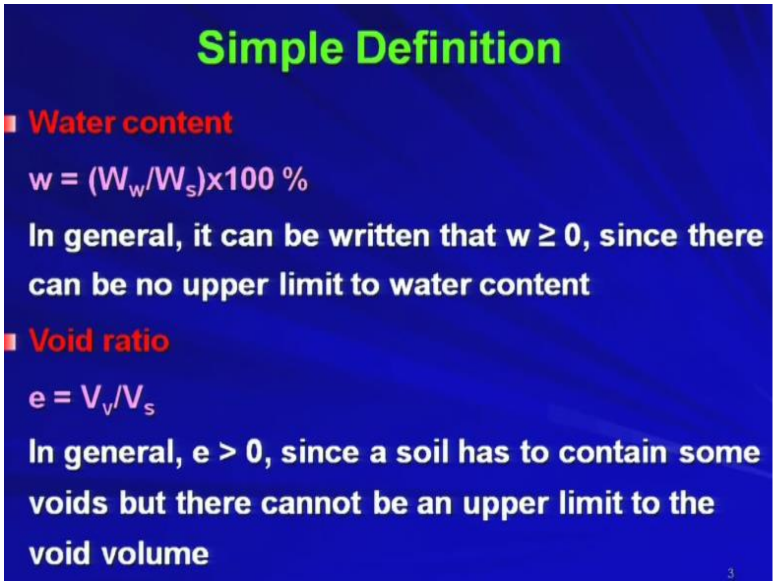

Now first definition is water content. Now what is water content? So, water content is the ratio of weight of water to the weight of solids, that means small w is the water content is equal to W W by W S into 100%. It is really expressed in percentage. So that means it says that how much water is present in the matrix, matrix means soil matrix in comparison to the weight of solids.

So, in general it can be written that small w that is the water content is greater than equal to 0 since there can be no upper limit to water content. Because you can have any weight of water present in the soil. So, there is no upper limit. But of course, there should be a lower limit that is 0. So, maximum or at the at the minimum what you can have, you can have the 2-phase system which is completely dry. So, there is no water at all.

So, W W is completely equal to 0. So that situation exist, but there is no upper limit for the water content. Now second definition is the void ratio. So, these definitions please I request you all please try to remember these definitions or understand these definitions because these definitions will be frequently used in the whole course whatever we will be learning in this particular subject.

Well, so coming to the void ratio. So, void ratio is generally expressed as small e which is nothing but equal to V V by V S. What is V V, volume of voids and what is V S, volume of solids. That means this is the ratio of volume of voids to the volume of solids. So, in general e greater than 0. Of course, e should be greater than 0 because e cannot be equal to 0 because your V V cannot be 0 simply. So, any soil matrix if you consider, you should have some V V.

So, if you have some V V so e must be greater than 0. Since the soil has to contain some voids, it is obvious, it is quite obvious, you cannot have any soil matrix which is void less okay. So, since the soil has to contain some voids, but there cannot be an upper limit to the void volume. So, because the soil has to contain some voids so e must be greater than 0, e cannot be equal to 0 and there cannot be any upper limit.

So, volume of voids could be anything. So, if it is very densely packed then volume of voids will be less. If it is very loosely packed, then your volume of voids will be more. It depends on how the matrix is getting formed.

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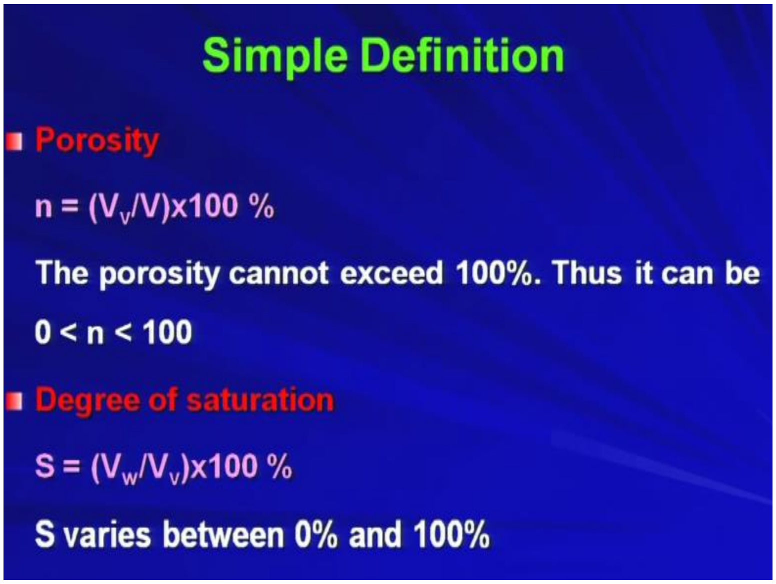

Then coming to the porosity. So, porosity is generally expressed in terms of n which is equal to V V by V that is the total volume. That means the ratio of volume of voids to the volume of total volume of total soil matrix and it is also expressed in percentage. So the porosity cannot exceed 100%, please remember.

So, this is the difference between porosity and the void ratio, where void ratio was not having any upper limit whereas the porosity is having the upper limit that is 100%. Why it is so? If you look at the equation or the expression V V at the most can be equal to V right. So V is the total volume so if I consider, I mean hypothetically if I consider, the total volume of the soil matrix is occupied by the total void space.

So that means there is no solid at all okay or if even if there are some solid particles they are negligible in terms in in comparison to the total volume of the matrix. In that situation your porosity must be equal to 100% but that is the upper limit. It cannot go beyond 100%. So thus it can be 0, n should be greater than 0 okay of course because no soil can have zero void space or the zero void volume. So, n must be greater than 0 but should be less than 100.

Then coming to the degree of saturation. So, degree of saturation is expressed by the ratio of volume of water by to the volume of voids into 100% that means again it is expressed in percentage. Now what does it mean? What do you mean by degree of saturation physically? Say suppose you have the voids now if I say this soil is 10% saturated or the degree of saturation of this soil is say 10% or degree of saturation of this soil is 30% so what does it mean basically. That means you have the voids. These voids will be occupied by either water or air.

Now if the void is getting occupied by water more, then your degree of saturation will be automatically increasing. So that is the idea or that basically that indication you will be getting from your degree of saturation value. That means how much of void space is getting saturated by the water. So V W by V V. So, S varies between 0% and 100%. Of course, that is true because at the most you can have V W equal to 0 that means completely dry situation that is again also 2-phase system.

So, you have soil solid particles and you have air. So, there is no water. In that situation your degree of saturation is equal to 0, simply 0 and if you consider fully saturated soil where you do not have any air then your V W becomes equal to V V as we have seen in the phase diagram. So, your S becomes 100%.

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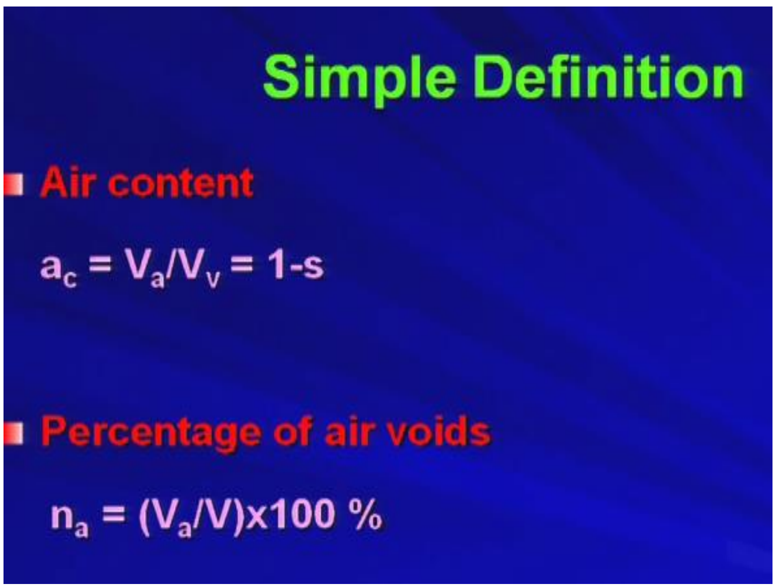

Now coming to the another definition, air content a c is defined by V a by V v which is nothing but 1 minus s from the definition. Now s is nothing but your degree of saturation. Now coming to the another definition, percentage of air voids that means how much air is present in comparison to the total volume of the matrix. So, this is nothing but the ratio of V a to the total volume V and it is also expressed in percentage.

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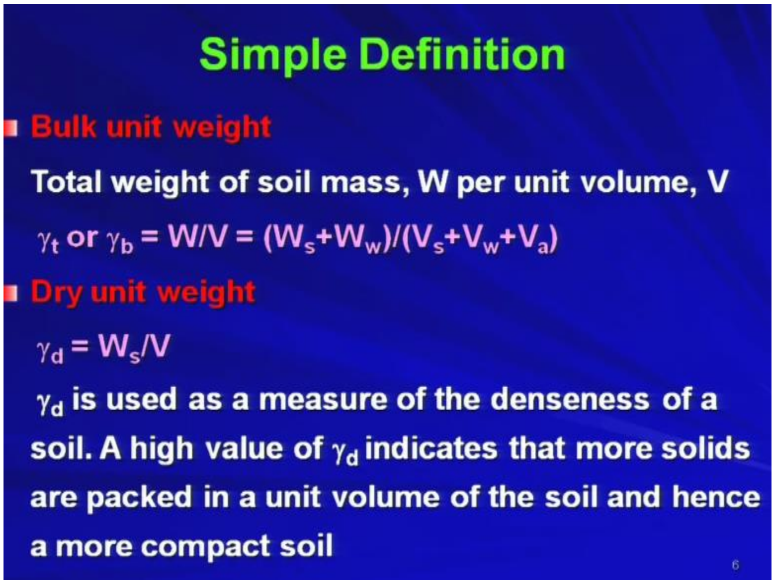

Then coming to the bulk unit weight. Now we are coming to very important definition that is bulk unit weight. That is nothing but the total weight of soil mass W okay which is nothing but equal to W s plus W w if water is present. If water is not present only W s per unit volume V. So, unit volume means the total volume of the matrix, whole system.

So, gamma, in some books you will be seeing gamma t or some books you will be seeing gamma b so I am writing both the things. So, gamma t or gamma b is equal to W by V, which is nothing but equal to W s plus W w divided by all hollows V s plus V w plus V a.

Now coming to the next definition, dry unit weight. Now what do you mean by dry unit weight. Dry unit weight is expressed as gamma d which is equal to W s by V. That means their weight of solids, weight of soil solids by the total volume of the matrix. Now what does it indicate? Why do we really need this dry unit weight? Because already we have defined (()) (15:30) unit weight bulk unit weight, now why do we need that?

So, gamma d is used as a measure of the denseness of a soil. Then if your gamma d is increasing then you can say or your indication should be thus we are going to more dense deposition of the soil. That means if gamma d increases that means weight of solids is increasing for a particular value of volume of total matrix. So, a high value of gamma d indicates that more solids are packed in a unit volume of the soil, right and hence a more compact soil. So that means if gamma d increases you will be getting more compactness or more denseness in the soil matrix.

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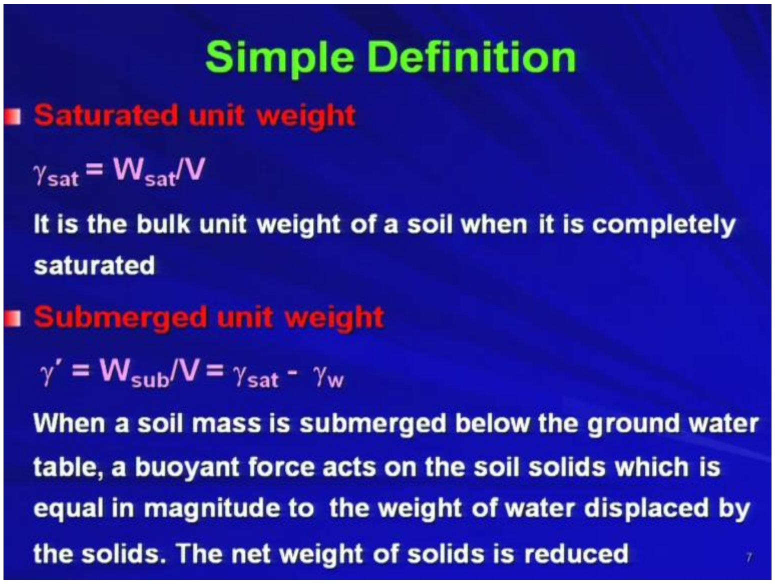

Then coming to the saturated unit weight. Now saturated unit weight when I am talking about, this is nothing but the bulk unit weight I mean we are defining this thing in little bit definite way to differentiate from the bulk unit weight. This is nothing but the bulk unit weight of the soil when it is completely saturated. So, if you see the expression gamma sat is equal to W saturated W sat by V. So, it is very similar to the bulk unit weight expression. Only thing is that we are talking or we are taking the weight of saturated soil.

Then submerged unit weight. Now why do we need this submerged unit weight? Suppose, if you consider water table, I mean you know the water table right for any kind of tubal construction or any kind of well construction you need to have the idea of water table. Now if you consider the soil below the water table, then of course soil will be experiencing some buoyancy force and because of that you will be getting some reduction in the unit weight as you know from the law of Archimedes.

So, the submerged unit weight is very important when you are drilling the soil below the water table. That means it is completely submerged, filled with water, water table is on the higher side. So, because of the submergence you will be getting some reduction. What is the reduction? So, gamma submerged is generally expressed as gamma prime is equal to W submerged by V which is equal to gamma sat that is whatever we have seen, gamma saturated gamma sat minus gamma w where gamma w is the unit weight of water.

So, when a soil mass is submerged below the ground water table, a buoyant force acts on the soil solids which is equal in magnitude to the weight of water displaced by the solids which is which is coming from the physics. So, there is no issue for that. So, the net weight of solids is reduced. So, if you do not consider this, if you consider the bulk unit weight even below the ground water table then your design is wrong. So, you need to consider the submerged unit weight which will be giving you the actual picture below the ground water table.

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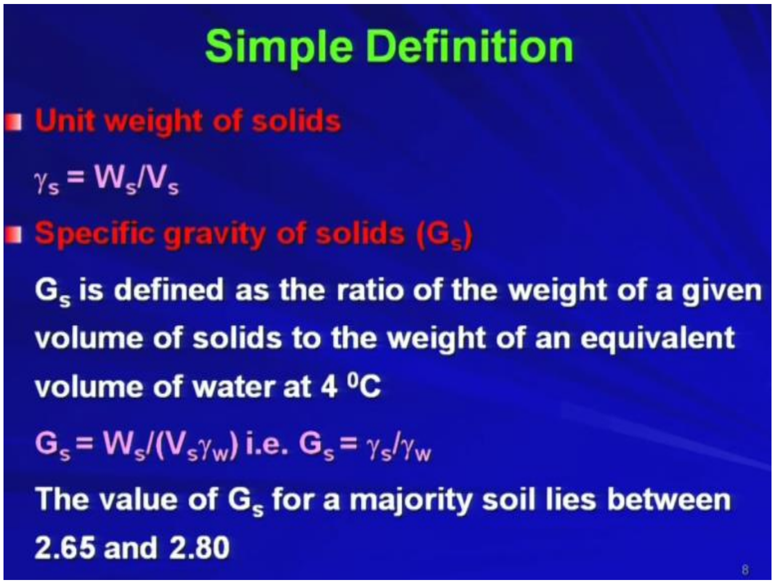

Then unit weight of solids, only solids. If we are considering only soil solids, then what should be the unit weight? So that is defined by gamma s which is equal to W s by V s. Then specific gravity of solids defined by G s. So, G s is defined as the ratio of the weight of a given volume of solids to the weight of an equivalent volume of water at 4 degree centigrade. So, if your water is at different temperature, then you need to of course you need to provide some correction.

Otherwise, by and large we generally consider that G s is equal to W s by V s into gamma w. That is G s is equal to gamma s by gamma which where gamma s already you have seen. Gamma s is the unit weight of solids and gamma w is the unit weight of water. So, the value of G s that is specific gravity of solids for a majority of soil lies between 2.65 and 2.8. So, whatever soil you generally take, it lies between 2.65 to 2.8. So, this is a very typical property of a of soil.

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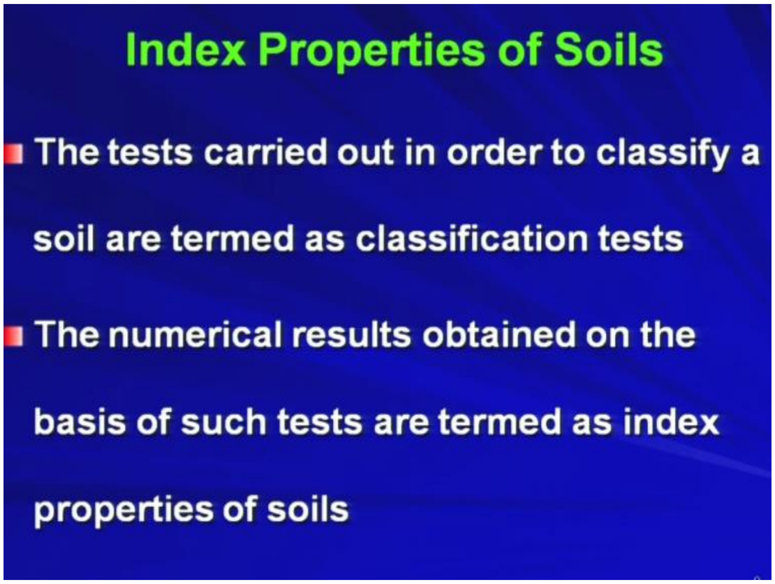

Now we are talking about the classification of soil. So, we need to classify of the soil. I mean you all know that from I mean without knowing the subject you know what is sand and what is clay. So, if I tell, if I give you some soil specimen, then by seeing the specimen you will say okay this is sand, this is clay, this is gravel, this is boulder, so something like that.

But those are the things, now if I if I ask you okay this is you are telling this is sand, now what type of sand, it is coarse sand or medium sand or fine sand. So, for that you need some quantification, you need some classification. Now if I say you are saying this is clay, whether it is really clay or silt. So, for that you need some quantification.

So, to quantify those things, to understand these things in a better way you need to classify the soil. For that you need to perform some test, laboratory experiments, so the tests carried out in order to classify a soil are termed as classification tests. The numerical results obtained on the basis of such tests are termed as index properties of soils.

Now basically when you are classifying the soil and define numerical results, numerical values, we will be seeing later on in the subsequent lecture, different numerical terms numerical parameters you will be observing and all those numerical parameters will be known as index properties of soil. Now suppose if I tell these are the index properties of this type of soil a person sitting in outside or sitting in anywhere in the world will understand okay what type of soil I really mean for.

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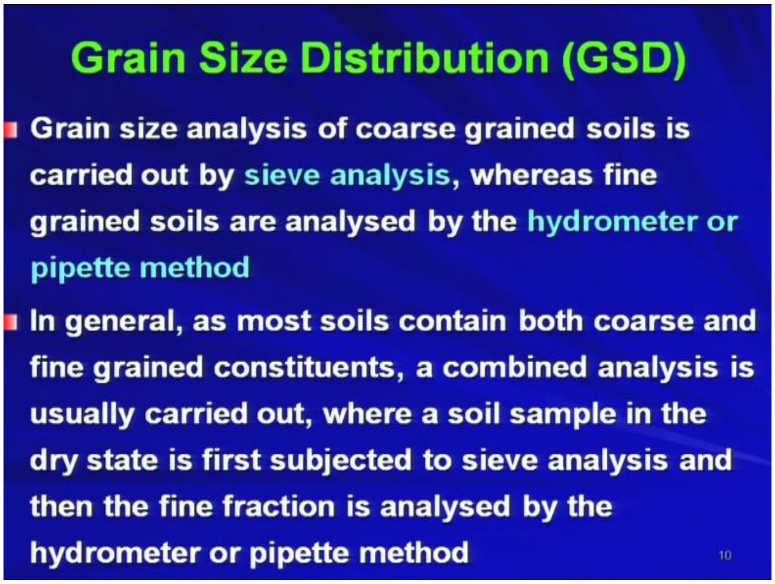

Now grain size analysis of coarse grained soils is carried out by sieve analysis, so we will be having a stack of sieves and that sieve analysis we will find out the gradation or the grain size analysis for the coarse grained soil, coarse grained means suppose you have boulder, cobbles, then sand. So those things are known as coarse grained soil. Whereas fine grained soil are analysed by the hydrometer or the pipette method.

So fine grained soil means clay, which you cannot see from your by your bare eyes right so those soils will be defined as fine grained soil. So, for fine grained soil classification you need hydrometer test. In general, as most soils contain both coarse and fine grained constituents, it is obvious as you know that if I if I give you the soil, you will be getting some percentage of sand mixed in that you will be getting some percentage of clay mixed in that, so it is a mixed of coarse grained and fine grained.

Then if you if I ask you to classify that thing then you should have some proper process or proper say method by which you can classify that. Now a combined analysis is usually carried out where a soil sample in the dry state is first subjected to sieve analysis and then the fine fraction is analysed by the hydrometer or pipette method. That is quite obvious. Because I mean already we have decided that the sieve analysis will be done to classify the coarse grained soil and hydrometer analysis will be done to classify the fine grained soil.

Now if you have the mixed property or the mixed population in the matrix then you need to perform both the test to classify the whole range of the soil particles. So that is there. So, in the dry state you will be doing the sieve analysis and in the hydrometer test basically you cannot do the dry analysis, you have to go for the wet analysis.

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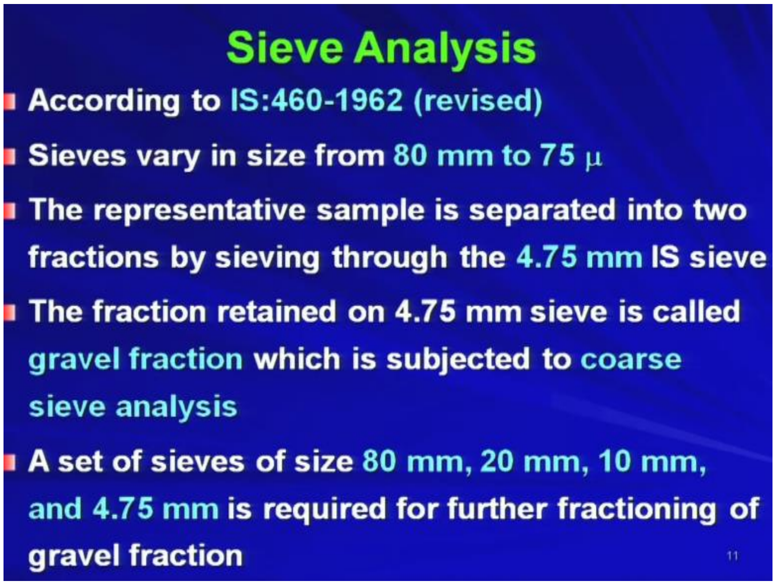

Now according to basically we are going to talk about the sieve analysis so it is now we will be talking about as per IS:460-1962 (revised). So, sieves vary in size from 80 mm to 75 micron. The representative sample is separated into 2 fractions by sieving through the 4.75 mm IS sieve.

The fraction retained on 4.75 mm sieve is called the gravel fraction which is subjected to coarse sieve analysis. So, you will be having in the sieve analysis itself you will be having 2 different sieve analysis. One is coarse sieve analysis another one is the fine sieve analysis. The coarse sieve analysis will be done for the gravel fraction which will be retained on 4.75 mm sieve. A set of sieves of size 80 mm, 20 mm, 10 mm, and 4.75 mm is required for further fractioning of gravel fraction.

So, you will be having the stack of different sieves as I told you 80 mm on the top, then 20 mm, then 10 mm, then 4.75 mm and then you will be putting the gravel fraction on top of the sieve and then you shake it and each sieve will be retaining some amount of particle and based on that you just classify okay. So, we will stop here today. So, in the next class we will be discussing about how to perform different sieve analysis.