Ground Improvement
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Module No. # 02
Lecture No. # 05
Compaction Control

So, in the earlier classes we were discussing about shallow compaction and deep compaction as the methods for improvement of ground under the classification mechanical modification of soils in which you will be able to get improvement in bearing capacity reduction in compressibility and also good whatever is the permeability reductions in permeability as well.

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Today, we would like to have how do we specify this specifications and also what do you mean by quality control in compaction. We would like to see some of these aspects. Specifications and control tests are required to ensure that you get the adequate performance of the foundation or the embankment of the compacted soil according to the chosen criteria. Here what do you mean by criteria is that you would, you should be talking about reduction in say for example, as I said, permeability or increase in bearing capacity and some of these aspects of objectives.

When you do control test, we should be… they have some criteria here. The test should be relevant say for example, when you say compaction as I just mentioned, we want a maximum dry density and optimum moisture content. So, this density and water content - they have to be related to stability. Say for example, the shear strength of the soil at that particular density and water content or in a particular range of water contents and density that is what we had been testing. So, if this strength criterion is met with by adopting or adhering to this density and water content, then the job is done. Even the same case in with respect to volume change in which we needed a specific density and we do not want lot of settlements or a volume change. So, that way the specification should be relevant to what you are interested in.

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Then the second objective would be that the cost effectiveness is very important because when you do the testing for example, in the case of the highway embankment the test expense should not be too much expensive and also why because they must be able give meaningful conclusions from with a minimum cost. So, when you try to compare the cost of construction and the consequence of failure the cost of investigation should be reasonably ok say for example, about 0.1 percent or 1 percent there should be some sort of specification in which one must be able to spend for developing specifications and quality control measures in a particular project. Then, whatever samples you are trying to test should be related to the purpose and also the estimated variation of soil properties being evaluated. What I mean is that, we have a particular laboratory test done and then the maximum gamma, maximum bulk density or the maximum density is about 1.8 ton per meter cube. So, I must have that in mind and then do that test. So, for example, if there is a variation of density about 55 to 10 percent, I must be able to pick out from the test results that particular information; to what extent these values are deviating the field values are deviating from the laboratory values or specified values; this is something very important.

So, when you are trying to have proper specifications in quality control, some of these points should be borne in mind and they should be relevant; they should be cost effective; they should be representative. So, all these criteria need to be met.

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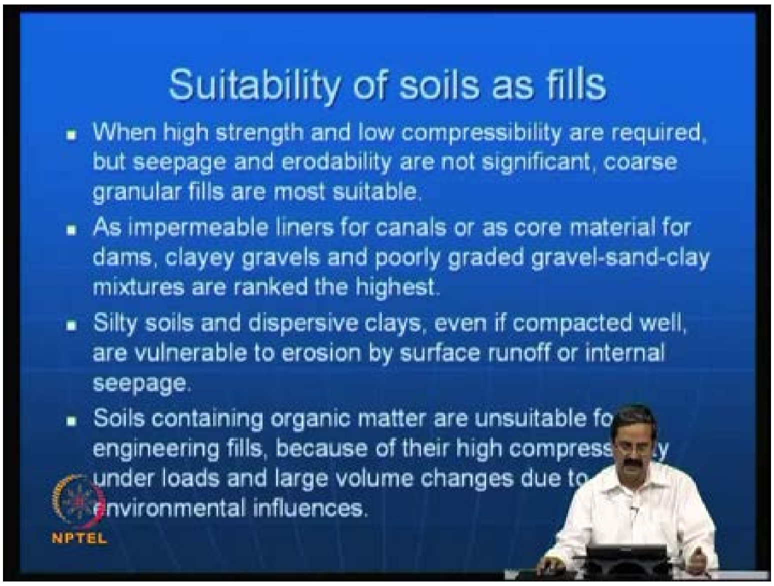

Before we go further, we must see why is this; some of this specification required we should understand that for example, in some cases when high strength and low compressibility are required, but seepage and the erodibility are not of significance. So, coarse granular fills are ok. So, like you can just take course granular material if you are interested in high strength and low compressibility like sands fine sands or medium dens [hand/sands] sands have this sort of behavior in which you get good strength and compressibility as well low compressibility.

Suppose you are looking for impermeable liners for canals; say for example, in canal linings the problem is that the seepage should not occur and the water should not be lost in seepage and because it should reach particular destination, that is one thing. So, it should serve as an impermeable substance to the extent possible and also as a core of the dams for example, we have in dams the core of the or the central portion of the dam itself is a impermeable membrane or sometimes clay liner also and then here we should be able to say that the some of this mixes like with lot of clay content and all that should be reasonably good.

So, there is another problem or something one should remember that in the case of silty soils and dispersive clays, actually I have seen couple of cases in which you have a dispersive clay. It may be very good when it is in dry condition, but when it has some surface runoff or there is a water contact, the problem is that it loses strength rapidly and they are vulnerable to erosion by surface runoff or internal seepage. Say for example, you construct a dam with this sort of silty soil material; there will be a cavity formations as just I was mentioning in the other class, that the clay disperses very fast; the particle to particle interaction is not there. So, under the presence of water it tries to move out.

So, the problem will be that if you have this sort of soils it is a risky thing. So, and then there could be some soils which you have lot of organic content. They are suitable for,… they are not really suitable for engineering fills because of the high compressibility under loads and large volume changes due to environmental influences. So, some of these ideas when,… one should have in mind, whatever is a type of dam, or a pavement, or a structure you are trying to think of, you must be able to have some ideas in mind and with regard to the general suitability. So, that you can take a decision properly; this is very important.

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So, when we do this compaction control test, why do we do this? Say for example, when your objective is to assess the strength and permeability, you cannot directly get them. So, we need the compaction control test to see that the requirement such as good strength and less compressibility and less permeability are assessed indirectly. That is, what we have; we have we are trying to do in this compaction control test and by taking a sample for a test or checking what we mean is that whether the water content that we got from the compaction curve say for example, optimum moisture content. Is it close to the or nearby or in the same range as that you got in the lab? This is what we would like to see and if the water content is not really in the same range then you need to really worry about it.

So, density is the same thing say for example, we know that the compaction curve in some places is, in some cases it is something like parabolic or some sort of curve and which means that any small change in the water content or the compactive effort could lead to lot of changes in density. So, one should really be very careful with that type of soil; so, control tests in terms of water content, density and penetration resistance. Actually, we will see that say for example, penetration tests are also done to check the suitability of soils as compact and then see that if the field compaction is done properly.

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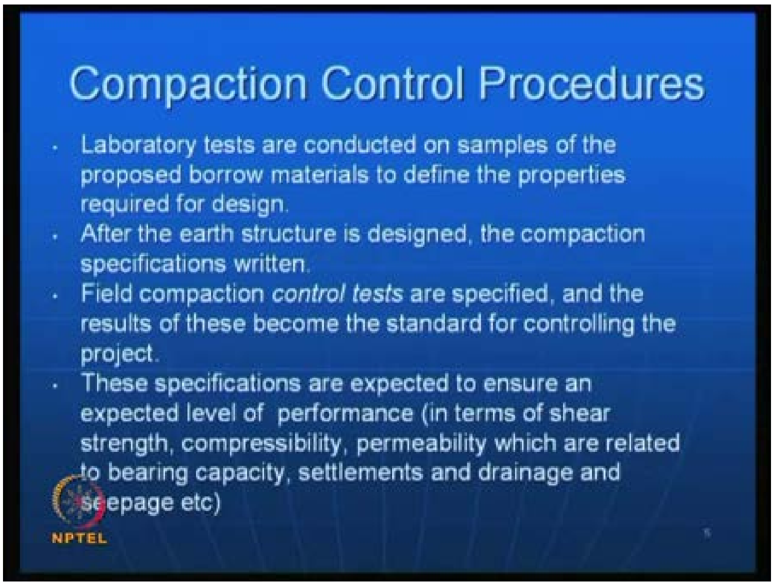

So, the procedure that we follow is that we do laboratory tests on samples of proposed borrowed materials to define properties required for design. What we do is that suppose, you are constructing a highway between two places you go to the nearby borrow materials. Say for example, you need lot of soil for you know for example, first you should check the suitability of the sub grade then you should have base layers. There are many soil layers; there are those two types say for example, if the soil is black cotton soil you must be able to put another layer on that and then see if that material has good properties. So, why we do laboratory test is that we should just see if the materials that you borrowed, soil materials that you borrowed, have good properties required for design.

What I mean is that you have an expansion soil layer and you do not want to have directly a load coming under the expansive soil. So, you have a cushion on that for example, some cushion required in actually some specification. Say that a cushion of about point 9 meters is required on the expansive soil. So, that it does not use the load; you are not directly in touch with the expansive soil. So, you have to specify some property for that material. Actually, we call it that particular soil layer that is above the expansive soil. We call it cohesive non-swelling layer it is a cohesive material, but it does not swell.

What it means is that, it has defined properties like cohesion, friction angle; it does not swell and all that whereas, the base soil is swelling. So, essentially you are trying to replace some amount of expansive soil with a non-swelling soil and then see that if it is all right. So, the properties of that non-swelling soil are very important here and we specify, say we have some specifications for that.

So, after that pavement structure is designed say for example, you design a pavement the c b r of the expansive soil is say some 3 percent or 4 percent and there are some methods which will tell you how much of thickness of cushion is required. We call it that cohesive non-swelling layer we call it a cushion. So, how much of thickness is required you can calculate. Then, what should be its properties one can calculate. So, once we design that the structure or the thickness of the non-swelling layer, you can also specify compaction specifications.

So, then we specify field control, field compaction control test because, like you know we have already got for that particular material this non-swelling soil; some maximum dry density and maximum or optimum water content. And, we try to specify based on those things what should be the field water content and field density; once you specify that they become the standard for controlling the project. For the whole project say for example, there is a 2 kilometer road in an expansive soil area and you have a cohesive non-swelling layer for a way of on that for the on the expansive soil. So, this becomes a standard for the project and you have to make sure that when you do that compaction of that cohesive non-swelling layer in the field using rollers or whatever or you have to follow these densities and water contents. As I just mentioned, these specifications are expected to ensure that an expected level of performance is expected in terms of shear strength, compressibility permeability which are related to bearing capacity settlements and drainage and seepage.

Say for example, we know that the particular soil is very poor. You want a particular amount of stronger soil at the top of the poor soil. So that, that is in terms of the shear strength, but since you cannot measure this shear strength directly you try to get the maximum dry density and water content.

Say for example, there is very soft soil and you want to increase the bearing capacity. The best way would be that you put a geo textile and put some 1 meter of sand there. So, the sand will have a good density and all that. The advantage is that now, the load is not directly coming on to the soft soil, but it is coming on to the sand cushion. So, sand the difference between the sand and clay is that this clay has a phi equal to 0; friction angle is 0 there is a cohesion, but whereas, you have a top material which is sand and the frictional angle is about 35 degrees. So, you can use that for a bearing capacity.

Say for example, the bearing capacity of soft soil is 5.14 c u; we say ultimate bearing capacity of the soft soil is 5.14 c u. So, if you know that the untrained shear strength of the soil as ten k p a its 5.14 into 10 k p a its about 51 k p a. But, now you are having a sand material at the top which is compacted and then you take its friction angle as 25 degrees and you will get a very good bearing capacity. One can make a bearing capacity calculations using that say 1 meter or 2 meter cushion and then see that can be used as a basis for your design or whatever specification. So, this is a very important thing that we try to specify this have this specifications to see that you are expecting some level of performance because I want a good bearing capacity and I also want less settlements and say for example, I want good permeability. Say for example, if I try to put a sandy layer at the top I am expecting a very good permeability from that material - that is what it means.

Now, what type of specifications we have? This one we should understand because, many people have different types of specifications. Here, one is called end product specification for example, in a particular highway project or in a building foundation, you expect the contractor is able to obtain the specified relative compaction. Say we say, that the compaction are, should be this much, but we do not really specify what type of equipment he has to use and all that. Our objective is only, in the end, like you know I want this density. I do not bother about what method you use; whether you can use the static methods, you can use rolling methods, you can do a dynamic compaction and all that I am not worried.

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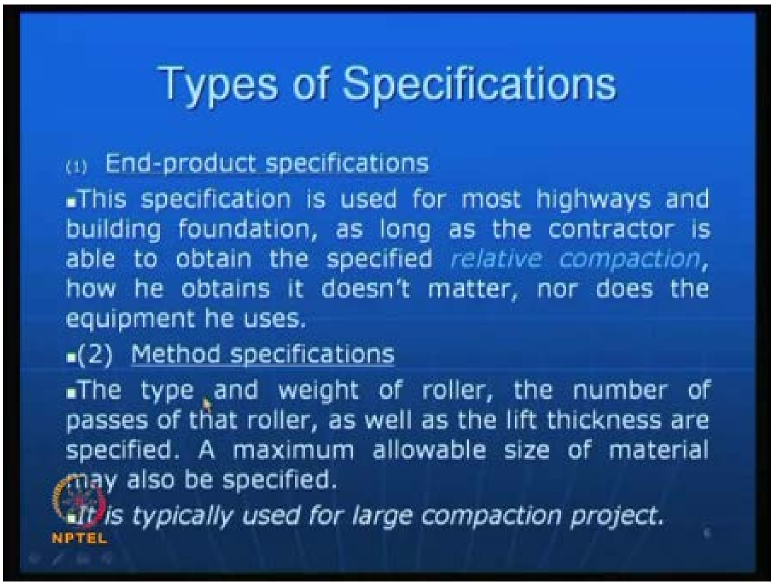

So, I am only interested in final product like getting a very good density; that is what it means here. Then in some projects particularly, in a very big project you need to specify the type and the weight of roller, the number of passes of that roller, as well as the lift thicknesses are specified. A maximum allowable size of the material may also be specified. So, it is very important that in some projects both options are allowable and particularly, the thing is that in a very big project what happens is that there are number of variables that could affect a particular project. Say, one should have options on these lines and this end of product specifications is a typical standard procedure; but in this in the second case, where you try to specify all the methods, specifications very clearly, it is normally for a very detailed project. Say for example, liquefaction you would like to prevent in a particular project.

So, it is not easy; it may not be alone sufficient to have this end product specifications. There it may be better to check very carefully what is the purpose and are the compaction is I mean, they for example, you are looking at liquefaction resistance highest liquefaction resistance. That is what is required here in a particular project where you are looking for very good liquefaction resistance.

In this case, you one can really do a detailed study or a model study. Say for example, you can take a small area of 200 square meters and do some type of testing on what type of roller, what weight of roller is required, how many number of passes are required and all that. One to do a small typical study and then specify the actual methods and specifications that are very appropriate for the project; this is very important.

The effectiveness of the compaction is specified in terms of the relative compaction or the percent compaction. So, that is defined in terms of the density that you get in the field divided by the density that is specified in the laboratory ok.

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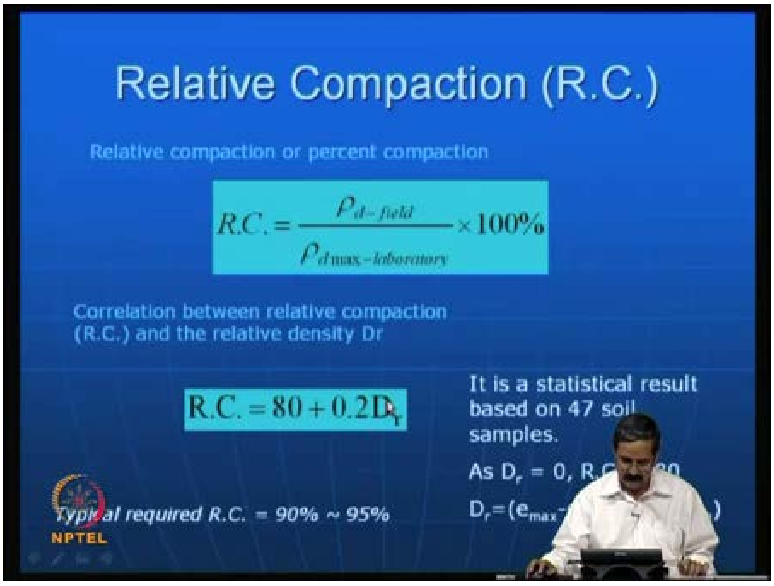

So, this is about is express as a percentage and the typical values that we want is about 90 to 95 percent. And there is a good correlation actually for example, you must be knowing about the term called relative density. In sands the relative density is nothing, but e max minus c divided by e max minus c min; this is what we know. So, one can even use some relationship like this and like if the relative density is very good then you can calculate this particular R.C. So, one can get the relative compaction effort or it is an idea of the relative compaction based on this or this.

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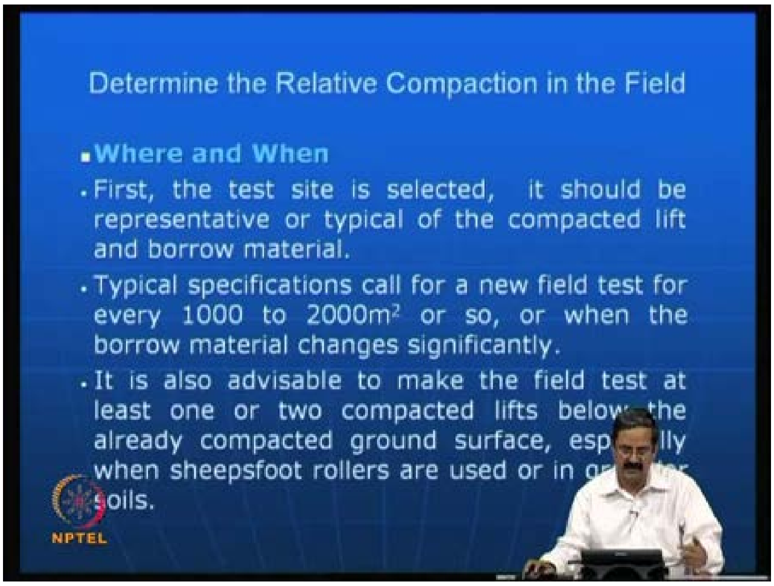

So, how do you do this in the field? This is very important and first the site is selected and the once you select the site it should be representative of the type of typical of the compacted lift like you know because you are trying to take a 30 centimeters lift and all that it should be of that material and also the same borrow pit material that you are selected. Then see there are some specifications that we have the typical specifications call for a new field test for every 1000 to 2000 meter square of the area.

Say for example, you have a highway project every say, 10 meters or 15 meters. So, 15 meters is that length and then you have the width of this road. So, you may need to multiply the overall area you have to specify that particular thing. What is the relative density achieved or what is the relative compaction achieved that must we able to understand; otherwise, it becomes difficult. So, this is the specifications are,… normally we do that when following; you select a site and also it should be representative of the typical compacted lift, as well as the borrow pit material and you should follow this specifications and in some cases what it means, it is possible that if the rolling you know sheepsfoot roller is used.

Say for example, it may not be sheepsfoot roller is a static type of testing in which you know the roller moves in the form of a static. It is just a mode of a static movement as opposed to a dynamic movement or a drum movement and all that the compactive effort imparted to the ground may not be very good. So, in such a case what we do is that we try to remove some layers. At least, like you know one or two compacted lifts below the already compacted layer. So, that you will see whether, because, when they start sheepsfoot roller moves. Start top layers may not be that good, but so, but then you can see its effect at the bottom. So, you want to confirm that one can do this.

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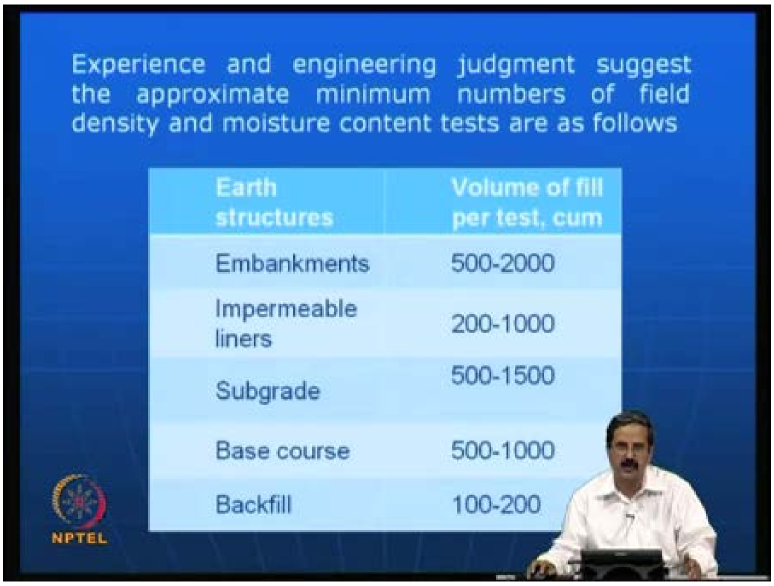

So, actually there are some specifications in geotechnical engineering literature on what should be the, you know, volume per test. You know say for example, you want to have an embankment say for example, a big highway embankment. So, if we have about 500 to 2000 meter cube of a material, you should definitely test. Have one test like you know the height of the embankment say 10 meters and you know its longitudinal section and you need to have a particular, you know the one at least one test there. Then say for example, impermeable liners say canal liner, canal lining where what is being allowed through this Canals. So, you do not want lot of permeation to occur from the canal. So, you need to have some criteria like this sub grade soils like base course soils, backfill, for a returning wall.

So, this is all some standard specifications one needs to understand. Otherwise, there will be otherwise you know people may question it. So, one needs to follow some of these specifications very carefully when you are walking in the site and see that these are all adhered to because this is very important; specifications need to be followed.

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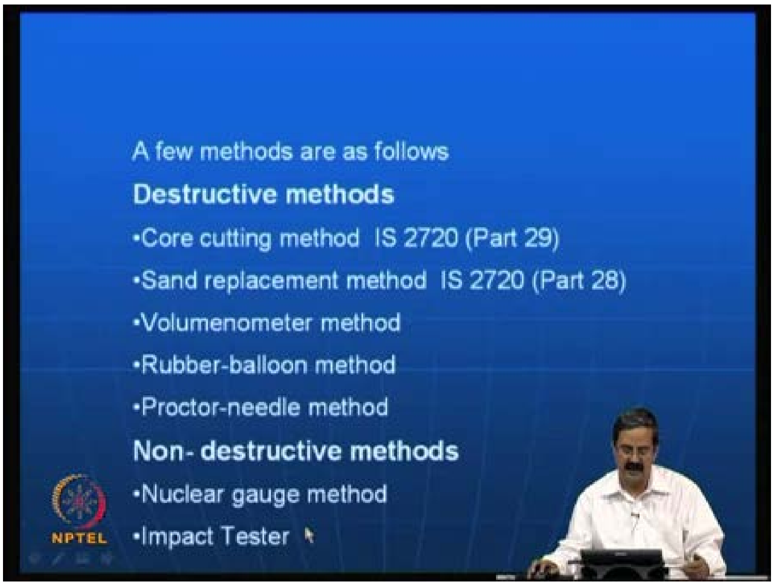

Then, ok, once we have these specifications we follow, but you have to do some testing. Now, how do you get the density and the water content of the sample in the undisturbed state in the field? It is a question and then one can say that the test can be classified as destructive test and non destructive test.

Say for example, a core cutting method is one example which we studied in under grade courses. Sand replacement is another method, volumenometer method, rubber-balloon method, proctor-needle method; these are all some methods where you remove some amount of soil from the sub grade or whatever is that and then test it. That is why you call it destructive because, normally when a soil is compacted you do not want some, you know already there is a you know, it is a very good soil. Say for example, it is a compacted sub grade; you remove some soil from there. What it means is that you have damaged a portion; that destroyed some portion there which you really have to I mean, that is not sometimes. So, this is a destructive sample is what we,… destructive method is what we call here. Then we have non destructive methods which are essentially based on nuclear, I mean, see the particle the part the travel of the nuclear particles are the impact tester like the radiations and all that we will just see.

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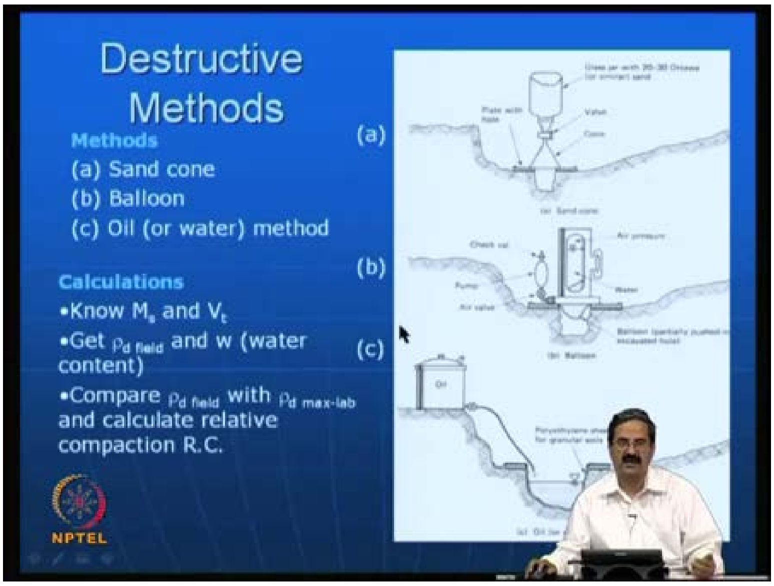

The destructive methods - some examples are: sand cone like this is where you know like I think we must have seen in under grade courses, where you want to particularly for a sub the highway. Here, you try to make a pit and then the objective here is that you have to know what is the amount of,…once here the objective here is essential to find out the density of the material bulk density and the water content. You make a small opening then remove the soil or the say, sub grade soil and then take it. Some amount of our water content and find out how much of sand can go in; like you know you can just you have a cone and then allow the sand to get in. Then, you will be knowing exactly how much of sand is replacing this material. Once you know the amount of sand that is replacing, you will know the density of the material. Like, by simple calculations of the fundamentals one can calculate what should have, what should have been the density of this sub grade material.

Then, the second case is about people call about water balloon or oil balloon and all that. One can also find out that the balloon can really fit into the shape and then you try to find out how much of volume change is there. And then, based on that you will try to calculate the volume of the particular cut you have made and also corresponding bulk density.

Say once you know the weight of the soil that is removed and also its volume you, will know its bulk density and you can also take some amount of material for water content. Once you know this water content density, you can check that is what we want.

So, that is what exactly we mean here. Like you know it is a weight and then the volume and then you know its field density and water content and you try to compare the field density with what should be achieved. What should have been achieved from based on laboratory test. So, once you know both of them, its just the ratio of that and you will get the relative compaction effort; that is it.

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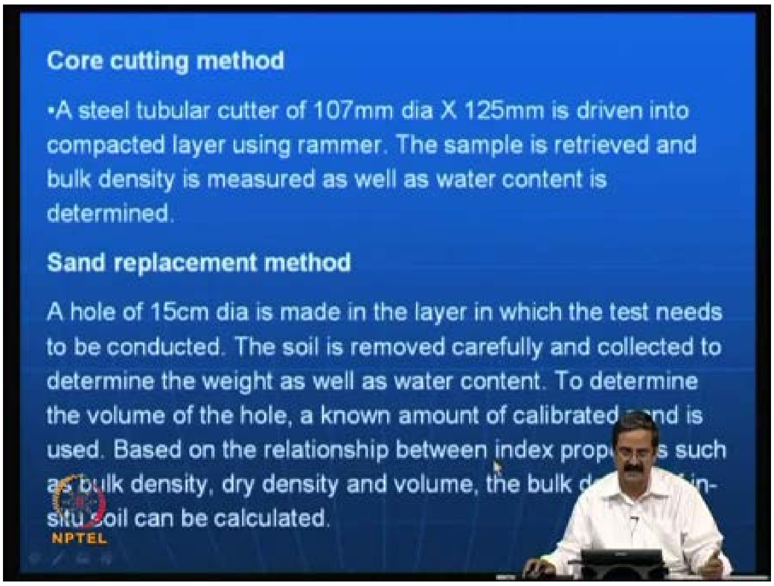

So, as I just mentioned in the core cutter method, you have a steel tubular tube of about 107 mm and then you have this specifications. You try to drive into the compacted layer using a rammer and then the sample is retrieved and the bulk density is measured. So, like as I just mentioned you know the basic fundamental properties and one can calculate. Same thing is this with sand replacement method in which you have a hole of about 15 centimeters diameter and then you put it in a you know you make that hole in the layer in which you need conduct the test.

So, the soil is carefully removed and collected to determine the weight of the soil as well as water content. Some amount you can always take it to find out the water content. So, to determine the volume of the hole a known amount of calibrated sand as I just mentioned, we should know it is the sand properties. Its density and all that in a standard volume property and once you know that one can calculate the density of the initiative soil. So, these two types have been widely used in many cases because they are very inexpensive; they do not cost anything. So, these are all routine tests that are used to a maximum extent.

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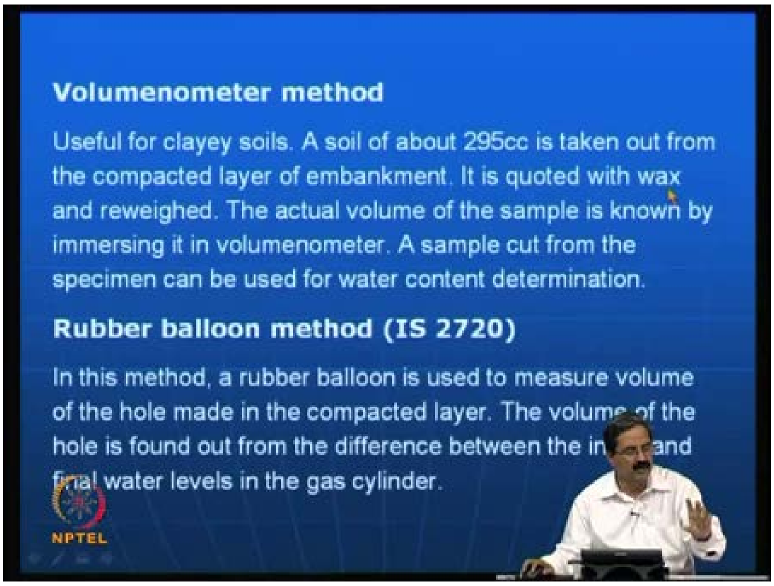

Then you have what is called volumenometer method. Actually, this also another simple method; actually, why we are doing the,… say, there are different types here like particularly this is useful for clayey soils and what we do is about 300 or 295 cc of the soil or the volume you know actually centimeter cube is taken from the compacted layer of the embankment. What we do is that, this say, for example, this much of soil is there we try to put it in the wax. This particular volume because you take, you took it; we do not know its exact volume you know it is a weight; but weight also you do not want to lose. The soil particles, like you can take a lump of clay from that particular thing like say 300 cc like this. Then you coat with wax is something that you know. It is an yellow liquid which can you know it you have a molten wax you dip into the wax and then the wax forms a quoting for the soil. So, the thing is that once you coat the soil with wax what it means is that the then you hold it in a some sort of a ah thread or something then that particular you know that density of the wax also like it is given in standard table.

So, that is what we are doing in that. So, we try to take a beaker and then immerse this particular thing in the say the beaker; it is about some, it has standard measurements in terms of the mm and all that. So, you mix the, you immerse this particular lump and which is coated with wax and then it displaces some amount of water. So, the moment you know the amount of water displaced you will know how much of volume of the soil plus mould is there; soil plus wax coating is there. So, you correct it. So, now, you know the specific gravity of that. Actually, you know it is also how much of wax is also known. So, based on those calculations you can exactly know its volume. Volume and the weight is already known. So, knowing the weight of the material and also the volume of the material, you know the bulk density and water content also can be found out by removing some amount of soil from the same material that you collected. So, this is a very simple method in which one can do systematically.

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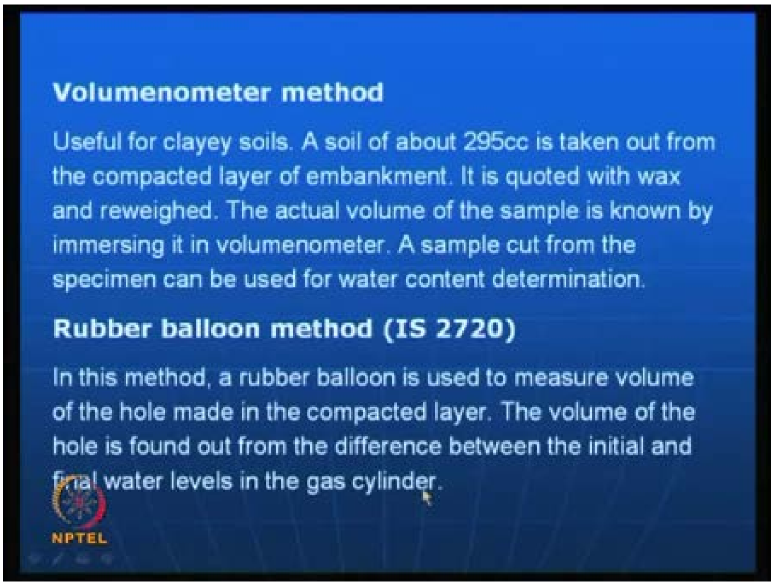

Then you have what is called rubber-balloon method. In this method, a rubber-balloon is used to measure volume of the hole in the compacted layer. The volume of the hole is found out from the difference between initial and final water levels in the gas cylinder.

So, you have couple of methods in which you can always,… the objective here is to find out its volume of the hole that you have made or volume of the, or the volume of the material that you have taken out. So, what we try to do is that we try to see do this as well; this is another simple test people have been using it.

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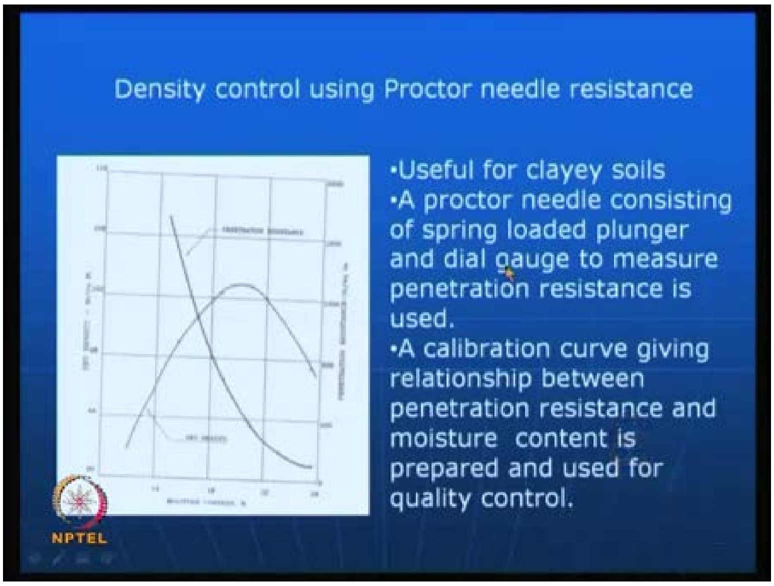

Then this is another type like, density control using proctor needle resistance. Actually, the proctor needle is something that its very useful for many materials like in the olden days it has been used significantly in construction of dams and it is a simple proctor needle. Like it is a sort of a penetration which has some, which can penetrate into the soil; it has a spring loaded plunger like you can push that plunger and then you have a dial gauge to measure the penetration resistance. So, in this particular thing what you have is that you have a dial gauge to measure the penetration resistance and also the plunger. You know you have to find out the diameter of the plunger and all that; it is a small a thing like this. So, it just can push in and then once you know it is the plunger and its resistance, then you can infer a lot. How do you infer? That is like this.

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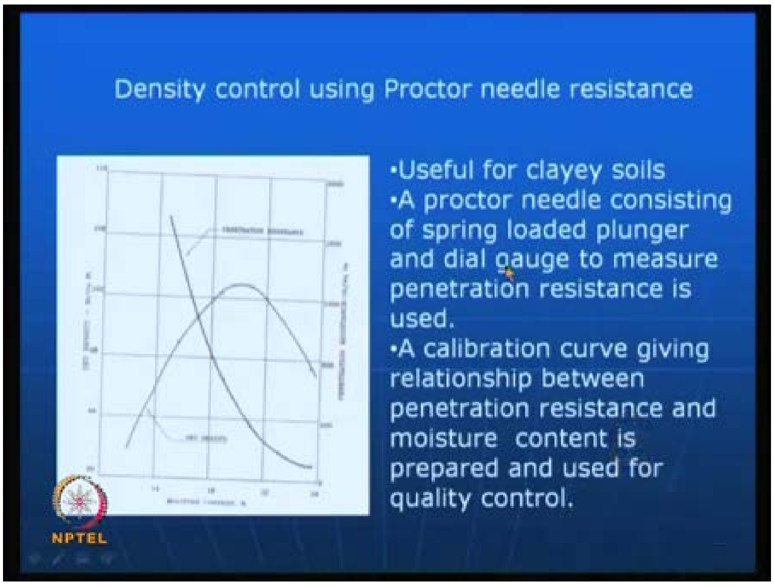

So, you have you have a say for example, you have a compaction curve like this which is in a in the form of a curve and for that you have a corresponding penetration resistance. Say for example, here the dry density is there and then its penetration resistance is given here in terms of the penetration resistance. How many pounds per square inch like one can here in this particular thing? Actually, this is the plot of moisture content here the dry density, here then the penetration resistance here. So, you have, you can see here that at low water content it has got good penetration, but as water content is increased in the fill then there is the reduction in the temperature resistance.

So, this is what is called a calibration curve. So, a calibration curve we prepare and then once you have this calibration curve once. So, for example, you get the field density in the, from the field. So, you can really infer that what is its say for example, you know particular density and particular water and then the water content. So, you can know exactly where it is. So, that is an advantage here.

That just by knowing a penetration resistance says what you get from the proctor needle is its penetration resistance. Suppose a penetration resistance is about 800 pounds per square inch. So, it is somewhere here or it is like. So, one can, it is well below, what it means is that, its somewhere here (Refer Slide Time: 33:00). The point have some… it is the, it is nowhere close to its maximum dry density and all that. One can really make some observations and improve specifications there like you know you can do some sort of other measures like. So, whether you can take a decision whether you should reject the sample or assent redo the whole work one can do something there.

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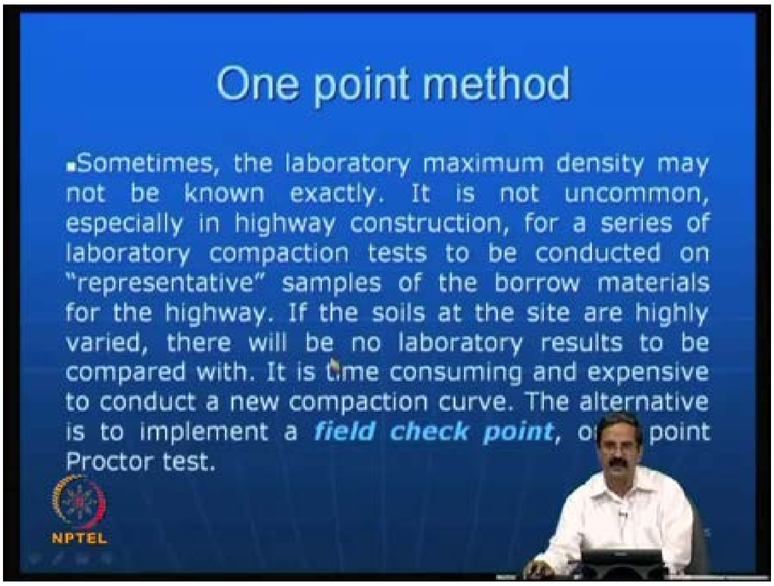

Sometimes what we do is that laboratory maximum density may not be known exactly. Actually, you know you do a, you have many samples. This is actually what is that in the field is that there are so many samples we are getting from borrow pit materials like it can be some 30 or 40 in a big project. You can have number of you cannot get so much of material required. So, you may have to really get lot of varieties of materials and sometimes you may not get the maximum density correctly; you know in the lab itself is sometimes is difficult.

So, what we do is that in as I just mentioned, it is not uncommon in especially in highway construction for a series of laboratory compaction curves to be conducted on the representative samples of the borrow pit materials to the highway. So, it is not easy.

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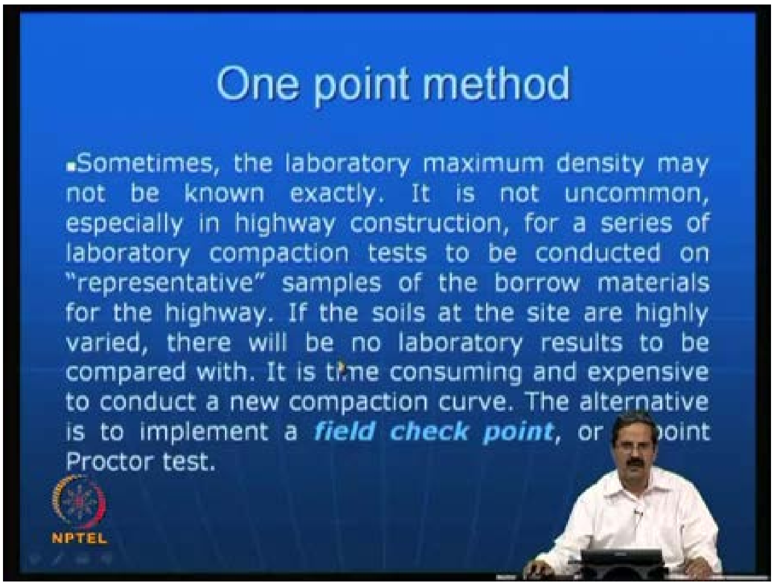

So, since the soils are highly varied and laboratory tests are also not easy to get, we use a method called what is called one point method. Like it is called field check point and I will just show you that see here in the field you know there is actually, this is given in literature like what you have is that depending on the type of soil. So, many curves are there like right from a b c d to z about 26 curves are there. Suppose, you measure some density and water content and if it falls somewhere here, you know it is just you are taking only one point here and then the moment you know the one point like either whatever is there you draw these two limps you are just drawing; you are accommodating that particular point somewhere here (Refer Slide Time: 34:08).

So, this will define its compaction curve it is a very interesting that without doing much of testing you have with single point with this as a basis. Actually, this is published in, it is standard guidelines because in some cases where it is not possible you must use this sort of information because finally, you must be able to calculate the I mean, form a compaction curve and then get the result. So, this is another simple method of getting the compaction curve and then do whatever compaction controls you want do later.

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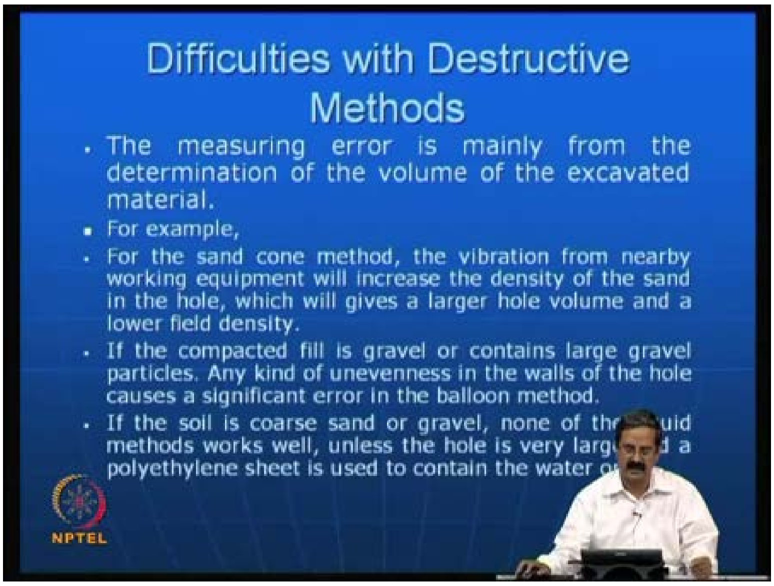

So, in the destructive methods say whatever you take whether it is for 1 point or 10 points or 100 points or you have some specifications like one sample for 1000 meter square or something like that, the problem with the destructive methods is that there could be some sort of errors. What is that the measurement error? It is always measuring error; it is always from the determination of the volume of the excavated material. You are excavating that material and the possibility is that if there is some 3 or 4 cc volume change, you know there is a problem or if you do not take the soil properly there could be some error. So, for example, in the sand cone method the vibration from nearby working equipment will increase the density of the sand in the hole which will give larger volume and a lower field density.

Say for example, you have taken a sample, but then the possibility is that the vibration effects are there and then you may know in a,… it may be specific to that particular bore hole or a location, but in some other place where there is no vibratory equipment close to that this problem may not come. The moment there is vibratory equipment next a sand material, the compaction is likely to be better and that is one possibility. If there could be even dilation also; so, it depends on the type of vibration that they have and one needs to be careful. So, did may this may lead to minor errors.

Then there are some cases where the compacted fill is gravel or contains large gravel particles. Any kind of unevenness in the walls of the hole causes significant error in the balloon method say for example, in some materials you know you have lot of big size particles. Also, like you know it can be even that volume can be 2 cc 3 cc or like 1 cc you know a small lump of clay or a gravel. And then, if you are trying to make it you know it can be, the surface can be uneven like you know for example, whatever opening you are trying to make in the destructive methods it need not be that it is very perfect. So, there could be unevenness and in the process there will be some errors of some 2 to 3 or 4 cc. One can calculate, what is the error that you can get by just ignoring this one. One should be very careful one can calculate say for example, if you make an error of 2 cc or 3 cc 3 cc in bulk density measurements, what is the error that you will have in the compaction curve? That one should understand.

Otherwise, all these methods and all that are useless because everything is volumetric here. So, one should be very careful in volumetric measurements. Even in the lab itself first of all that one should be very careful in getting the compaction curve properly and you should also understand the sensitivity of the compaction curve to volume changes. Once you know that are sensitive due to sensitive of the compaction curve to water content and volume changes then filed in that field it becomes much better the other point is that if the soil is coarse sand or gravel none of the liquid method say for example, you have in some kinds oil and all that they are not be very useful unless a hole is very large and a polyethylene sheet is used contained the or water.

So, there are some methods that you know as I just mentioned even by one can do it is all just a replacement you know you can use the sand replacement you can do a liquid replacement anything even say for example, you do a shrinkage limit test its nothing, but a mercury displacement you know you are trying to find out the shrinkage volume by using the mercury displacement. So, one should be very careful particularly one you are trying to deal with materials like this ok.

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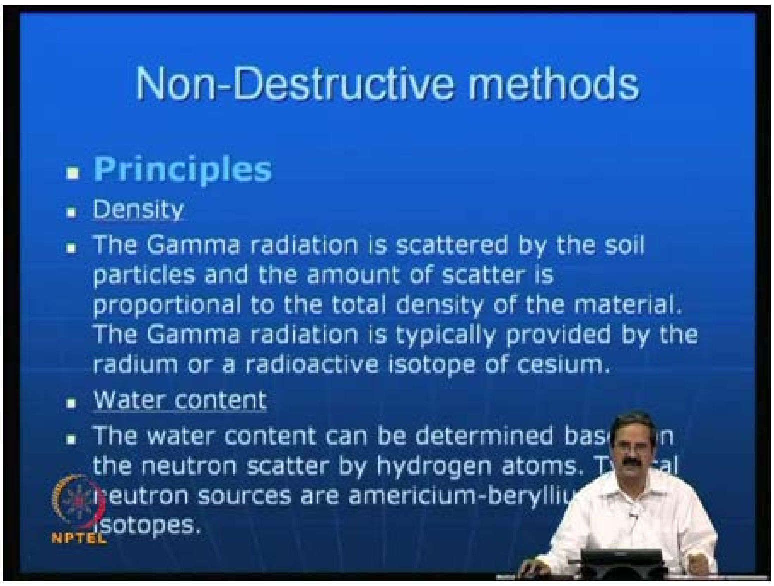

Then you can talk about non destructive methods which are you know definitely superior because here you are not allowing the samples to get disturbed and the thing is that you do not make you can some of the equipment you know it can be done without you know causing a disturbance to traffic on the road sometimes you can just say when you trying to do a sand replacement method you know you have to really say that you know there should not be any disturbance at least a few meters away you know it should not you should just you should not be disturbed.

Like as I just mentioned in the case of sands also if you are trying to make a sand replacement method if you are doing that there should not be too much of disturbance nearby that problems are overcome if you are able to use non destructive methods in which suppose you are trying to find out the density.

Here the there are two principles if the objective is to get the density and water content and how do you get the density actually some of this measurements are by scattering of gamma radiation.

So, the here the principle is that the amount of once you allow the scatter to take place and the the actually soil particles scatter it actually the moment it comes from a source then it is the particles the soil particles scatter it and the amount of scatter is proportional the total density of the material.

That is a principle here and gamma radiation is typically provided by a radium or some radioactive isotope of cesium these are all some materials that we are getting and water content is something that can be determined by neutron scatter you know then by hydrogen atoms the typical neutron sources are americium-beryllium isotopes again this is again a type of material in which you are trying to use non destructive testing.

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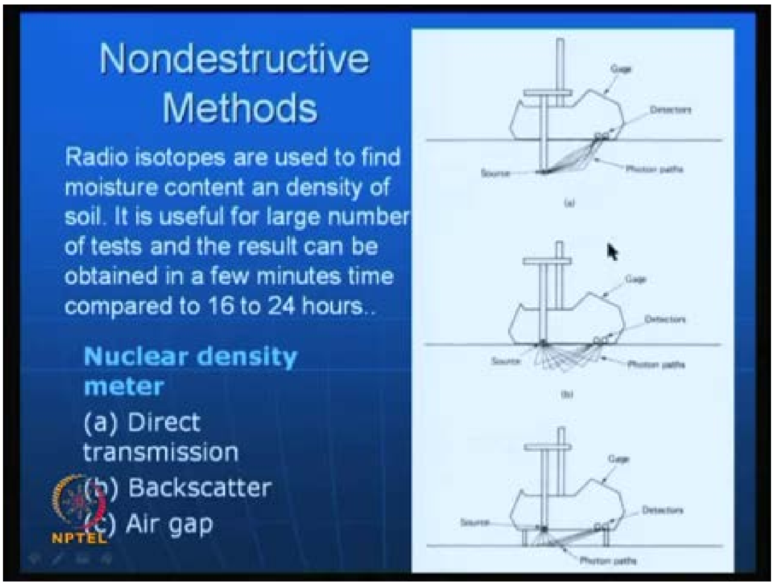

For example as I just mentioned here there is one equipment here you can just see that this is that gauge and then this is a source and then this is that soil and you know you have a scattering the photon particles or paths of the photon particles is like this and then we have detectors. There is one there are couple of ways here like as I just mention you have a radio isotopes to find out the moisture content and density and its useful for large number of tests and the result can be obtained in a few minutes compare to 16 to 24 hours say for example, you are trying to get the density and water content in a lab it takes you have to wait for 16 to 24 hours.

And nuclear density meter is something that we can use say for example, here one is a direct transmission like you know then there is another called backscatter the third one is air gap we can see that this is a source of scattering in which you are allowing the gamma radiation is to come. So, you place here and then you have a scattering here this is one thing it is called direct transmission and of course, this also have some sort of penetration here, but the second thing would be the backscatter in which you have a source here you have a pick up receivers here. So, you can see that the scattering of particles then you have a air gap also. So, for example, in some purpose in some cases we need to have an air gap also that could also give some interpretation. It is just that you have different ways of doing the same thing and then here the objective is that you are trying to find out the based on the scattering you can calculate the density.

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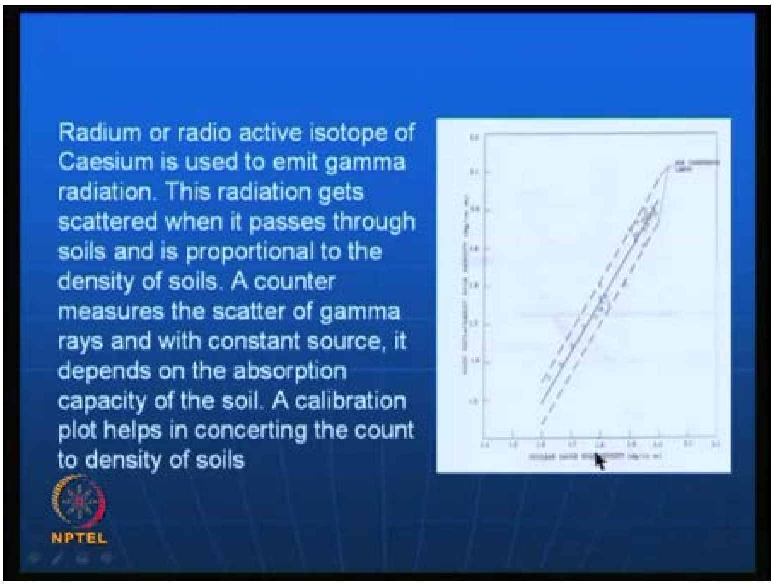

So, as I just mentioned a few minutes back radium or radioactive isotope of cesium is used to emit gamma radiation this radiation gets scattered when it passes through the soils and is proportional the density of soils this is very important. A counter measures is scatter of the gamma rays and with the constant source. So, for example, you keep the source constant it means that the scattering depends on the absorption capacity of the soil and which again is related to density; so, density and water content. So, what we do is that we prepare some calibration chart calibration charts like this say for example, this is the what you get from a nuclear gauge bulk density and this is what is from the sand replacement method. So, you have to get a relationship between them and then see to what extent it is accurate. So, you have to define all these points like you should do one a number of tests at a same location at different locations using both methods one is using the nuclear methods the other one is using the standard methods. Once you do that and then plot a relationship and one can these are all ninety five percent confidence level lines on either side one can use those ah information very appropriately and then see once suppose the soil is of borrow pit material which has supplied lot of quantities.

Then, you develop this sort of methods it is a the quality control is very easy say for example, in a big highway project it can be done very fast very efficiently compare to say for example, sand replacement method use where you keep on making the holes then take the sample then the you go back and after twenty four hours you get the water content density. So, compare to that this is using the nuclear density measurements you this much better.

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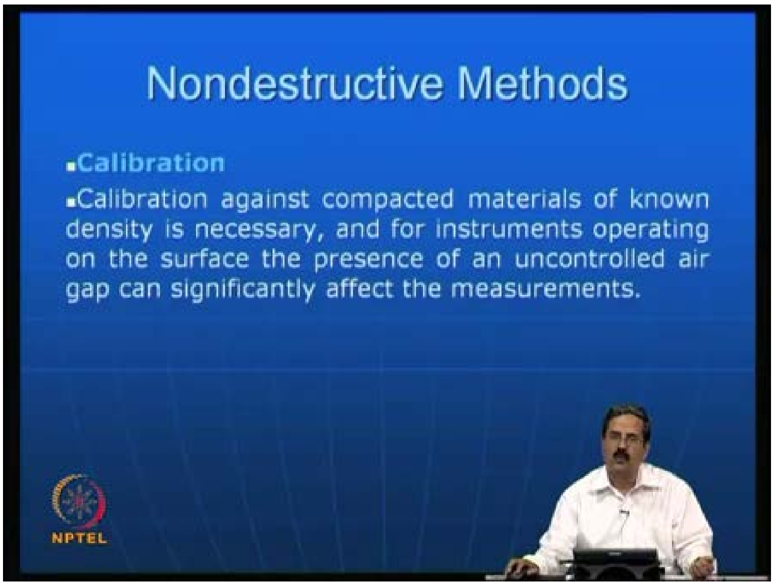

As I just mentioned calibration is important here and calibration is against the compacted materials of known density and for instruments operating on the surface the presence of an uncontrolled air gap can be significantly affect the measurements. So, one should be very careful with the air gaps presence of air gaps and all that because you know through the air you know there could be misleading results one should be very careful there.

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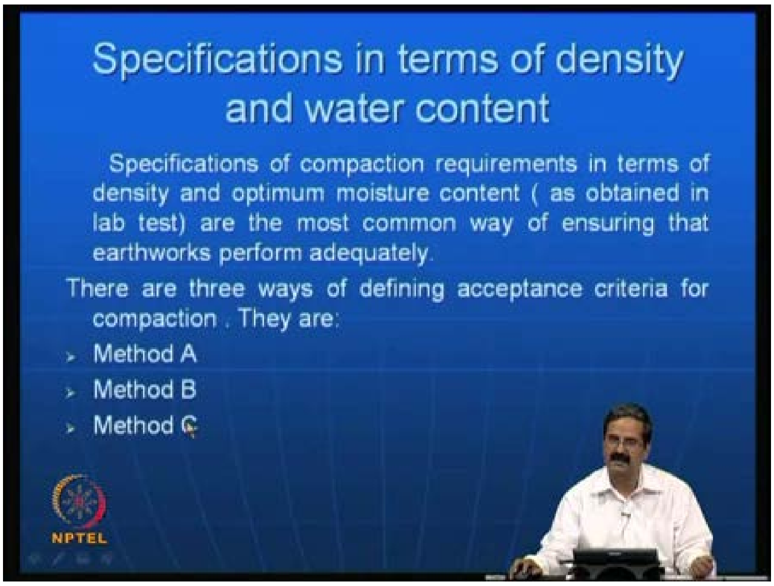

Then some more points that we should understand how this specifications are presented in the field like how do you the objective here is as I said you have to say that the earthworks are you know the whatever it the earthwork done is satisfactory.

So, there are three white three ways of defining the acceptance criteria one is called method there are three methods method A method B and method C this simply states that the method a is to have the soil has to be compacted above a certain minimum density.

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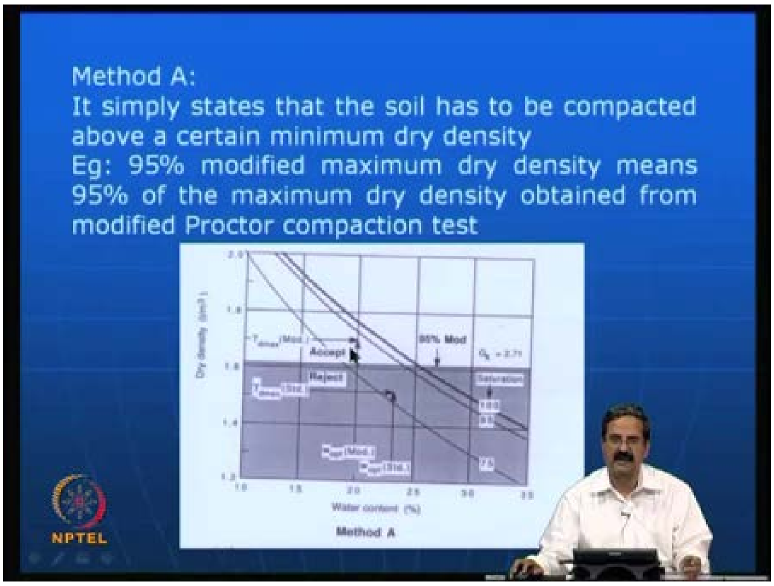

Say for example, this is the water content versus dry density you just simply say that this is the line I will accept whatever points above that are acceptable not bellow. So, you are just trying to say that yeah the only the density as the criteria.

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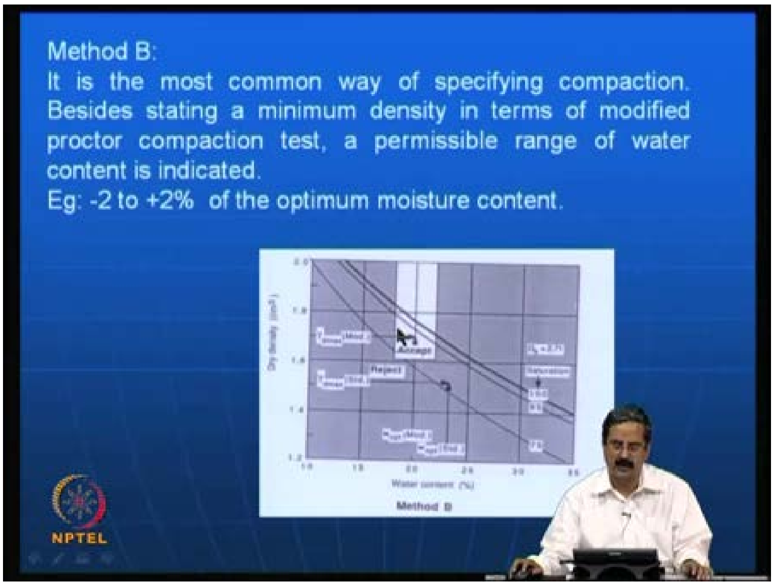

Now, this is somewhat better because you are trying to say here that um you besides a minimum density that you have here also its specifying some water contents like you know I have the water content range also like you know you can see that the water you instead of just defining one line of density you have certain range of water contents here. Say for example, here in this case about seventeen point five to 22 point 5 you know it depends on the actual curve that compaction curve that you get and if the compaction curve is relatively flat there it is you can have a wider variation here.

So, even you can specify that yeah just this density is minimum I expect, but I need to have this much variations of this water content are all right. So, I must be able to say that under your acceptance criteria this is again a very important point.

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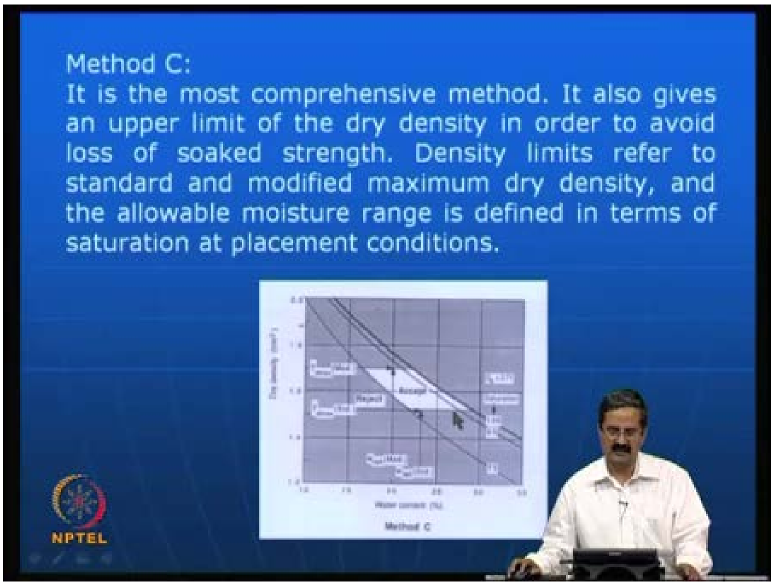

Some more better, somewhat better this is the where I can even say that I can even specify the upper limit for the density say you have density variations which are given by horizontal lines and water content variations also. So, if you this is the region of acceptance you are giving a big reasonable a good window like if the points are here then it is satisfactory then if the points are somewhere here they are not satisfactory.

So, by telling that you are the samples in this region are acceptable what it means is that as I just mentioned it will have good engineering properties whatever you wanted it will have a very good minimum strength of a particular quantity that you wanted or say for example, minimum settlement or minimum compressibility of something you wanted or even the minimum permeability. So, these are all required and this is what we try to say.

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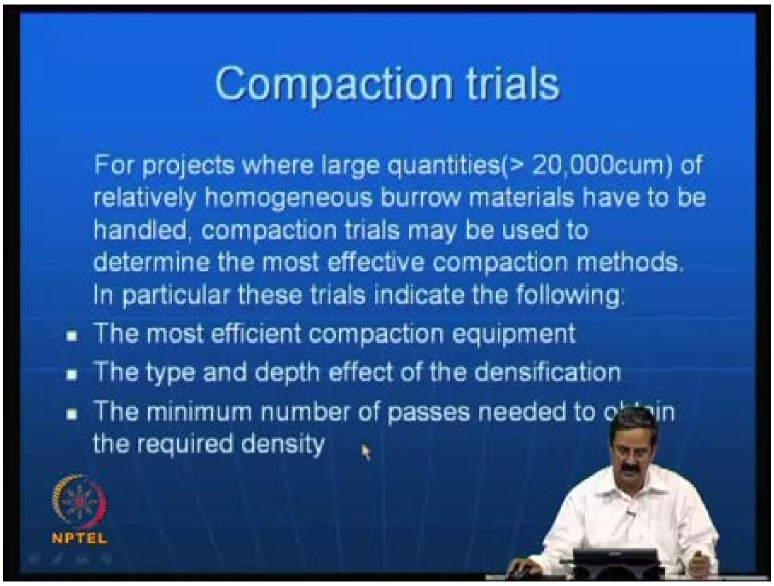

Sometimes like in a big project the advantage would be that you better do compaction trials because what happens going by certain specification is one thing, but try to come out with project based specifications like you have a big area somebody have some 10,000 crores project in a for an embankment or a this thing is better that you have a specifications based on the material available there and try to understand the soil behavior of the materials.

Say for example, you may have sands silts clays there are. So, many varieties in the same big area and once they should not affect your result. So, the trials you can do and then you can get information about most efficient compaction method and equipment say for example, there are different types of equipment there are different types of compaction and even get some information on that then the type and depth effect of the densification minimum number of passes needed to obtain required density.

For example what is the number of passes somebody says is 6 passes, 8 passes, 4 passes; you can optimize say for example, you are paying the contractor for that only like you know if you as a owner say for example, I take a particular project in where say for example, a big industry they are they are owning a particular they are trying to do construction.

So, instead just giving to a contractor they can do some preliminary test with some independent consultant and do some test and give it to contractor and a contractor also check the same thing. So, they can really they will have a very good interaction between a owner and a contractor and trying to share the information we come out with proper specifications for the big project.

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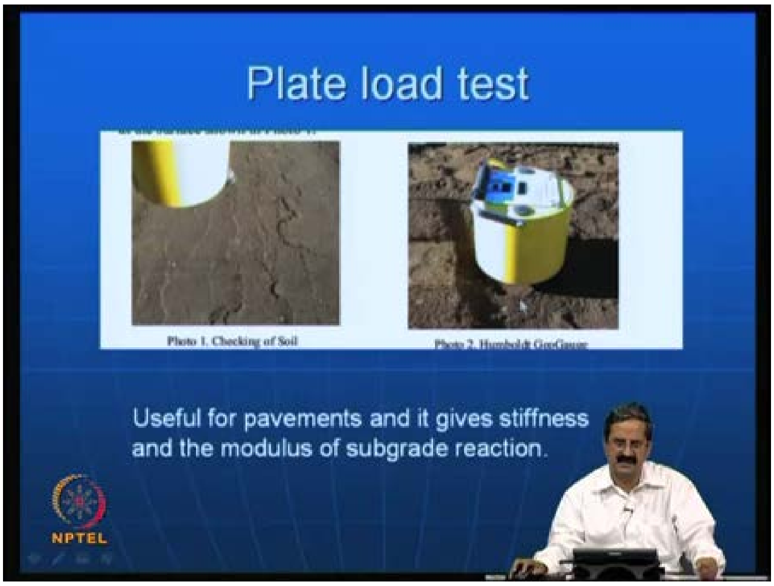

And nowadays what is called see actually plate load test that we studied is also an important approach to measure the say for example, plate load test we use to calculate the modulus of sub grade reaction in the case of pavements like k value you get.

So, it is very useful for pavements and it gives stiffness and the modulus of the sub grade reaction we have now an a simple equipment which is from the company called geo gauge in which you can test on the sample and directly from indicator it gives some what is the k value directly. Sometimes you know it is very useful k value based on the. So, you have certain laboratory things done and then this is like a penetrometer test. So, like that one can use this about very cheap it is not about 5 to 5 lacks or something many people can use this for quality control like you know you just check it and then it has it will may be intensively get the results it is a very interesting set up

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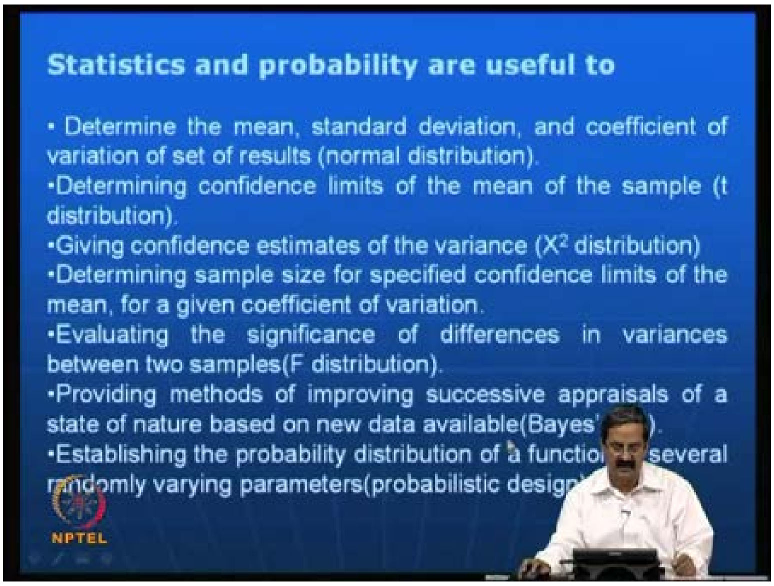

I would like to highlight you the importance of a [stas/statistics] statistics and probability in compaction control this is very important because you are dealing with varieties of soils and you know you will not get exactly the same gamma d that you have say for example, you specify some maximum dry density and maximum water content there will be always variations and how much is permissible is very important you should decide on that otherwise they will have a problem.

So, we try to find out what is the mean value say for example, the density variations are there. So, variations are say 10 percent 20 percent. So, you will have a mean value which is the average value again a standard deviation which you know how much deviation is acceptable in some case. Then the coefficient of variation is nothing, but it is the standard deviation by mean value we call it we have the standard deviation say for example, the dry density is changing by point 1.1 divided by 1.9. Point 1 is standard deviation and 1.9 ton per meter cube is the mean. So, 1 point that point one divided by 1.9 gives you the coefficient of variation. In terms of the percentage, 0.1 divided by 1.9 into 100, gives you the coefficient of variation. So, you can say that I do not allow more than ten percent variation that is a very nice way of telling rather than telling anything.

Then sometimes it is always important to find out the confidence limits of the mean of the sample say for example, what is the say I may say that it is a mean value is 1.9 [ta/ton] ton per meter ton per meter cube or 19 kilo hundred per meter cube, but how much you are confident is it are you confident to the 90 percent or 95 percent? Are you really did you do it some test to say.

Say for example, if I want to say its 95 percent I am confident about that number I must do some number of tests. So, that is possible say for example, how many tests should be done? The other day just now, we are discussing about number of test to be done in a meter cube of sample in say 1000 meter cube of samples or something. So, here you can clearly say that yes, I am 95 percent, I am very confident that this is a mean value because sometimes if the mean is wrong, everything is wrong.

So, you can also give confidence limits to the mean value. You can also give confidence limits to the variance. Also, variance is nothing, but its variation like standard deviation square is called variation. You can use some of the distributions which are simple and the objective is that you can comment on how many number of samples are required say for example, say, obviously, in the field if you go, somebody says I have taken 5 samples or somebody says 20 samples.

However, be sure that the samples, this number of samples gives you the correct information. So, definitely you can decide on the number of samples; you can justify the total project cost in a proper way. This is a very useful way of talking about the sample size because, in a big project if, when it is very big project you cannot say if there are few samples they have taken its wrong. You cannot also take a many number of samples because that leads to expensive lot,… of expenditure and then it is an investment. So, we do not want. So, you have to justify as a contractor or an owner that this is what I need - optimum number. So, that one can say here.

Then say for example, there are two contractors doing a good job or a bad job or whatever, say how do you want to blacklist a contractor or how do you want to appreciate contractor or how do you suggest a contractor that your methods are not good? So, you have to discuss with the contractor and tell them that yeah, you are not doing correctly there. Otherwise, he will not listen to you; he will simply do the work and give a shady job. It is a very hopeless situation most of the people will be in. So, it is always possible to say that by you know, using statistics to how do two persons can be compared.

Say for example, I will tell you the example: cricket scores of two cricketers you know who is good. Like, who is good, average and good? Standard deviation is less is better than a fellow who hits a century and next time it is a duck out. So, it is like that you know because it is always possible that you can really give a weightage to average and the mean value and then take a decision. Then, sometimes there are some methods that we know one can have that using Baye's rules and however, one can use lot of information it they have lot of significance using probabilistic design as well.

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What I want to say is that, the compaction using mechanical means particularly shallow compaction what I mean is about 1 meter. 1 meter - 2 meter say for example, highways and all that are embankments where you construct; in a series of lifts you come out. It is very important that the static compaction or the any of this compaction methods are a good way of ensuring good engineering behavior. For we have still advanced methods here. In fact, people have been using sensor technology and there are lots of advances here. So, actually there is an, actually there is an exciting area here people have been walking a lot on this.

So, the static compaction or the I mean, the shallow compaction using static methods, the dynamic methods or any other methods, has been very helpful in at getting the required engineering response from soils; thank you.