Geotechnical Engineering I
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Lecture-15
Compaction Characteristics of Soils-II

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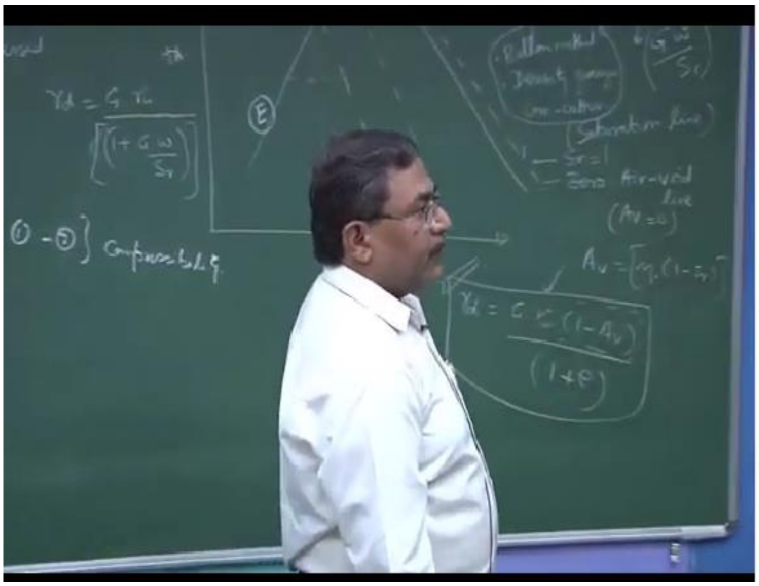

What you were talking about is what we do is we benchmark our compaction effort by drawing a line, this is what is known as zero air void line. We normally define this as Av = 0. This is the place at which Sr = 1 hypothetical situation. You must have noticed we have been talking about the situations for the soils which are non clay soils. All the results are valid for non clays as I said the moment you achieve optimal.

And the moment you add moisture and compact it water comes out of the soil clear. So, Sr = 1 this is also known as saturation line. So, if this line is the saturation line, let us say 1 1 zero air voids would be Av = 0, is this okay. Did you get the answer to your question, So saturation is somewhere here. If I draw a line, which is like this, this; these other controls of saturation. You know the relationship gamma d = G into gamma w over 1 + e is not going to be much used to me if I try to interpret the results by using this equation why.

Whether there is a foreign, foreigner sitting over here is in the form of e so I had to get rid of this e, how can I get rid of this e, is this okay, got it. So what I have d1, I am plotting the compaction characteristics on a 2 dimensional plane, gamma D and w and the contours are of S. So this is your Sr that means the equation for a saturation line would be gamma D = G gamma w over 1 + G w over Sr. Is this okay, fine. So the moment S = 1, this is a normal equation G gamma w over 1 + G w.

So G is very important to be determined for the soil. Remember any mistake which are going to do over here would get reflected in this is this part okay. Have you understood this saturation thing. So, these are the contours what it indicates at this point the saturation of the sample is equal to this, which I can compute from here because gamma D is known, w is known, clear G is known Sr can be obtain clear.

So, very intelligently we are plotting 3 characteristics on a 2 dimensional plane, density of the matrix for a given moisture content and what type of saturation you have achieved. I am sure you will realize that Av is nothing can you tell what will be the value of Av in terms of porosity or saturation quick u need not to spend much time. So, if I say porosity of the system is known what will be the Av value.

How many of you agree with this 1 – Sr is what, what is Sr saturation 1 – Sr is unsaturated state of the material, this is the porosity volume of voids divided by total volume clear. So, what you get is the Av value right. Now, what you try to do is you should prove that gamma D = G gamma w 1 – Av over 1 + e. Now, this is a very interesting equation. Philosophically, what you are doing is you are applying a correction factor of 1 – Av to the density of the dry material.

This is the way to remember this 1 - Av is a sort of a saturation value for the state of saturation, which is not 100%, try to prove this. See the point is you cannot compact the material with the same energy. So, this curve is energy specific, clear. So, here what has happened. In this direction, the energy increases clear right, but, saturation line remains constant. Why because this is materially specific, remember.

Depending upon the material which you are compacting this G remains constant and hence the saturation line is material dependent. It will not shift.

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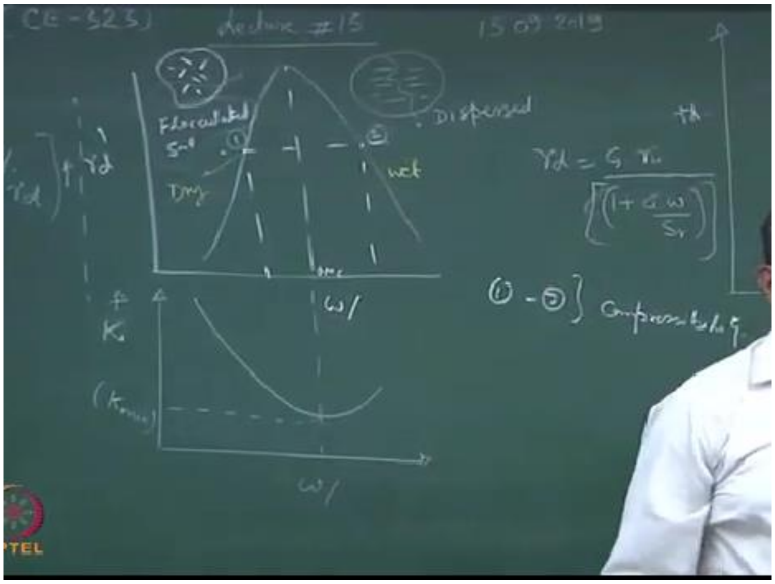

The compaction curve has a peculiar bell shaped characteristic. Nobody asked this question that for a given gamma D, there are 2 values of the moisture, u know there is nobody asked. So, we have point number 1, we have point number 2 and there must be a reason for this. The reason is if you look into the micro structure which we talked about the grain structure of the soils, this side is flocculate system.

However, as you keep on imparting more and more energy in the form by adding more moisture, what happens is this flocculated system gets converted to disperse state. You remember we have talking about the grain structure of the soil from a disorderly state of the grains the grains have become ordered by adding more moisture. So, what moisture does to this soil, it acts as a lubricant fine.

So, the more and more moisture you add the particles, the grain start slipping over each other, they become more order you are compacting them. So, they have got aligned like a ferromagnetic material. The ferromagnetic takes care of the alignment of the magnetic poles which get creating the system. So, truly speaking 1 and 2 are very interesting parameters or state of the material for the same gamma D for a person who is into construction industry alright.

One of the interpretations would be if I plot gamma d sorry, if I plot hydraulic conductivity as a function of moisture content of excuse me, because I have not discussed about hydraulic conductivity in the class. But if you not have much difficulty in understanding this; the beautiful example of how 2 types of mechanisms can be superimposed on the compaction characteristics. Remember, when we were talking about flocculated soil structure, I use the word that this is going to be more porous as compared to the one which has more dispersed.

So, that means the hydraulic conductivity is going to be dropping very significantly and this is how the curve looks like. So, in the flocculate state of the material you have high permeabilities at OMC. This is a minimum, k minimum and beyond OMC it picks up a bit why, because look at the graph your gamma t is decreasing in this region is it not, in this region the gamma d picks up so, this is there the system is becoming denser and this is where the system is becoming less denser.

So, less density because of dispersed state is going to create lower permeability, this type of arrangement of grains is going to restrict the movement of any type of fluid through this. So, if I was a petroleum geophysicist and if I do an exploration in the middle of the sea, and if I get the samples of the soils which are totally dispersed, I wasted my money in exploration and this is how most of the wells are discarded.

Because a dispersed structure because of the structure is not going to allow the permeation of the fluid so easily. It is going to be very zigzag there is a lot of hindrance with the particles are going to create for the movement of the fluid as compared to this system, where the fluid movement could be easier. So, this is 1 of the ways to match hydraulic conductivity, moisture content variation with gamma d moisture content variation on the compaction curve.

This point is still remains partially unanswered that what are the difference between 1 and 2 when the gamma d is same. Now, this is what is known as the dry state of the material in terms of gamma d and this is what is known as the wet state of the material. The compressibilities of the system are going to be totally different when you compare 1 and 2. So, what is the difference between 1 and 2. The compressibility is going to be different.

So, if you are making a cricket pitch or if you are making an embankment or you are making a airstrip or if you are making a earthen dam or you are making a foundation system, you have to be very careful about where you are going to compact and what point you are going to select for constructing the structure whether the wet of optimum or dry of optimum. Now, the logic says wherever the water logging is going to take place like urban dams.

Where you do not want water to percolate through the compacted soil mass easily because that is the whole idea i should be compact in the material at gamma d wet why, because the hydraulic conductivity is less, you got the answer, when you are creating an embankment for the traffic or railway, where you want cross genies to occur, it will be a good idea to talk about the gamma d which is on the dry side.

Because this system shows more strength as compared to the system the flocculated structure is much more capable of taking higher loads as compared to the dispersed load. In disperse load, if you remember the settlements are going to be a big issue. These type of information can be deciphered from a simple test, which is known as compaction test. Clear, and that is why I was saying let us use the word compaction characteristics and not only the compaction curve characteristics are much more broader.

And they cannot a lot of information about the material as compared to the curves. Now, we have been talking a lot about the fine grain materials, what about the coarse grain materials, there is a phenomena which is associated with sands.

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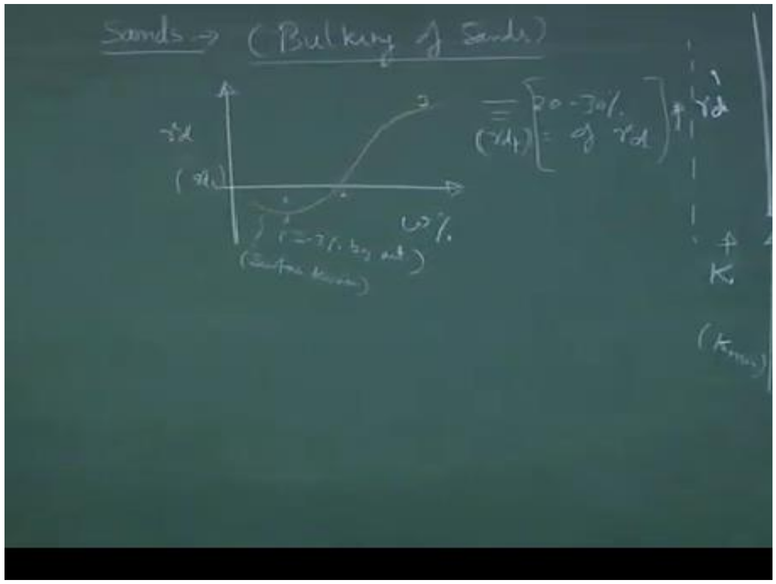

If you try to compact them this is what is known as bulking of sands. So, what happens here is when you talk about the bulking of sands you know it is a very funny material, what is observed is that initially the gamma d decreases when you add the moisture into sands or sandy soils attains a minimum value of gamma d and then it rises. This behaviour is known as bulking, will be analyzing this behaviour based on the cistern theory in the second course, which is going to be more rigorous than the first course.

This is a introduction to the subject, what is the interpretation. When you add moisture to sands find sands the density drop is because of the surface tension clear. So, this is the process in which the surface tension is resisting you know, the compression of the particles, you keep on adding more and more moisture, surface tension gets dissoluted, that is the wrong word dissoluted, but what I am trying to indicate is it disappears.

So, by adding more and more water, this is approximately at 2 to 3% by weight. So, bulking moisture content is 2 to 3% by weight beyond which the capillarity is lost, the more and more water you add, the air gets expelled, the density increases. Now this whole process is known as bulking of sand. And this is where you get 20 to 30% of gamma d. So if I say this is gamma d initial this would be the gamma d final which will be an enhancement of 20 to 30% is this okay.

If I further play with this graph in the previous lecture we have been talking about effective stresses and the suction and the power of pressures. So, I would like to complete the series.

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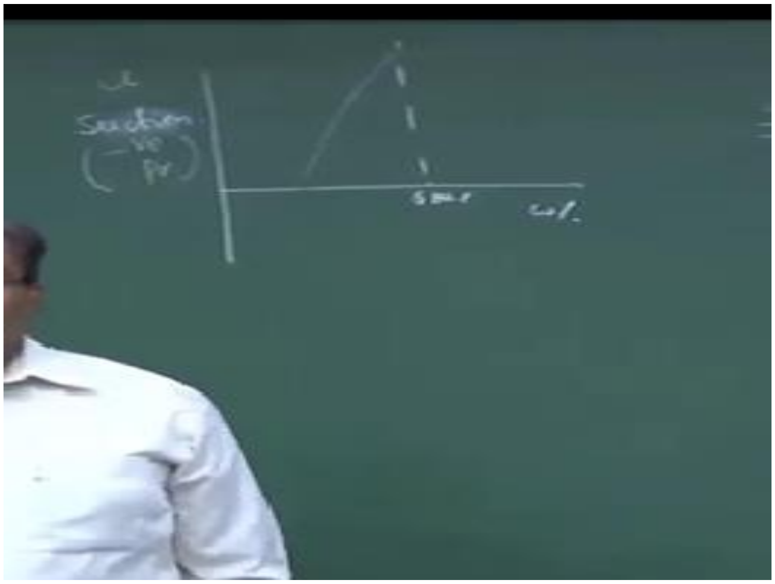

So if I define uw with respect to moisture content and this is the OMC what will happen, the more and more you compact the soil you are expelling the moisture clear. So, the pores water pressures are going to be not part of pressure let us use the word suction negativity pressures or pressures. So, what is happening is the more and more you compact the more and more air gets expelled out the section increases at OMC.

This is the maximum possible moisture with the system is having but just to left hand side of this, the system has maximum possible suction in it. These types of situations are going to be extremely problematic you imagine in every year in Bombay city, the tracks get flooded during rains alright. So, imagine that you have created an embankment rains come water logging takes place and close to OMC you have maximum suction which is getting developed in the system.

Given a chance because of this suction the tendency of the material would be to suck most of the moisture which is available freely and hence the soil must be need the track becomes wet, and realizing this So, next time when the trains move what is going to happen. These equal amount of the pore water pressure is going to get developed enhance our effectiveness are going to decrease.

So, it becomes very tricky to operate trains or the infrastructure vehicle or traffic if you are not taking care of how to compact the soils clear. So the best way would be go to the matter of optimum, there is no such thing getting developed, the volumetric deformations are going to be extremely less when you are dealing with the wet state of the material. So, core of the dams are mostly compacted at the wet of the moisture content for the same gamma d.

This is okay, 2 advantage I am getting, first thing is the permeabilities are going to be low as compared to the dry state of the same gamma d and second is the settlements and the lateral deformations are not lateral, vertical deformations are going to be extremely less when I compact the material at the back of the OMC clear.

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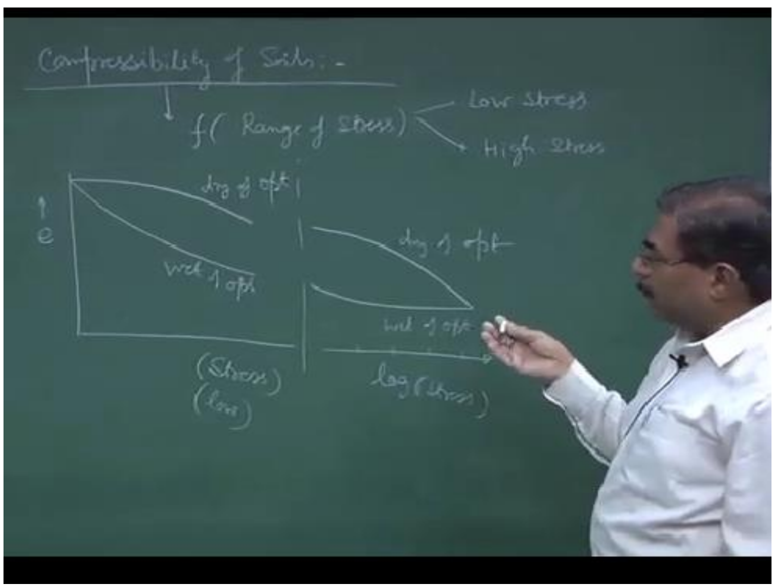

So I was talking about the compressibility here. Normally compressibility is a function of range of stress. Sometimes we define things as a low stress and sometimes we define this as the high stress. So, suppose if I plot void ratio as a function of stress, I will use that term as stress for the time being when we are dealing with the low stresses in ranges of kilopascals fine. This is the response of the soil on the dry of optimum and wet of optimum.

What I am trying to show here is wet of optimum for low stresses in the kilopascals range, the volumetric deformations are going to be more as compared to dry for optimum clear. Fine this graph continues as if I have broken the access and if I am dealing with a very high stresses it has to be plotted on a log scale. We normally do not take the log of the number we plot it on the log scale that means this has shifted from kilopascals to megapascals.

So, then you are plotting it on a log scale clear, what are the interpretation this remains the dry of optimum and this becomes the wet of optimum. On the wet of optimum, the volumetric reductions are going to be less for higher stresses as compared to dry of optimal. I repeat, when I was talking about creating the core of the dams the dam sites are approximately few 100 of meters or maybe few 10s of meters depending upon the type of dam you are constructing.

So, the chances are that you are going to work in the log of stress ranges. When you are compacting the soil at wet of optimum, the volumetric deformations are going to be less clear, as compared to dry of optimum. So, this point becomes an obvious choice, when you are dealing with the low stresses railway tracks transportation systems like payments, low stresses, the philosophy is different the dry of optimum deformations are going to be lesser than wet of optimal.

You know, we were doing in the previous lecture, the state of stress and I had given you some idea about the compacted state of the material. If you remember, since my fourth, fifth lecture I m talking about variably saturated soil mass okay.

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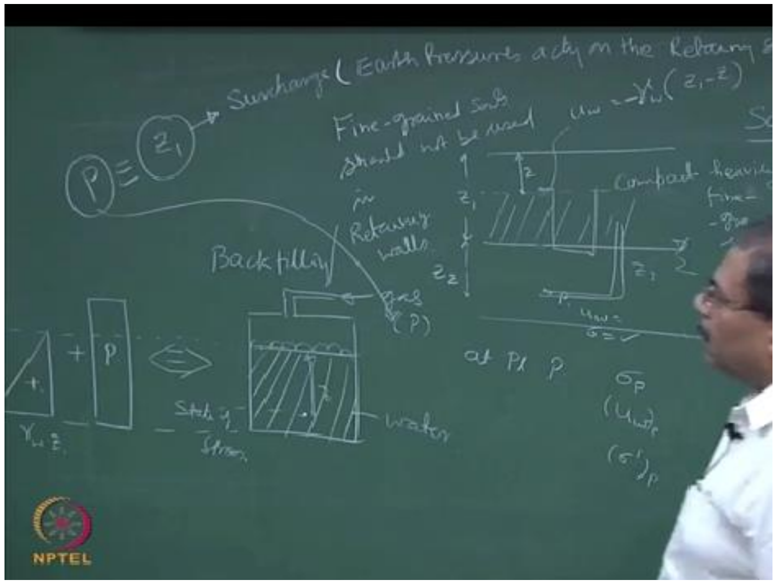

So, say water table is here. And I had put a condition that if I compact this soil mass or layer heavily. And if this happens to be fine grain material, let us say, what is going to happen. This analysis you should be doing yourself. I will give you some steps which you can follow. So, first thing is because of the capillarity associated with the compacted material, which is a fine grain type. If I consider a point over here at a depth of let us say z.

And the thickness of this layer is that z 1 and if I consider a point over here, let us say, .p and this is z 2 if I asked you to compute at ,p what a state of stress sigma p or a pressure at p and the effective stress at P. So this becomes interesting case. It is not difficult; I hope you can solve it still. Remember the concepts of finding on the corner pressure here. This is the capillary zone you will have to put a tensor meter here you can compute the u w value.

What will the value of uw, sorry at this point you are trying to find out this is the capillary zone, this is a peak of the capillary zone was if you remember this is the capillarity, you will get a state of 0. Apply mind before you are writing something on the piece of paper. See practice of engineering is nowadays, you know, legal, are you aware of this, whatever you write and sign is a legal document.

You can be pulled up in any court of law, remember, and then the damages are extremely high both ends, you get a lot of money, definitely. But if you are in trouble, then you might have to pay for the loans. So this is a maximum value hello, the maximum value of the capillarity. Remember, clear, so it happens, do not worry. I also did similar mistakes. So this is going to be gamma w and what is the funda.

You got to put the 10 so meter over here and then find out what is the drop in the water head. So this is that z 1 – z and negative value is this okay finished at this point it is simple, you put a physiometer. So this becomes your z 2. So at this point I know the value of uw, I know the value of sigma. Sigma is going to be tricky why, this is the saturated system, this is saturated, this is dry, depending upon the material property.

It is okay. So you have to be careful. This problem is a real life problem, which, if you solve would teach you a very interesting lesson that why we should not use fine grain materials in retaining wall or for backfilling for that matter. Because you should prove this, this whole layer acts as a surcharge. What is surcharge, in your any mechanics course you must have done this problems.

The container which is filled with some fluid say water and then you are pressurizing this by injecting a gas into it alright. Like, if I said that the gas pressure is p, and if I ask you to find out the pressure at this point at a depth of z over here you can solve this easily is not you must have done this in your 10, +2 and afterwards. So, this is the p pressure which is acting constant and this will get added up to so this is P which I can show like this also informative student loan.

You must be doing the structure analysis plus this is the air or pressure is this okay, so, when you have the fine grain material which is heavily compacted, this becomes a sort of a surcharge, which is equivalent to p. And hence, later on we will study in the second course is not our specialty will be in the second course yes that because of the surcharges, the earth pressures which are coming acting on the retaining system will go up.

And that becomes a big issue. So I have talked about compaction process today, compaction characteristics, how to interpret the compaction curves, how to use these compaction characteristics and designing different structures. And the most critical one is the beautiful example of compacted fine grain material out x on the stability of the systems which will be analyzing in the next course.