Geology and Soil Mechanics
Prof. P. Ghosh
Department of Civil Engineering
Indian Institute of Technology Kanpur
Lecture - 11
Soil Compaction- A

Welcome back. Welcome to the course Geology and Soil Mechanics. So, today we are going to start the new topic that is soil compaction. Now what do you mean by compaction. So, in your day to day life you have come across this process, this compaction process but knowingly or unknowingly I mean what are the mechanisms and how it is done you do not I mean you never thought about that.

So, however, in case of soil compaction that means when the compaction process is involved in the soil mechanics we need to know few things and we need to know and where actually this soil compaction is required and how to obtain or how to achieve this soil compaction in the field.

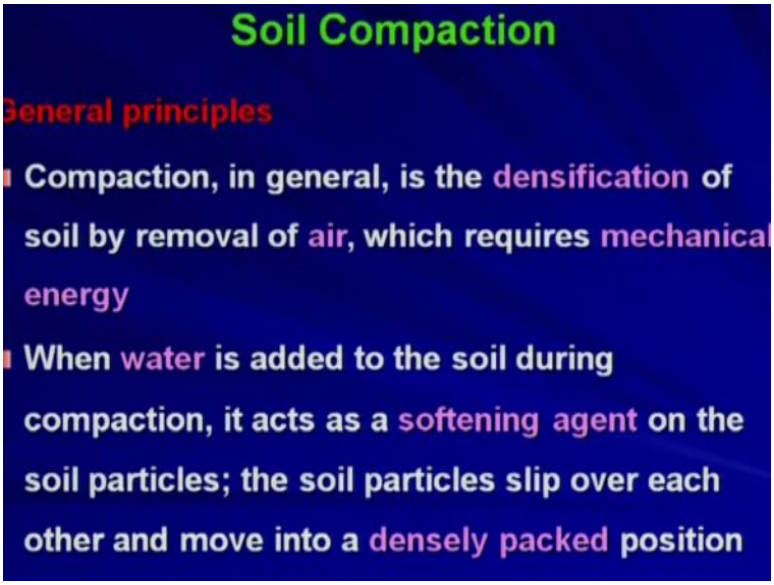
(Refer Slide Time: 00:56)

Now in the construction of highway, you might have seen in several occasions that in the construction of highway, embankments, earth dams, and many other engineering structures, loose soils must be compacted to increase their unit weight. So, you might have seen that, that whenever you are passing somewhere so in the in the highway construction or the embankment construction or the earth dam construction you might have seen that rollers are passing over the layers of soil right.

So, you might have seen that and you know from the knowledge or from your intuition that the roller is compacting the soil. Now this passing of roller or the layers of soil or how much moisture I mean water will be mixed with the soil, so those things are having some I mean specified quantity right?

So, you cannot have some arbitrary number of passage of roller or arbitrary amount of water to be mixed with soil, so this cannot be arbitrary. So, everything is decided based on some mechanics or based on some parameters, right? We will now learn those things in this particular topic.

(Refer Slide Time: 02:08)



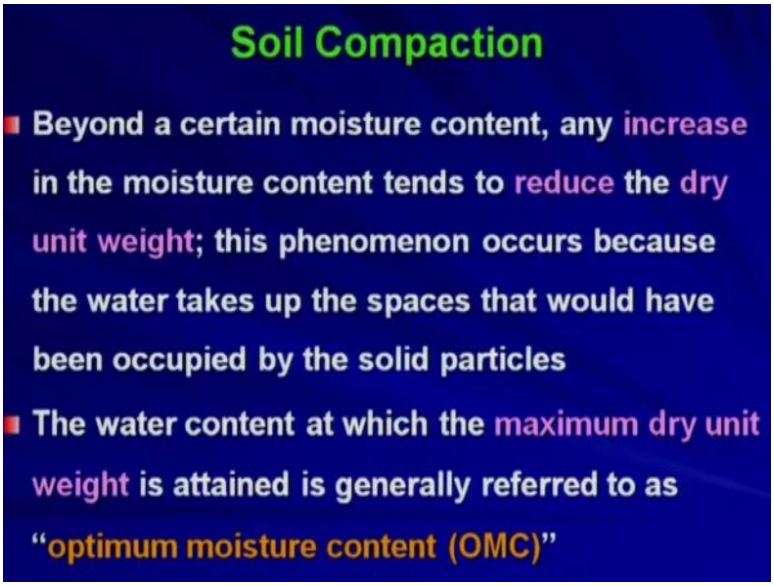
Now coming to the general principles. Compaction in general is the densification of soil by removal of air, which requires mechanical energy. So, if you recall or if you remember that if you want to put food grain in a particular jar and when the jar is not sufficient enough to accommodate the whole food grain, what you generally do? You just shake the jar so that the food grain again you can I mean the more amount of food grain can be accumulated in the jar right, you do that.

So, that is nothing but your compaction. So, basically what you do during your shaking? When you are shaking you are giving some mechanical energy right I mean through the shaking and because of that your air inside the food grain is going out and because of that you are getting the reorientation of the particles and ultimately you are getting the densification so that you can accumulate more food grain in the jar**.**

The same mechanism or the same methodology or same phenomena is equally applicable to the soil mechanics. So, in soil basically what we are doing, we are densifying the soil by removing the air from the soil matrix through some mechanical energy application. When water is added to the soil during compaction, so during compaction we generally add water as you have seen in the highway construction when the rollers were passing over the soil layers at that time some person used to put some water in the I mean in the compacted soil.

So, that means we are mixing water. So, when water is added to the soil during compaction it acts as a softening agent on the soil particles. The soil particles slip over each other and move into a densely packed position right. So, what basically you do, you add you try I mean continue adding water inside the soil and the soil and the water will basically act as the lubricant right. So, when the water will go inside the soil matrix the soil particles will reorient and they will be coming much closer to each other and they will be packed densely. So, this is basically happening during the slippage of soil particles due to the lubrication of water.

(Refer Slide Time: 04:37)



Now you keep on continuing the addition of water, now what will happen? So, you are adding some water, you are getting some densification, you are adding more water you are getting densification and so on but at certain point that means beyond a certain moisture content any increase in the moisture content tends to reduce the dry unit weight that means if you continue adding water inside the soil initially or the gradually you will be getting some increase in the densification which is measured by the dry unit weight as you have seen in the very first few

lectures that dry unit weight is nothing but the indication of the densification of the soil packing right.

So, if you keep on increasing the water content that means water addition in the soil matrix then initially you will be getting the increase in the dry unit weight which is indicating the increment in the densification, but after reaching a certain point and beyond that point if you still adding the water inside the soil what will happen? You will be getting some reduction in the density, reduction in the dry unit weight.

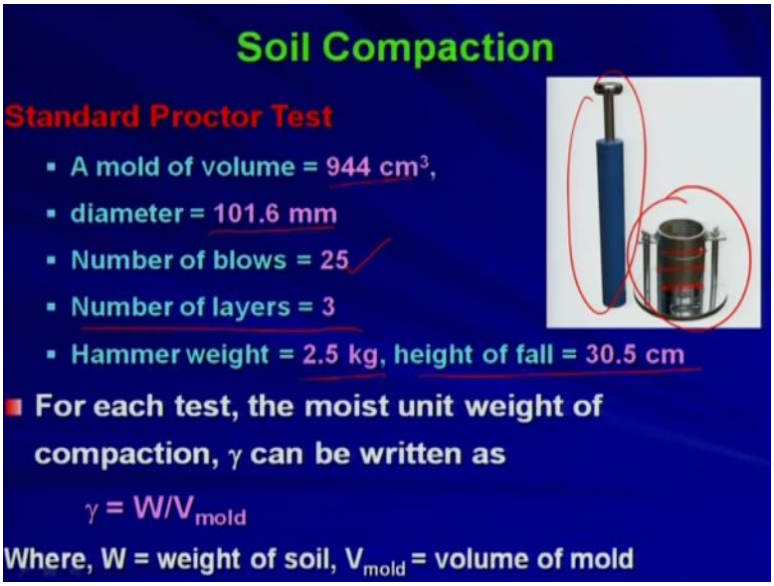
That means your densification is now getting reduced. So, this phenomena occurs because the water takes up the spaces that would have been occupied by the solid particles. Now if you add more and more water so water will take the space or take the position of the soil particles where the soil particles was were supposed to be there but now water is taking that space so you will be getting some reduction in the densification. That means the soil particles will be dispersed and ultimately you will be getting the reduction in the dry unit weight.

The water content at which the maximum dry unit weight is attained is generally referred to as optimum moisture content as OMC. Now what does it mean? So, what you are doing basically? You are adding water and you are measuring dry unit weight and slowly if you keep on increasing the water content then you will be seeing your dry unit is also increasing but at certain point you will be getting the maximum dry unit weight for a certain moisture content or the water content right? After that it will fall because the water will occupy the space where the particles were supposed to be right? Already we have seen.

So, you will be getting initial increase, it is reaching some peak and then it will be falling down. That peak will be denoted as the maximum dry unit weight. You will be getting the maximum dry unit weight at the peak and the corresponding water content or the moisture content will be known as optimum moisture content or the optimum water content which will be known as OMC in soil mechanics. So, now onward whenever I will be talking about OMC that means that will refer optimum moisture content.

Now to quantify or to get the results so I mean if you want to establish this kind of curve say dry unit weight versus water content then you need to perform some laboratory experiments and that is known as standard proctor test.

(Refer Slide Time: 07:51)



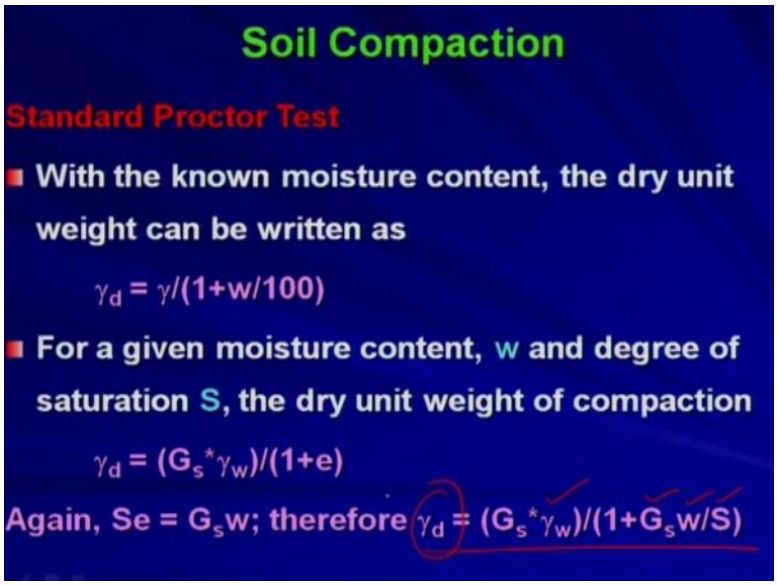
So, basically what we have here? So, we have a mold, a steel mold okay which is having the volume of 944 cubic centimeter okay, 944 centimeter cube, so this is the volume of the mold and the diameter of the mold is 101.6 millimeter. Now what we what we do basically? We add some water okay, some known quantity of water in the soil, taken soil, and then we mix it properly and then we put that thing in the mold layer wise, so in 3 layers, so number of layers will be 3.

So, say we are putting the first layer and with this hammer, so this is the hammer okay, so with this hammer we tamp it or we ram it for 25 number of blows so 25 number of blows will be coming from this hammer and each layer will be compacted by 25 number of blows of this particular or the specific hammer. So, hammer weight is 2.5 kg and the height of fall of the hammer which is free fall that is 30.5 centimeter okay.

So, now this is the first layer we have compacted. Now we are putting the second layer and then we are compacting again then we are putting the third layer we are compacting again and then basically we stop the experiment.

Now what we do after that? For each test, the moist unit weight of compaction that is gamma can be written as gamma is equal to W that is the weight of soil that is whatever soil you have taken divided by the volume of mold. So, that will give you the moist unit weight of compaction okay. So, that we can calculate.

(Refer Slide Time: 09:40)

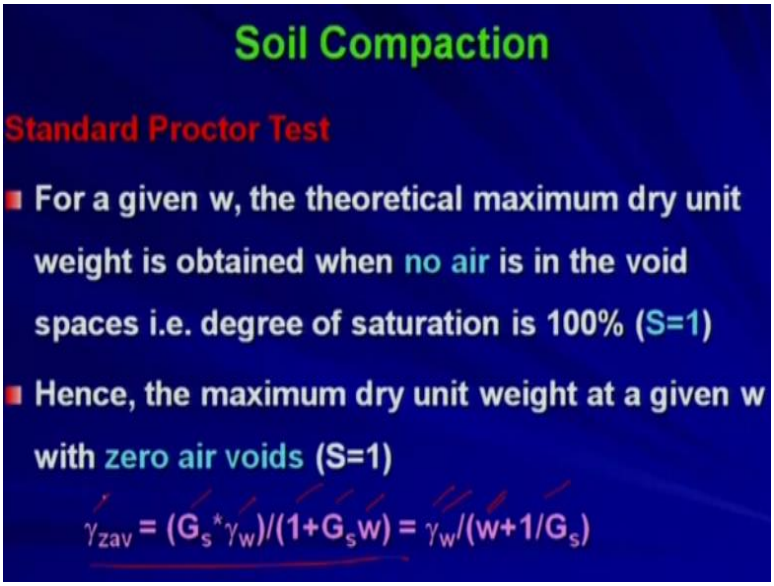


Now with the known moisture content because you are adding the water in the soil okay, in the given soil, so you know the moisture content or the known amount of water content. The dry unit weight can be written as gamma d is equal to, so these expressions can be derived from the basic definitions whatever we have learnt in the very first few classes, right?

So, gamma d that is the dry unit weight is equal to moist unit weight that is gamma divided by 1 plus w, w is the moisture content in percentage by 100. Now for a given moisture content that is w and degree of saturation say S, the dry unit weight of compaction can be obtained by this expression that is gamma d is equal to G s that is the specific gravity of soil into gamma w that is the unit weight of water divided by 1 plus e where e is the void ratio.

Now again we know from our earlier definition that A c that is the degree of saturation multiplied by the void ratio is equal to G s into w. Therefore, gamma d can be expressed by this expression G s into gamma w by 1 plus G s w, w is the water content by degree of saturation S. So, if you know the degree of saturation, if you know the water content, if you know the specific gravity of soil, and if you know the unit weight of water, you can find out the dry unit weight of the soil.

(Refer Slide Time: 11:10)



Now for a given water content the theoretical maximum dry unit weight is obtained when no air is in the void space, that is degree of saturation is 100% that is S equal to 1 right? So, when you will be achieving I mean if I ask you to achieve the maximum dry unit weight when the maximum dry unit weight will be achieved then at that time your soil will be 2 face system. It will be fully saturated. There will be no air in the void space.

So, if you can achieve that kind of condition that is there is no air in the void space, only water and solid particles are there then that will be classified as a 2 face system and in that situation, you will be getting the maximum dry unit weight that is the maximum possible or maximum say targeted dry unit weight right, but frankly speaking or truly speaking you will never get or never reach that kind of that amount of unit weight, dry unit weight because that is not achievable.

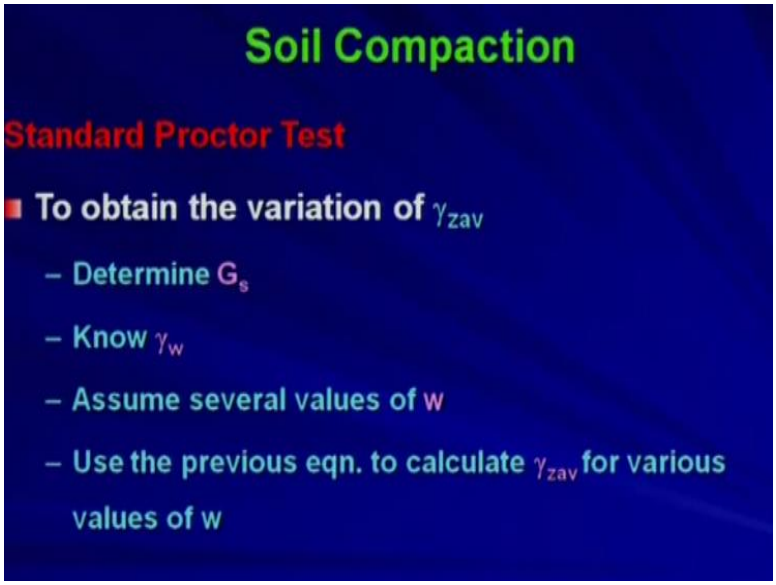
That is the that is a kind of say ideal situation where you are getting only water and air. So, all the air only water and soil particles. All the airs will be taking out from the soil matrix but that is not achievable, try to understand. So, but that situation we can derive from the mathematics. So, hence the maximum dry unit weight at a given water content with zero air voids because if you have zero air voids that means the void is completely free from air, it is completely full of water that is that condition is known as zero air void condition that means that happens at the degree of saturation equal to 1.

So, the maximum dry unit weight at a given water content with zero air voids can be given by this expression. So, in the previous slide we have seen so gamma d was given by this G s so if you look at this gamma d was expressed by this expression now here actually you have S equal

to 1 so now your gamma at the zero air void condition is equal to G s into gamma w divided by 1 plus G s into the water content w. Now if I take G s out I will be getting gamma w divided by water content plus 1 by G s right.

So, if you know G s of the particular soil and if you because this is because you can vary the water content you are adding different amount of water in the soil and then you are doing the test. So, with the different value or different magnitudes of w the water content and if you know the unit weight of water then you will be getting the maximum I mean possible or maximum targeted dry unit weight of the soil and that is happening at the zero air void condition.

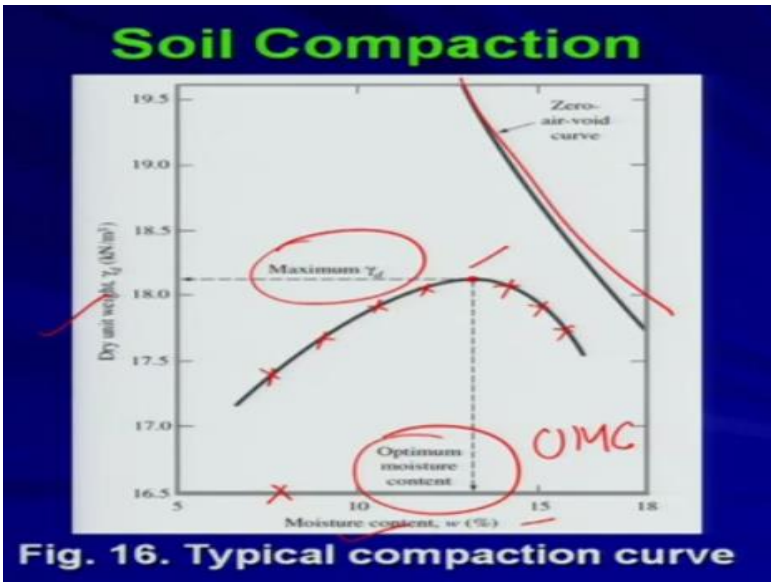
(Refer Slide Time: 14:18)



To obtain the variation of gamma at zero air void gamma zav, so what are the things you need to do? So, first you determine G s that is the specific gravity of soil solid. Then you know gamma w that is the unit weight of water. Then assume several values of water content. So, you start with some value of water content and you go on increasing the water content because this is kind a theoretical knowledge or theoretical say concept right, zero air void is a theoretical concept, practically it is not achievable okay.

So, assume several values of water content and use the previous equation to calculate gamma zav for various values of w and then you plot with respect to dry unit weight and if you plot that thing in the unit weight and unit weight versus water content space so you will be getting one line right. Now coming to the actual plot whatever you will be getting from your compaction test in the laboratory.

(Refer Slide Time: 15:23)



Basically, as I told you so for different values of so we are plotting dry unit weight versus moisture content. So, for different moisture content okay you will be getting different gamma zav okay which will be giving you the zero air void curve. So, that is known as zero air void curve or zero air void line in soil mechanics. So, this is your ideal situation. In no case your compaction curve will touch this or cross this right.

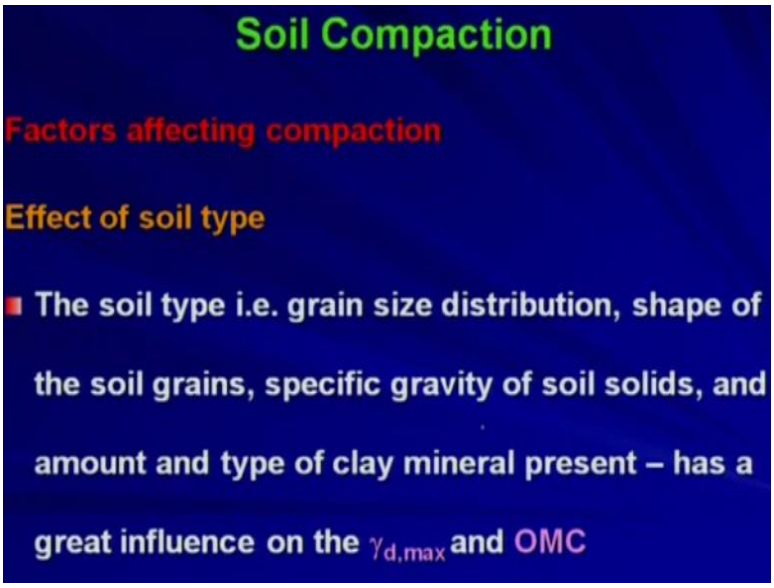
This is your ideal condition where you have degree of saturation is 1 and there is no air inside the void space okay. Now you are doing the actual compaction test. For different say water content you will be getting different point or different magnitude of dry unit weight and as you go on increasing the water content you will be getting increment in the dry unit weight and after reaching the maximum okay again if you continue adding water then you will be getting decrease or the reduction in the dry unit weight as we have discussed so far.

So, now you have I mean if you join the points you will be getting the curve which is known as compaction curve. Now this rate point okay which will be basically denoting the maximum dry unit weight and the corresponding water content will be known as optimum moisture content or OMC. I hope now you have understood what exactly we are doing. So, basically you are taking the soil and then you are adding some water, water inside the I mean in the soil matrix okay and then basically that will that will tell you that will talk about your water content okay.

Then you perform the test in the laboratory through the standard proctor test and then you obtain gamma d by these calculations and you get these points, different points and then finally you get

the whole curve which is known as the compaction curve and from the curve basically you find out the maximum dry unit weight and OMC. So, these 2 parameters are essential or important to quantity the compaction I mean property of the soil.

(Refer Slide Time: 17:43)



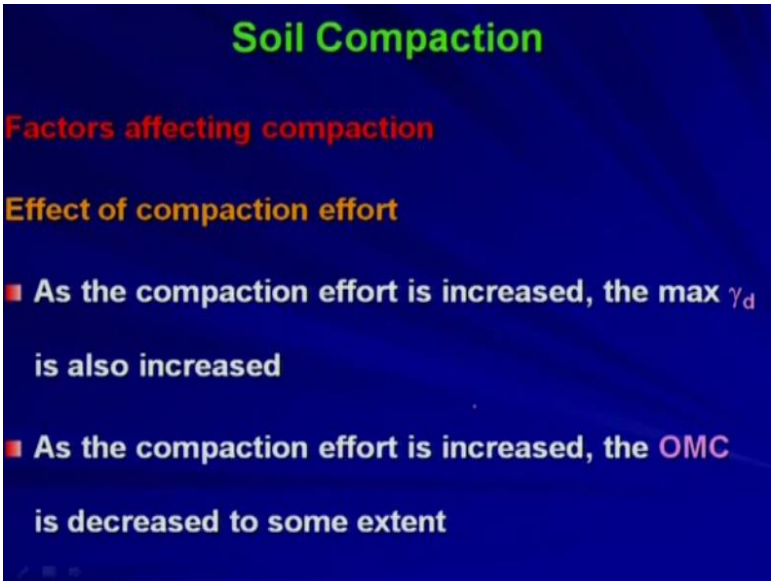
Now what are the factors affecting compaction. Effect of soil type. Now the soil type that is grain size distribution, shape of the soil grains, specific gravity of soil solids, and the amount of amount and type of clay mineral present has a great influence on the gamma d max that is maximum dry unit weight and OMC right.

So, what are the things are affecting? Grain size distribution, because if you have poorly graded soil or if you have uniformly graded, poorly graded, or well graded soil okay you will be getting different degree of compaction. So, if you have uniformly graded or the poorly graded soil your compaction will be less whereas if you have the well graded soil you will be having more compaction for the same material right.

Then shape of the soil grains. If you have the angular shape of the soil grain okay which will be compacting more and then the rounded shape. So, these are coming from the how they are getting packed because ultimately the compaction is achieved through the packing of the soil particles, how they are getting packed or how the void space is getting less right, the void space is I mean through the air expulsion how you are getting less number of I mean less amount of or less volume of voids right. That will talk about the compaction.

Then clay minerals. Then you know that if you have different clay minerals you will be having different types of say whether it is dispersed or whether it is flocculated so that kind of structure depends on the clay minerals, how the charges are present in the clay particles or the surrounding surface right. So, based on that you will be getting some compaction, different compaction for different types of clay minerals right.

(Refer Slide Time: 19:29)

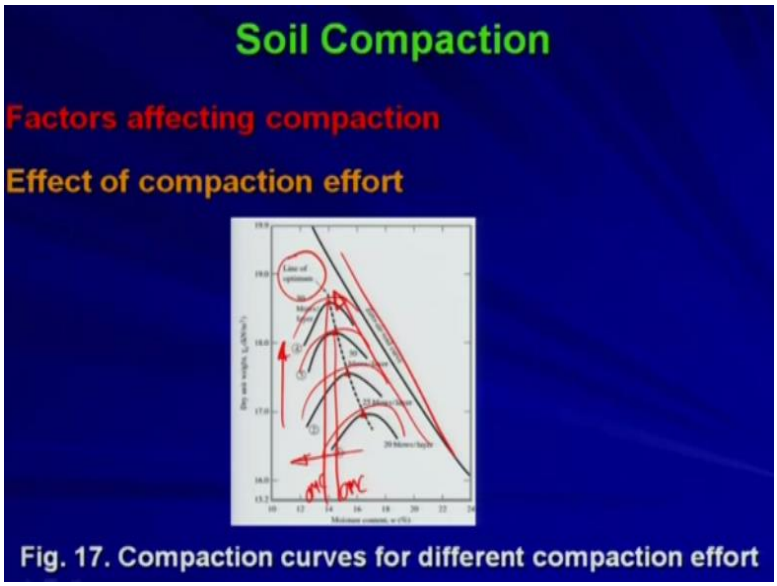


Now effect of compaction effort. Now what is compaction effort? Compaction effort means when you are giving the number of blows say with the standard proctor test you have seen that 25 number of blows you are giving per layer. Now if you increase the number of blows that means you are giving you giving the soil more compaction energy right? So, your compaction effort is getting more if you increase the number of blows. So, if you do that then what should be the effect on compaction?

As the compaction effort is increased, that means as you are giving more compaction energy to the soil, the maximum dry unit weight is also increased that means your maximum dry unit weight will be going on increasing with the increase in compaction effort. That means if you increase the number of blows your dry unit weight will be increasing, maximum dry unit weight will be increasing.

As the compaction effort is increased, that means if you give the number of if you increase the number of blows, the OMC is decreased to some extent. That means the optimum moisture content which is corresponding to the maximum dry unit weight will be decreasing.

(Refer Slide Time: 20:45)



Now if you look at this figure then it will be clear to you. So, okay, so this is your zero air void line which is not achievable. It is a kind of say theoretical line okay. So, now with 20 blows per layer you are getting this one is the first compaction curve. With 25 number of blows you are getting this. With 30 number of blows you are getting this. With 50 number of blows you are getting this right? So, what you are getting ultimately?

So, with 20 number of blows your gamma d max was here. With 25 number of blows your gamma d max is here. Similarly, gamma d max for 30 blows here and gamma d max for 50 blows is here right. So, if you connect this line. So, this line basically if you drop a vertical line these are giving you OMC at different number of blows.

So, if you join these lines that will be known as line of optimum and as you see if you increase the number of blows okay you gamma d max is increasing whereas your OMC is decreasing right, OMC is moving in this direction and gamma d max is moving in this direction. So, as you increase the compaction effort your gamma d max will be increasing whereas OMC will be decreasing right.

So, thank you. I will stop here today. So, we will be continuing the soil compaction part in the next lecture. Thank you very much.