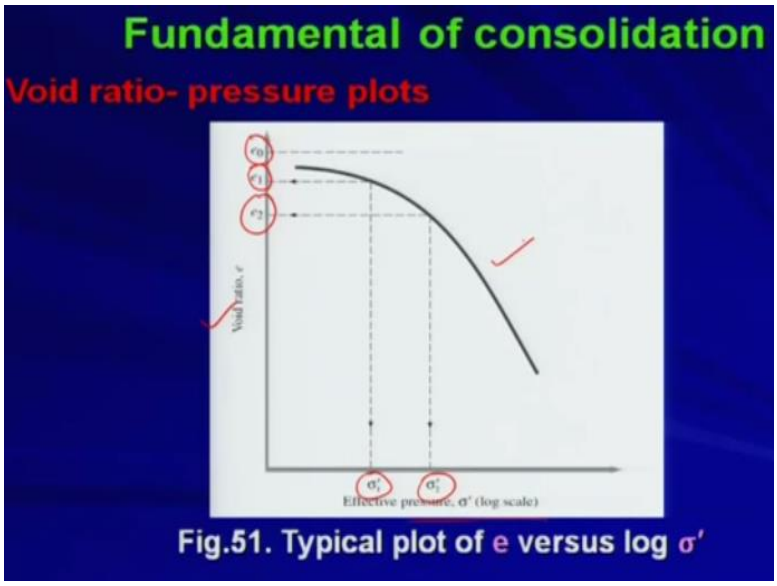
Geology and Soil Mechanics
Prof. P. Ghosh
Department of Civil Engineering
Indian Institute of Technology Kanpur
Lecture - 31
Consolidation - A

Welcome back. So, in the last lecture we just discussed about several issues related to the consolidation and there we have found out that we can will be able to plot the variation of void ratio with respect to the effective pressure. That means if you increase the effective pressure that means basically you are increasing the total stress or the total pressure and that ultimately that will increase or enhance the effective pressure so that will be same. The total stress increment will be is equal to effective stress increment at the end of consolidation of course. So, you can so if you vary the effective pressure you can get the variation in void ratio and which can be plotted in some semilog plot right. So that already we have discussed in the last lecture.

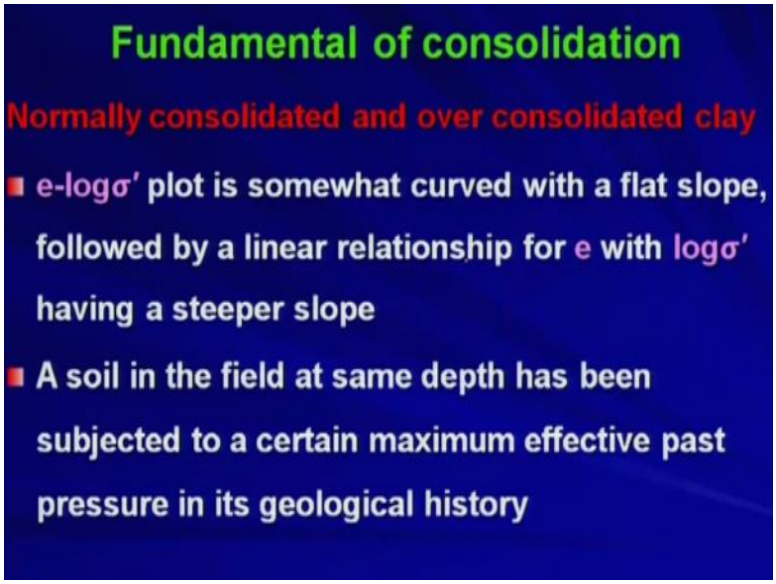
(Refer Slide Time: 01:08)



So now we will see in this lecture we will see that how the plot will be looking like. So, along y axis you will be having void ratio e that is the normal axis and along x axis that is your log scale so along x axis you have the effective pressure. So that means say e not was your initial void ratio okay. So now if you increase the total stress sigma 1 and which will be eventually will be becoming the effective pressure sigma 1 prime at the end of consolidation at that time you will be getting some reduction in void ratio that is say delta e 1 and so you will be getting the final void ratio as e 1 which is equal to e not minus delta e 1 right already we have calculated in the

last lecture. Similarly, if you increase the effective pressure rather total pressure and which will be eventually becoming the effective pressure. So, if you increase that, that is sigma 1 prime to sigma 2 prime if you go you will be getting further reduction in the void ratio and you will be getting the void ratio as e 2. So, these are the things we have seen and we have seen that how to calculate all these parameters all these values right. So, you will be getting so if you join this thing so you will be getting a nonlinear curve like this okay.

(Refer Slide Time: 02:29)



Now e-log sigma prime plot is somewhat curved with a flat slope followed by a linear relationship for e with log sigma prime having a steeper slope okay. So, I mean this is a common trend or the common say scenario observed in the consolidation plot so initially it will be curved with a flatter slope and then you will be having some linear relationship with steeper slope. A soil in the field at same day has been subjected to a certain maximum effective past pressure in its geological history right.

So please try to understand. It is very conceptual. A soil in the field at same depth has been subjected to a certain maximum effective past pressure in its geological history. Now what does it mean? It means that suppose you have some soil deposit okay if you go to some depth ok and if you consider some soil block or the soil element that soil element will I mean already has experienced some previous pressure or the pressure history or the stress history.

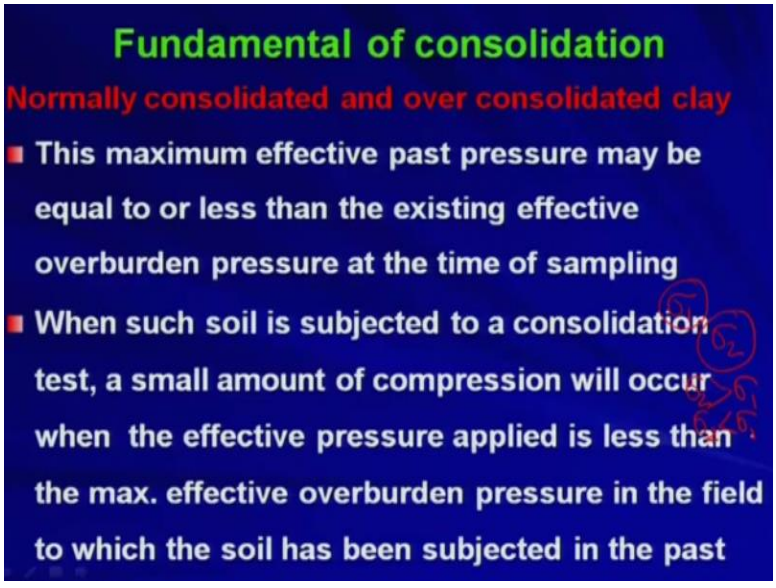
Suppose for example suppose I have some soil deposit and on top of that long back maybe some glacier was there okay. Now this glacier is not there because the glacier has gone out gone away

and it has become water or whatever. So, glacier is not existing now. So, what will happen? Due to the glacier, the soil is already compressed already consolidated under that pressure whatever pressure was developed or generated by the glacier.

Now the glacier is not there but soil will remember that stress history. Soil is having a very I mean good memory right. Soil will remember that stress history that already I have experienced this much of stress due to the glacier. Now the glacier is not there that is different issue but I can remember that much of stress, for that much of stress I am already compressed or I am consolidated right.

So, this is nothing but very important phenomena and this is this will tell you something about the soil whether it is over-consolidated or normally consolidated or pre-consolidated something like that okay so we will come to that point later. I hope that you have understood right. The soil which has already experienced some stress in past right, geological history, okay so it has experienced that and now that pressure or that load is not there but still it will remember that history.

(Refer Slide Time: 05:29)



So, this maximum effective past pressure maybe equal to or less than the existing effective overburden pressure at the time of sampling, quite obvious right. Due to that glacier, whatever example I put in front of you due to that glacier whatever stress was generated and whatever due to that the soil was compressed. Now you are going to construct some building. If that building is I mean the building will create some extra stress or extra pressure right in the soil.

Now if that pressure is get that pressure due to that building newly constructed building it maybe or may not be greater than that the previous or the historical glacier pressure. Am I right. So, glacier pressure suppose the glacier has given me some sigma 1 okay so now soil is compressed or has been compressed under this pressure. Now the glacier is not there but still soil can remember that I have been compressed under this pressure okay by the glacier.

Now you are constructing some building okay and or maybe some structure on top of the soil and that structure is giving some pressure or creating some pressure sigma 2. Now this sigma 2 maybe greater than sigma 1 or sigma 2 may be less than sigma 1 right. So, if your sigma 2 is greater than sigma 1 that means you are crossing its previous history. That means soil will tell okay you are crossing my limit.

Already I have experienced this much of pressure but now you are increasing the pressure so I will compress. But if your sigma 2 is less than sigma 1 that means soil will say oh okay I have already experienced this much of pressure earlier now you are applying this much of pressure which is nothing for me so I will not compress. So, this is the thing soil will remember okay. So, I hope that you have understood this thing okay.

So now when such soil is subjected to a consolidation, consolidation test, a small amount of compression will occur when the effective pressure applied is less than the maximum effective overburden pressure right so in the field to which the soil has been subjected in the past. So please try to understand. When such soil whatever soil we have discussed just now that means it has got some previous history okay when such soil is subjected to a consolidation test a small amount of compression will occur small amount of compression will occur when the effective pressure applied is less than the maximum effective overburden pressure.

That means if this condition is valid sigma 2 is less than sigma 1 if this condition is existing or is getting applied then which is the which the soil has been subjected in the past that means whatever load you are applying now due to construction of some new structure that load or that I mean that structure will give some pressure and that pressure is less than the previous or the historical pressure whatever soil has already experienced.

So, under that situation you will be getting very marginal or the small amount of deformation right I mean very marginal deformation because soil will say already I have experienced this much of this is something like that say suppose you can carry 10kg or suppose I mean your capacity is 10kg right. So now if I apply some 15kg load on top of you then you cannot take care

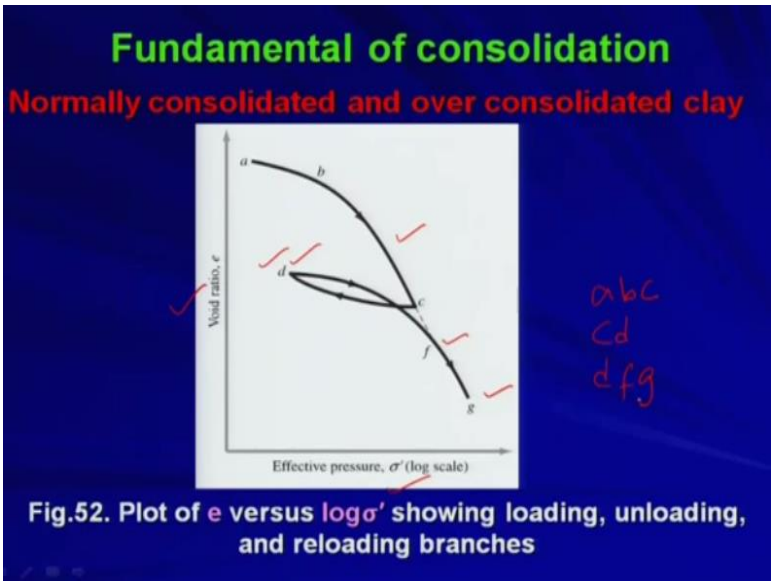
of that but if I give you say 8kg or 5kg then you will say already I my capacity is 10kg so I can carry 5kg or 8kg right. So, this is something like that.

(Refer Slide Time: 09:22)

So, when the effective pressure on the soil become greater than the maximum effective past pressure the change in the void ratio is much larger and the e-log sigma prime relationship is practically linear with a steeper slope. So, this is happening during that time okay steeper slope when you will be getting the steeper slope the when the effective pressure on the soil become greater than the maximum effective past pressure. That means when your sigma 2 is greater than sigma 1 at that time you will be getting very steeper slope.

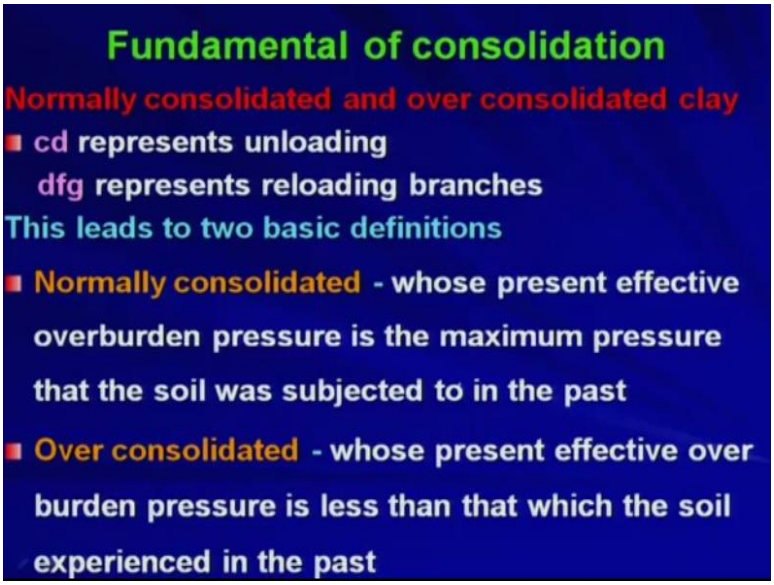
Initially you will be getting very flatter slope as I told you in the e-log sigma prime plot I told you that initially you will be getting very flatter slope. When you will be getting the flatter slope at that time your sigma 2 was less than your sigma 1 that historical or the previous or the past pressure right. Now you are increasing the pressure and that basically sigma 2 is now becoming greater than sigma 1 so that now soil will say no this much of pressure I have not experienced okay now I have to compress. That is the phenomena okay. So, at that time, you will be getting very steep slope in the e-log sigma prime plot.

(Refer Slide Time: 10:31)



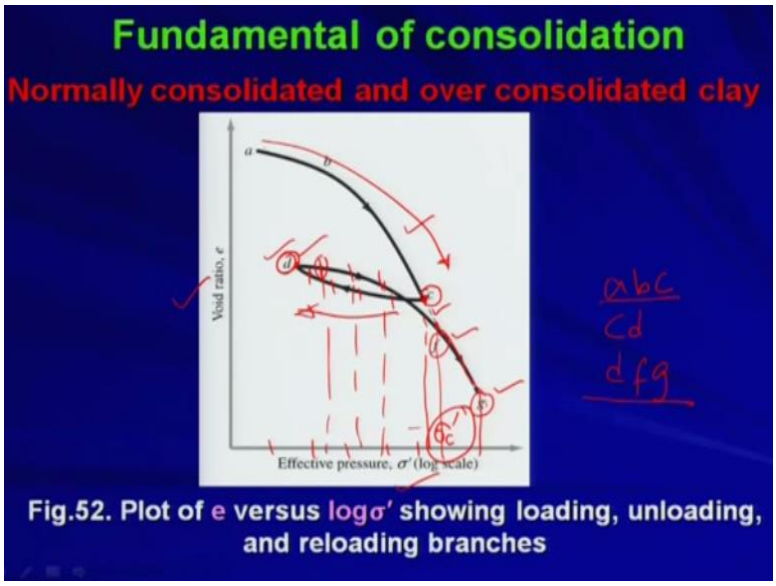
So now you can see here. So, this is nothing but very typical e versus log sigma prime plot. So, I will so you have a b c part and then you have f to d part right c to d part and then further d to f and g. So, you have a b c one part okay or then you have c d part and then you have d f g. So, there are 3 distinct parts okays. Now we will see that what are these parts.

(Refer Slide Time: 11:10)



cd represents unloading. So, if you look at the figure once again cd so that means you are loading it

(Refer Slide Time: 11:14)



If you if you move in this direction a to c okay you are loading it. That means you are increasing the load right and due to that you are getting some reduction in void ratio. Now after reaching c you are unloading it. That means you are reducing the load or you are reducing the effective stress. So that means you are moving in this direction right. So that means you will be getting some enhancement or some increase in the void ratio.

So, you are reaching d okay. Now after reaching d you are reloading it. So dfg represents the reloading branches. So df and g this path will talk about the reloading. That means say when you are at d try to understand. When you are at d if you apply load so the soil was already compressed at some loading c. So, say sigma c sigma c prime. The soil was already compressed at sigma c prime.

Now some unloading happened in the along the path cd. Now you are at point d. Now you are reloading it right. What you are doing? You are reloading it. That means you are applying the load again. What will happen? You are reloading but you see you are getting a flatter slope why? Now whatever stress you are getting all this stresses they are less than your past pressure sigma c prime am I right.

So, you will not be getting very steep slope the flatter slope. Soil will say already this much I have experienced sigma c prime what you are putting now. Now whatever putting I can take care of that. So now once you reach this point f say for example f it will not be exactly matching to point c some gap will be there as shown as dotted. So, once you reach f then soil will say no this

much of pressure I have not experienced. Now I have to do something or I have to compress. So now you will be getting very steep slope from f to g okay.

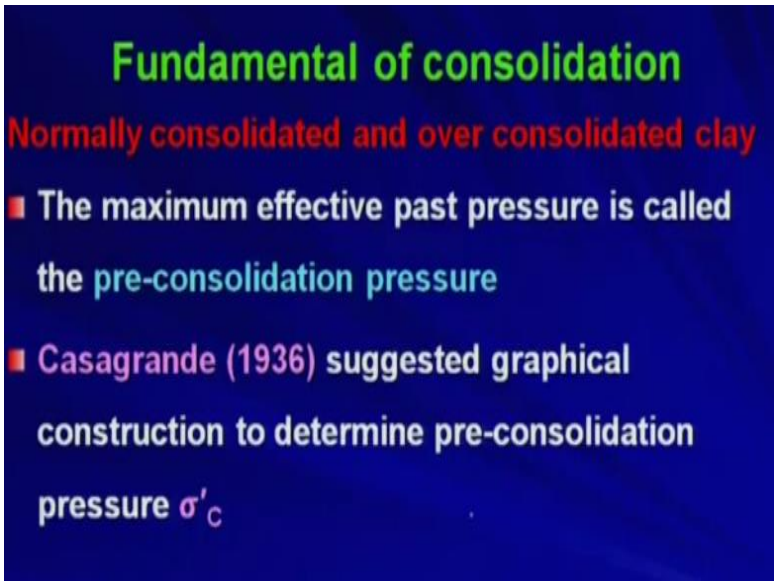
So, this is happening actually. So, from d to f you will be getting flatter slope because soil has already experienced this much of pressure. Now from f to g you will be getting very steep slope because soil has not experienced this thing earlier. So, this leads to 2 basic definitions. First one is normally consolidated whose present effective overburden pressure is the maximum pressure that the soil was subjected to in the past.

So, when I say my soil is normally consolidated that means whatever pressure I am applying under that pressure soil I mean that is the pressure what soil has experienced I mean that is the maximum pressure rather the soil has experienced in the past also right. So, if you look at this point say when I am moving from f to g do you think the soil has experienced the pressure greater than say sigma f or sigma g no never right.

The soil from f to g will be behaving as normally consolidated soil. That means soil has not experienced this much of pressure never in its lifetime okay. So that is normally consolidated. Now the second one is over-consolidated now whose present effective over burden pressure is less than that which the soil experienced in the past. So, when you are moving from d to f at that time the soil will be behaving as over-consolidated.

That means soil has already experienced the pressure sigma c prime. But now whatever pressure you are applying that is less than sigma c prime so soil will say okay I am already experienced this much so do not expect anything very new from me so I know how to carry right. So, this is at that time the soil will be known as over-consolidated soil.

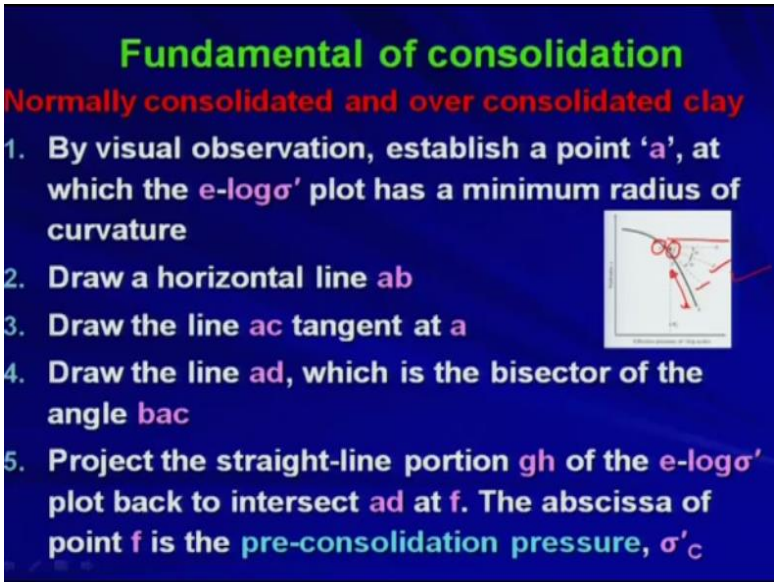
(Refer Slide Time: 15:45)



So, the maximum effective past pressure is called the pre-consolidation pressure. So, this is very important. So, if you want to construct some building or any structure on the soil you need to know what is the pre-consolidation pressure of that particular deposit. Now why you need to know? You need to know that pre-consolidation because you need to find out at which pressure the soil was already compressed. That is the past pressure the soil was already compressed and soil has experienced that much of pressure.

Now whatever pressure I am applying due to construction of some new structure whether that is giving more than that past pressure or less than that past pressure. That past pressure is very important for me. If it is if my structure is giving pressure which is more than the past pressure then I will be observing or I will be expecting some different behaviour whereas if my past pressure is greater than the new existing or new applied pressure then my behaviour will be different or the soil behaviour will be different right. So, this is very important. So, for that Casagrande in 1936 suggested some graphical construction to determine pre-consolidation pressure sigma c prime.

(Refer Slide Time: 17:04)



So, let us see how we can find out okay. So Casagrande has proposed this is some e-log e-log sigma pre-prime plot okay and this is the plot so we will explain all those things what are the things what are the steps are involved to find out the pre-consolidation pressure. Now this is the figure whatever figure I just showed you I have taken that thing in a smaller scale to understand this thing.

The first thing is that first step by visual observation establish a point a okay by visual observation establish a point a at which the e-log sigma prime plot has a minimum radius of curvature. So that comes from visual observation and because of the visual observation it is dependent on individual's perception right. Anyway, so you find out the point where the radius of curvature is minimum in the e-log sigma prime plot.

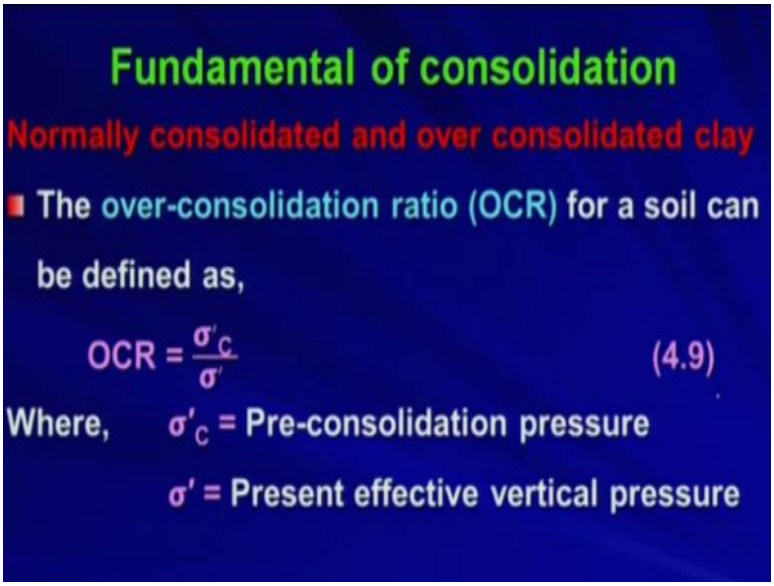
So that is nothing but say point a. Now in the next step draw a horizontal line ab okay draw a horizontal line ab. Then in the third step draw the line ac tangent at a so ac so that is nothing but the tangent at a. So, you draw a line ac which is tangent at a. Draw the line ad which is the bisector of the angle bac so ad which is nothing but the bisector of angle bac okay. Then project the straight line portion gh.

So, what is your gh? This is your gh right. This is the straight line portion of course. Project the straight line portion gh of the e-log sigma prime plot back to intersect ad okay at f okay. The abscissa of point a is the pre-consolidation pressure sigma c prime understood. So, we have got the pre-consolidation pressure. So, what does it mean? If your pressure, if your applied pressure is less than sigma c prime the behaviour of soil will be different because the soil will be behaving

as over-consolidated soil and if you cross this limit and if you move in this direction that means your applied pressure is greater than your sigma c prime then the behaviour of soil will be different.

That will be behaving as normally consolidated soil. I hope that you have understood. So, the steps involved. So, this is proposed by Casagrande right. So, these steps if you follow then you will be getting the pre-consolidation pressure sigma c prime and that will give you the boundary okay which will tell okay if you are on the left side of the boundary then the behaviour will be something else and if you are on the right side of the boundary then you will be having some different behaviour.

(Refer Slide Time: 20:19)



Now based on that we can we can find out that how much over-consolidation or how much over-consolidation soil we are having. Now over-consolidation ratio is I mean is indicated or is applied to find out that thing. So, the over-consolidated ratio for a soil can be defined as OCR is equal to sigma c prime by sigma prime okay where sigma c prime is nothing but the pre-consolidation pressure whatever just now we have seen and sigma prime is the present effective vertical pressure right.

So, your if your OCR is 1 if your OCR is sigma c prime is constant right so sigma c for a particular soil or for a particular deposit sigma c prime you have obtained. Now this sigma prime you can play with because now you are going to apply some extra or additional pressure or some

externally external structure you are putting so because of that you are getting some sigma prime. Now you can vary sigma prime but sigma c prime is fixed for that particular deposit.

Now so once you increase sigma prime gradually right so initially sigma prime will be maybe less than sigma c prime or maybe greater than sigma c prime. If it is less than sigma c prime then your OCR will be greater than 1. So, if your OCR is greater than 1 that means the soil will be behaving as over-consolidated soil am I right? If your OCR is becoming less than 1 that means your soil will be behaving as normally consolidated soil.

Your OCR 1 means you are at the boundary that means if you just cross the boundary you will be entering the normally consolidated soil range or the region whereas just on the left side you will be entering the over-consolidation range or the region. So, I will stop here today. So, in the next lecture we will see that we will try to find out how to observe the or how to calculate the deformation or the settlement due to consolidation from one reconsolidation theory. Thank you very much.