Geotechnical Engineering II / Foundation Engineering

Prof. Dilip Kumar Baidya
Department of Civil Engineering
Indian Institute of Technology, Kharagpur

Lecture – 28
Earth Pressure Theories

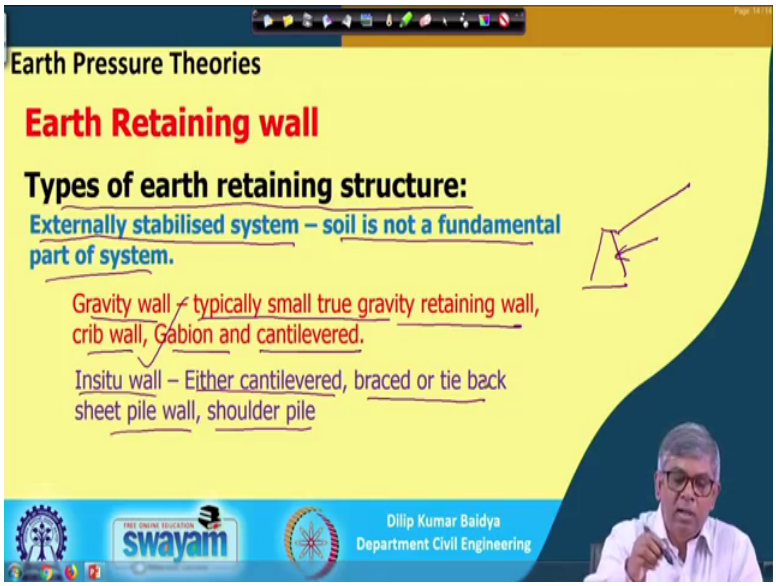
Good morning, once again and welcome you to this lecture series of Foundation Engineering and that too today I will talk a new topic that is Earth Pressure Theories initially few classes. And then based on earth pressure theory whatever pressure will be estimated and then using that we will do stability analysis of the earth retaining wall. And this earth pressure theories actually why it is necessary because different types of earth retaining wall will be there and sometimes the wall will be because of the wall condition the pressure will be different.

Rigid flexible that is one type and then with friction without friction there will be another type, then movement of the wall something towards back field away from the back field, like that flexible situations can happen in the field as a and actual field condition and because of this change of this field condition pressure on the wall will be changing. So, while designing you have to consider those pressure actually so, that we can properly design the section of the wall.

With that intension we need to know first estimate the earth pressure behind whatever, when to wall actually, function of the wall is what? Suppose in a hill areas you want to develop some facilities like a road then, you have to cut the hill and make a road. Now, if the hill slope is too steep and hill rock qualities not good in that case you cannot keep the cut surface of the earth just open, sometime you need to support.

Similarly in some places you have to while making railways you have to some places you have to cut, excavate, some places you have to fill and when you will be passing those areas then that when you are cutting the soil then the soil has to be retained by retaining wall. Similarly when there is embedment is made that also to be retained by the wall. So, that and while designing those wall actually you have to find out how much pressure is coming because of the backfield. So, that is the thing, that is the intention to know, that is the intention actually why you need to study earth pressure theories.

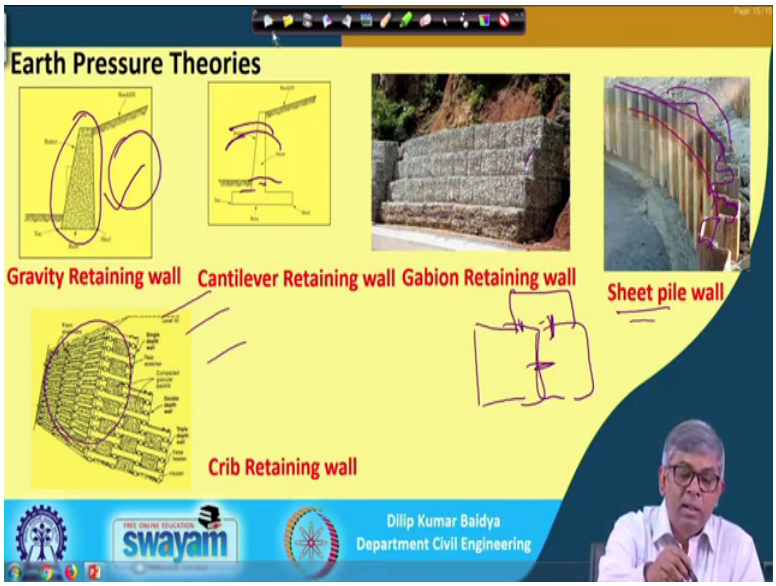
(Refer Slide Time: 02:53)



Now let me go to the same thing just as introduction. So, before going to know earth pressure theories, so, first of all type of earth retaining structures. They are actually, there are two broadly two types actually externally stabilized system that is soil is not a fundamental part of the system. That means, when the soil is not a fundamental part of the system means for the stability of the wall the soil is not helping, soil is only imposing the pressure or load on the wall, but not in the stability they are not part of it. So, in that case that is called externally stabilized system and the examples are, actually gravity wall sorry gravity wall and they are typically small to small true gravity retaining wall, crib wall gabion or cantilevered wall cantilevered.

So, they are actually gravity wall and then some of them in situ wall they are actually either cantilever, braced or tie back sheet pile wall shoulder pile they are actually in situ wall. That means, directly in the sheet type of things we can insert in the ground to retain the soil. So, these are the two externally stabilized; that means, if there is a wall something like this and what soil retain here soil only giving pressure nothing else. So, that is called externally stabilized wall and I will just show you some of the figure here.

(Refer Slide Time: 04:33)



You can see here that I have mentioned that this is actually one gravity retaining wall, this is the body of the retaining wall and this is the retained soil and this is one cantilever retaining wall you can see. That cantilever means what? This is inside the soil in the up to this and this portion free to move with respect to this is like a fixed here and it is rotating here. So, that is why it is called cantilever retaining wall.

And this is actually typically gabion wall, you can see gabion is what that through by using wire mess you can make a big box like and in the box, inside the box you can keep a big size rock masses actually that is they are actually like gravel or boulders filled with those wire mess. And then we will make a box like things and these boxes are connected. So, if you put another opening they will also connect here.

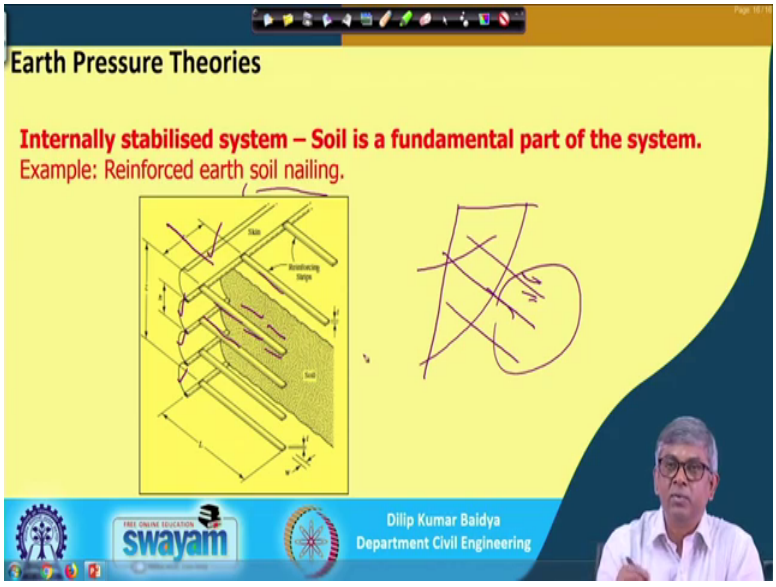
So, when they are used like this and one after one and stressed and again one after stressed like that and then going by behind then the entire soil then this entire mass become like wall and behind that soil can be retained, that is called gabion wall. And this is another type of wall that is called crib wall; crib wall actually like that initially I have put a bar here little above with this raised and then over that we have number of them I will put and again number of them I will put there like that a nest type of things will form. And this is the one nest type of things, this is the members and then cross members and those insight it can be filled up with granular soil and then entire things will act like

a wall at this side soil can be retained and they are all little bit some advantages are there and is easy to cost act maybe less very economic.

So, because of that this type of wall also particularly in a large volume construction may be used and another type of in situ wall actually sheet pile wall you can see, these are the thin sheets and they are interlocked each other. So, this is one piece this is another piece. So, this will be penetrated and this will be locked and then penetrated then this will be again locked here and it will be penetrated like that. One after are connected and penetrated then it will be form a wall and the retain these wall soil or anything can be retained, this side sometime something what are the same, what are the soil this many thing can be possible.

So, these are all different varieties or different categories of retaining earth retaining wall and they are function is to retain the soil and now while designing how much pressure behind that, that our intention to find out. So, next thing is as I have mentioned one type of wall is externally stabilized wall, they are actually gravity cantilever retaining wall, gabion wall, crib wall and all.

(Refer Slide Time: 07:40)



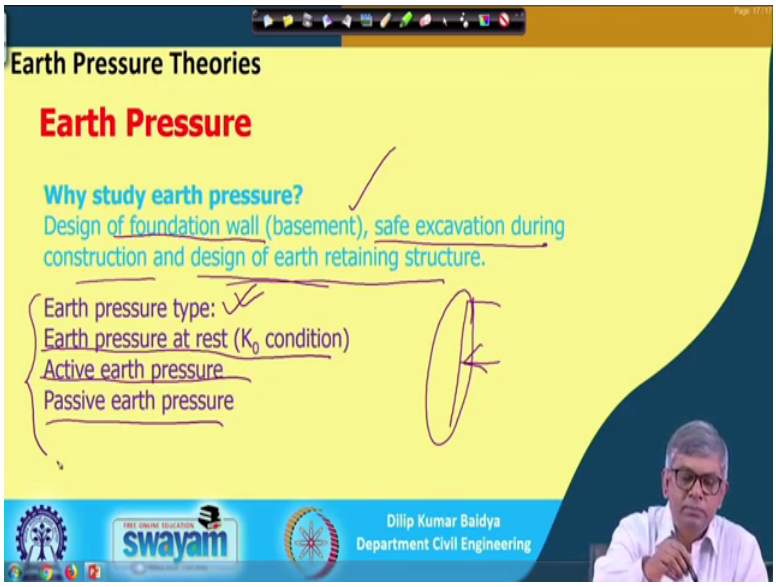
The next type is internally stabilized wall, here actually there will be wall like thing will be there structure will be there, but they are not really walls they are facing element and that facing element will be hold by something else. And actually, what actually in the those on the facing element there will be some reinforcing rod or steep will be connected

and it will be penetrated inside the soil backfield soil. And when it will be done then the facing element will have tendency to move upward and since the facing element connected with the steel rod and steep and then while it will be pulling out from the soil then between the soil and steep or rod then frictional will develop.

So, that because of that friction ultimately this rod will not come out and facing will not, facing element will be there anywhere in the in the position. So, that is the way if you construct a retaining wall that is called internally stabilized system and or sometime it is called reinforced earth wall. And you can see this is the example they are actually facing element these are the facing element, this is facing element, this is facing element each facing element there are some steeps rod are connected and they are inside the soil mass.

When these wall try to move this side and then there will be frictional force will develop in this direction between the soil and rod and this is the way the soil also in the part of the stability of the wall. So, because of that it is called internally stabilized system ok. So, this is actually example is reinforce earth soil, reinforce earth soil nailing both actually soil nailing also can be done, soil nailing is something like this. So, like that you can penetrate and some of field your surface is something like that; so, nail should be penetrated inside the stable zone. So, that when you will try to move then it will have friction actually here and it will finally, help to retain in the position. So, this is one type of retaining wall.

(Refer Slide Time: 09:52)



Now, as I have already mentioned that why study earth pressure, this is the reason is that design of foundation wall; that means, you have to basement safe excavation during construction and design of earth retaining wall. So, there are several application, the design of foundation wall in the basement.

So, they are actually basement wall will have pressure, they are actually you have to pressure calculate then safe excavation during construction. That means, when you excavate then how much depth we can do without support etcetera that is also coming from this and also design of the retaining earth structure. Now the excavation is too high then it will not be, you will not be able to unsupported it cannot be done unsupported. So, when you put support then that on that support how much pressure will come and you have to and based on that you have to design.

So, that is the reason; and now why earth then earth pressure type now. What are the different types of earth pressure? As I have told you that depending upon type of soil type, wall type, the movement type, pressure will change the broadly we divide into three categories; one is earth pressure at rest condition, earth pressure active earth pressure and passive earth pressure. And what are those actually? When the wall retain the soil when wall retain the soil and on that there is no movement of the wall.

So, as it is the pressure is not enough and because of that pressure on the wall discharged that there is no movement at all, that is called at rest condition. So, that is an active earth pressure means what when the wall is standing because of the earth pressure it will have some pressure. And because of this pressure the wall will have tendency to move away from the back field like this, if it is there then it will move like this; when it moves like this, then when it moves like this; obviously, whatever before movement whatever pressure was there if the wall moves away from the backfield; obviously, there will be pressure release; that means, pressure will be reduced.

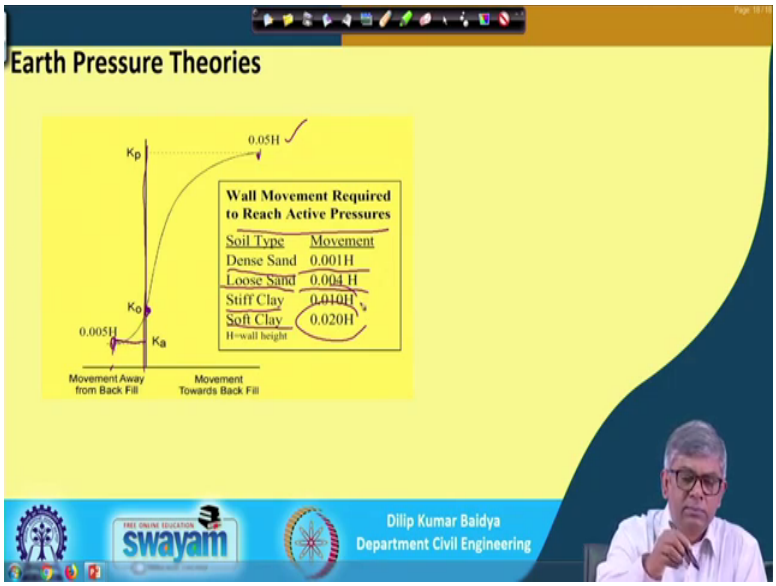
And when it movement will be there will be some limiting movement, up to subways that the with the movement; with the movement of the wall the value will be decreased decrease and finally, it will reach to a minimum value and beyond that it will fail. So, that minimum value what will reach that is called earth pressure at active condition.

So, that is another condition; that means, when wall moves away from the backfield. Similarly when the wall moves towards the backfield that is this can condition because

of several reason the wall can be moved towards back field and when it moves towards the backfield; obviously, when there is no movement whatever pressure was there they are now with movement the pressure will be increasing slowly.

And when movement, little movement the little increased then further movement and further increased and further movement further increased like that, it will reach to a maximum value and if you move further than soil will fail. So, that is actually before failure, whatever maximum value it reach that is called earth pressure at passive conditions. So, that is the three condition we, generally three type of earth pressure we consider.

(Refer Slide Time: 13:24)

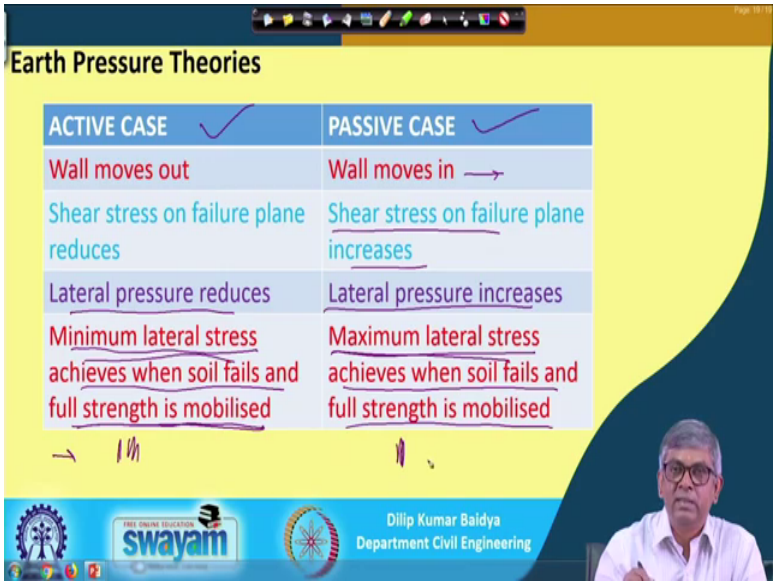


And these three type of earth pressure we can see here that wall movement required to achieve full active or full passive and with the with the movement of the wall and the active and passive case this, with this diagram it is shown. You can see active earth pressure at rest means there is no wall movement wall, this is the wall actually and this is the movement that is active condition. To achieve the full active condition the wall movement this much is required, that is actually what 0.005 times H; that means, to achieve full active condition movement required is 0.005 H where, H is the height of the wall.

Whereas, to achieve full passive condition the wall movement required actually one-tenth of that 0.005 H ten times actually. In fact, ten times; that means, 0.05 H where H is

the thickness height of the wall. So, here actually for wall movement required to reach active pressure actually for different types of soil it is given dense sand actually 0.001 H, this is 0.005 is the maximum and loose sand actually it is 0.004 H, stiff clay 0.010 H soft clay 0.02 H. So, it can go up 0.005, but these are the different types of soil, the movement required to achieve full active case.

(Refer Slide Time: 15:09)



And you can see now the two active case and passive case qualitative difference, this is active case and this is passive case. So, active case actually what happens wall moves away from the back field and passive case wall moves towards back field and moves in and one is moves out. And shear stress on the failure plane reduces; that means, when wall moves away from the backfield then; obviously, shear failure plane shear stress will be reduced whereas, in passive case shear stress failure plane will be increases.

Then third is a lateral pressure reduces; so, shear stress it reduces and same time on the air in the when it is not no movement whatever pressure when the movement then obviously, lateral pressure will be reduced for the active case and lateral pressure will be increases for passive case. And minimum lateral stress and maximum lateral stress; that means, active case with the movement of the wall actually it is decreasing the, but the active case means when it is max minimum value.

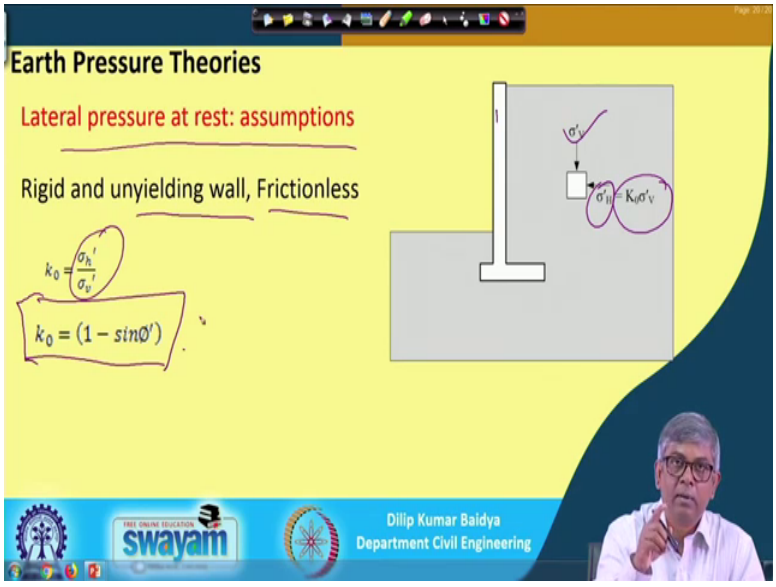
That means, that is a minimum lateral pressure without fail, active case mean minimum lateral pressure without fail before fail and similarly passive case is the maximum value

before failing. So, one is minimum and another is maximum and achieves sorry minimum that is to achieve when soil fails and full strength is mobilized, this is the minimum lateral stress achieved when soil fails and full strength is mobilized whereas, maximum lateral strength is achieved so when soil fails and full strength is mobilized.

So, one more thing actually I have not added until and next I will explain this one. So, we know that at a particular point vertical stress and horizontal stress and they are identical to each other and they are principal stress ok. So, vertical stress in the normal case vertical stress will be more than the lateral stress. So, because of that in vertical stress will be principal stress and horizontal stress will be minor principal stress actually in the active case.

Whereas, passive case that will change, actually vertical become minor and horizontal become majors because it becomes the larger so, that I will discuss once again later on in the appropriate place. But otherwise that is a point can be added here that here actually vertical stress is the major and here actually lateral stress is the pressure is a major principle stress.

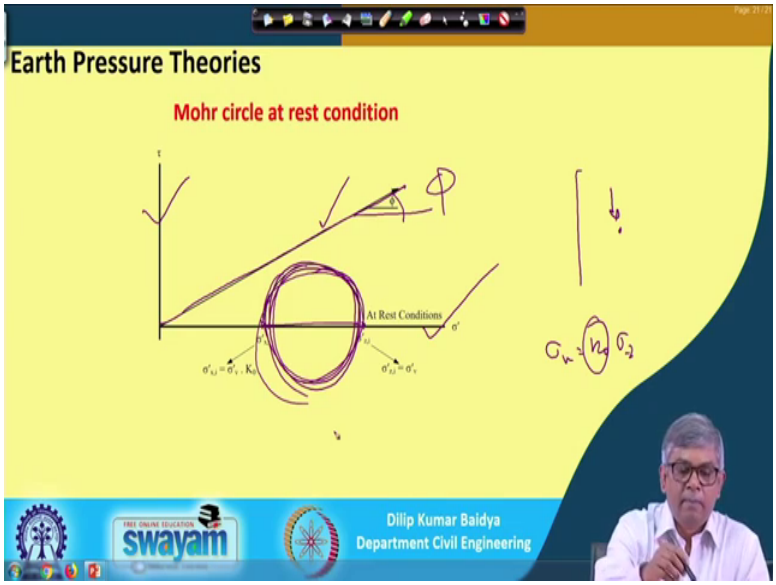
(Refer Slide Time: 17:59)



And you can see here this is the one lateral pressure at rest: assumption, rigid wall and an unyielding wall frictionless rigid. So, this wall is rigid unyielding; that means, not neither move this way not that way and frictionless, if this is the case then K naught actually; that means, if it is sigma v dash here then sigma H will be dash will we K naught times K

v sigma v dash and value of K naught actually ratio of sigma h by sigma v and for this actually there are theories available by which you can find out k naught condition the approximate value of earth pressure coefficient is 1 minus sign phi dash. And so, if we phi is 30 degrees then 1 minus sin 30; that means, whatever value is come ok. So, this is at rest condition.

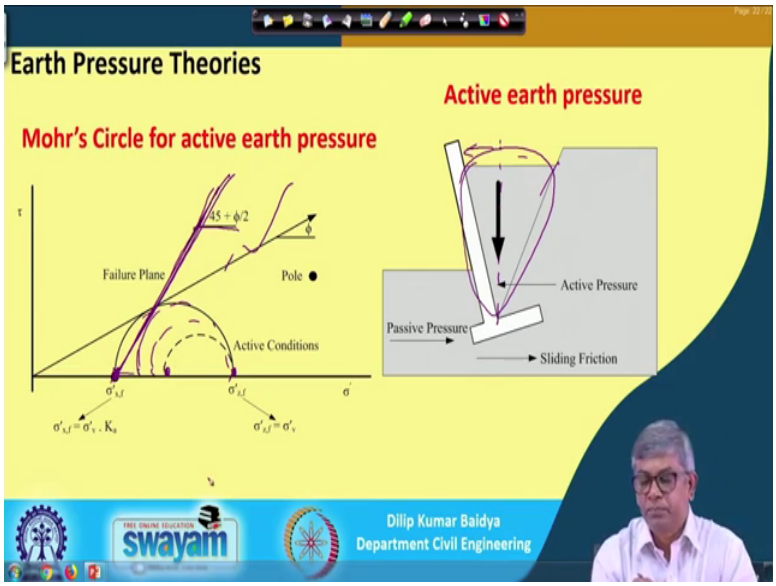
(Refer Slide Time: 19:06)



Similarly, more circle at rest condition how it will be? You can see that tau versus sigma plot if I do tau axis and this is sigma axis and then a particular soil will have a particular failure in below. And this slope of the line will give you the phi of the soil, but if I add at rest condition; that means, is it is a this is sigma z at particular point that this is the wall and I have considered this one and I have calculated sigma z.

So, this is the value of sigma z that is major principal stress, and sigma h actually sigma h will be k naught times sigma z that value definitely since k naught is small. So, it will be smaller and that will be there. So, if I take this is major principal this is minor principal stress; that means, this is the diameter of the circle. Then if I draw a circle then this will be the Mohr circle corresponding to that stress condition, that particular stress condition this is the Mohr circle. And when you draw the Mohr circle for at rest condition that Mohr circle will be much below the failure envelope, that this is the failure envelope, but Mohr circle you can see below the failure envelope it will not touch even.

(Refer Slide Time: 20:30)



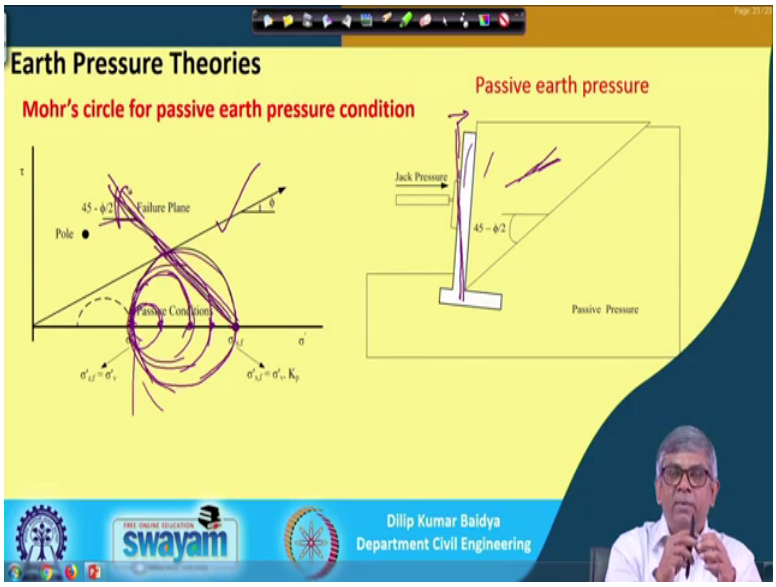
Now, next is actually active earth pressure, actually you can see that as I have mentioned that the wall was initially maybe somewhere here and slowly it is moving this direction. When it moves this way then soil also move and then finally, soil will fail in the form of a wedge like this ok and then when the soil moves like this then what happens the initially sigma z was there and then little movement and the sigma h might have become like this. Even further decrease sigma h may be it may become like this, further decreasing sigma h maybe like this, like that at just at failure sigma h may become like this so; that means, the minimum value of the lateral stress.

So, we if you do; that means, now at a failure condition that when the soil just fail this is the major principle stress and this is a minor principal stress and now; that means, major principles stress minus such as you know that they are in the opposite direction. So, that must be the diameter of the circle. So, with this taking, this taken as a diameter if I complete the circle and if we know the more envelope already for the particular soil and you will see that circle I have drawn will be the tangential to the failure envelope of the soil.

So, this is the one you can see and this is the failure envelope and this is the Mohr circle they are tangential to that. And from this one and to the tangent if I draw this line this gives you the actually failure plane and this is, this failure plane actually what angle it makes with the horizontal it is 45 degrees plus phi by 2. So, these are all actually

observation based on some theories so will show that later on. If this is the phi the failure envelope, a failure plane on the active case will be inclined to horizontal will be 45 degrees plus phi by 2 ok.

(Refer Slide Time: 22:46)



Now, this is suppose a another case; that means, your wall moving with towards the backfield; that means, initially the wall was this vertical and it was rigid and slowly it starts moving this direction.

When it starts moving this direction as I have mentioned that pressure will be increasing and with time will be increasing and then finally, at a particular amount of movement it will soil ways will be moved like this, the entire soil will move like this and will fail. And when it fails actually and then you can see that the initially sigma z was here and when wall moves towards a backfield we know that the pressure will be increasing and initially is our little movement maybe it become this value and further movements the value may be something like this.

So; that means, when it moves here the Mohr circle is this one, when it moves here; that means, Mohr cycle is like this when it suppose further increase the value become sigma lateral will become this then your Mohr circle maybe like this.

And then finally, at failure suppose the value become this much, then this is the minor principal stress and this is the major principle stress. So, that what I have mentioned at

the beginning that during active earth pressure that your vertical stress is the major principle stress and lateral stress is the minor principle stress. Whereas, in passive case your vertical stress is minor principal stress and lateral stress is equal to major principal stress so, that is the thing. So, this is minor and this is major. So, then we know that this is nothing, but the diameter of the Mohr circle. So, if I complete the Mohr circle now this is a Mohr circle and if you see that finally, that Mohr circle become tangential to the envelope ok.

So, this is the failure envelope phi and so, if I now join with this is the major principle stress from the major principle stress to this envelope if I extend, in intersect then that will give you actually your failure plane. So, major to the failure envelope that if you connect that become the failure plane and that failure plane you can see that it is making an angle with horizontal 45 degrees minus phi by 2.

So, these angle actually so; that means, that when your wall moves away from the backfield when it show the failure plane that failure plane will be 45 degrees plus phi by 2 with horizontal. And when a passive case that when wall moves towards backfield then when soil will fail at an angle 45 degrees minus phi by 2 that is one thing. One is 45 degrees plus phi by 2 another is this 45 degrees minus phi by 2, these are the two important observation.

Second observation is that in the active case your in active case your vertical stress is the major principle stress and lateral stress is the minor principle stress. Whereas, in passive case your vertical stress is the minor principle stress and your lateral stress is the major principle stress. So, two important things to be remembered, actually these are all sometimes small question to be there and we have to be very careful.

So; that means and every time another three important things to be noted that at rest condition your Mohr circle will be much below the envelope whereas, in active and passive case both the cases your a failure envelope or Mohr circle will be tangential; Mohr circle will be tangential to the failure envelope and below and these are the things to be noted.

So, these are all qualitative; that means, what is active case, what is passive case, what is active at rest condition? These are qualitative information I have given you and now another qualitative information that active earth pressure actually pressure will be in

between and active case will be; active case will be minimum then at rest condition and passive condition is a maximum and at rest condition pressure is in between ok. It is not average, but some value between this; so, that I have shown in the diagram.

So, two three things to be noted that active pressure will be minimum value, passive pressure is the maximum value at rest condition in between some value. And for active case wall movement from the away from the wall and for the passive case wall movement towards the wall and then active at rest condition failure envelope will be below the envelope Mohr circle will be below the envelope whereas, active and passive case will be both will be tangential.

And so, an active case your failure plane will be 45 degrees plus, but 45 degrees plus phi by 2 with horizontal whereas, at passive case the failure plane will be 45 degrees plus phi by 2 with horizontal. So, these are the important things has to be kept in mind. So, these are all qualitative now, what is active, what is passive, what is at rest condition. Now we have to find out if it is active case what will be the value of the active pressure or active thrust on the wall or what is the active passive pressure or passive thrust on the wall that has to be quantified so that I will do in the next module.

Thank you.