Geology and Soil Mechanics
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Lecture - 50
Earth Pressure on Retaining wall

Welcome to the course Geology and Soil Mechanics. So, in the last couple of lectures we solved few problems on the shear strength of soil. So, today we will be starting the new chapter that is earth pressure theory on the retaining wall or any kind of structure which is retaining some soil on the other side okay. So, this kind of structure is very common in practice. So, you know I mean slope stability or retaining structure or embankment or any kind of say any structure which is creating or which is dumping a mass of soil. So, that will basically need to understand the pressure exerted on the on any kind of plane okay.

So, suppose you might have seen that water waterfront structure or some retaining structure so on one side you have nothing actually I mean you have some other structure like your road or any kind of say built up area but on the other side okay on one side you have this kind of say structure like road or highway or embankment or any kind of say civil engineering structure and on the other side it is retaining the soil okay. So, this kind of structure will be experiencing some pressure exerted by the soil mass basically which is retained by this wall okay.

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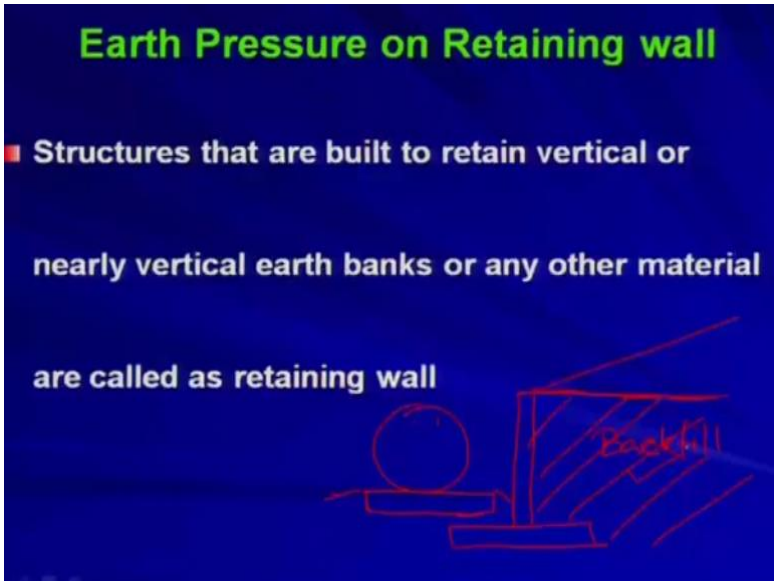

So, structures that are built to retain vertical or nearly vertical earth banks or any other material are called as retaining wall. So, that means you might have seen I mean this is very common in

say hilly terrain or hilly road if you travel by any kind of hilly hill station or something like that you will be seeing on one side you will be having the mountain or the hill slope and that is retained by some wall concrete wall or masonry wall or maybe rock masonry wall any kind of I mean this kind of wall right.

To know the stability of this wall or to understand the stability of this wall you need to know the concept of earth pressure which is a very important okay phenomena in soil mechanics. Suppose I mean you might have seen say suppose this kind of wall you have okay and on one side you have the soil. So, this is known as backfill and on another side, you may have road okay or maybe other structure any kind of civil engineering structure which will be coming on this side on this side but this side will be filled with soil okay.

So, this soil this filled up soil is known as backfill and this soil is retained by this wall so that is why this wall is known as retaining wall and now this slope could be vertical backfill I mean vertical that means horizontal surface. This surface maybe horizontal or maybe inclined okay. So, whatever maybe the case the wall is supposed to carry the pressure which is exerted by this backfill soil. Now we need to understand how much pressure it will exert on the wall okay. So, there are different conditions at which you will be getting the pressure on the wall. So, what are the different conditions?

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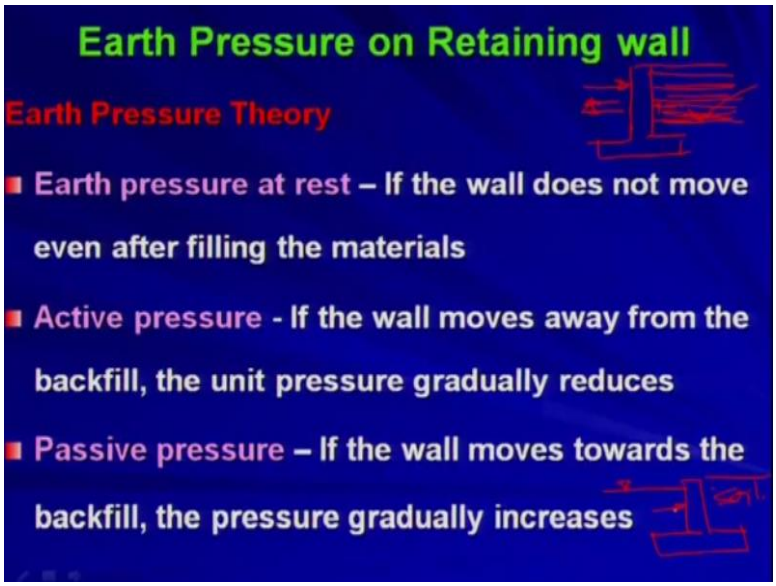

First one is earth pressure at rest. So, whenever we are talking about earth pressure basically earth pressure is nothing but the lateral pressure okay and already we have seen in the previous

say drawing that you have the retaining wall and on one side on one side you have the built-up area or any other civil engineering structure and another side you will be having the backfill.

Now this backfill due to this vertical pressure it will exert some horizontal pressure and we will see I mean why this horizontal pressure is actually coming into the picture I mean how it is coming into the picture. So, some horizontal pressure will be exerted on the wall retaining wall. This horizontal pressure is known as earth pressure and we need to understand the earth pressure the determination of earth pressure at different conditions.

For example, first one is earth pressure at rest. Now if the wall does not move even after filling the material. That means when first what is the procedure? First, we construct the wall. So, this is the wall we construct say it could be concrete wall it could be RCC wall or maybe rock masonry wall or maybe brick wall depending on the situation you can go for different kinds of wall. Now this wall will be constructed first and then we fill the soil and we compact this soil to the desired strength and that is why it is known as backfill. That means you are filling it back okay.

So, if the wall does not move. Now you are filling it I mean you are making the backfill on the other side of the wall. Now if the wall does not move even after filling the materials that means even after filling the backfill material if the wall does not move that means whatever wall was constructed generally what is the tendency that you fill the material wall will try to move or try to slide from the original location to the other side right.

But if the wall does not move that condition is known as at that time whatever pressure is exerted by the soil by the backfill soil on the wall will be known as earth pressure at rest condition okay. Now the second condition is active pressure. If the wall moves away from the backfill the unit pressure gradually reduces. That means in this situation if the wall moves in this direction due to the backfill that means you are filling it you are compacting it and due to that whatever pressure is exerted on the wall okay so this is the pressure exerted on the wall and due to that pressure if the wall starts moving away from the backfill then that condition is known as active condition and at that time whatever pressure will be exerted on the wall that will be known as active pressure.

Pressure means earth pressure as I told you that active pressure or earth pressure at rest whatever we are talking about that is nothing but the lateral pressure okay the pressure on the wall that means horizontal pressure on the wall okay. Now similarly obviously there could be another

condition where the wall moves towards the backfill. Now that is known as passive pressure so in passive pressure if the wall moves towards the backfill the pressure gradually increases.

That means in case of active state what happened that wall starts moving away from the backfill so therefore pressure is getting released the pressure I mean whatever pressure was there at rest condition slowly or gradually it will be released or it will be decreased okay and to get the active state but in case of passive state wall is moving in this direction. That means wall is moving towards the backfill that means you are pushing the wall towards the backfill.

So, therefore your pressure will be increasing okay further from the rest condition whatever you had the pressure at rest condition your pressure will be further increasing at active state. Now what kind of I mean condition or what kind of situation will cause this kind of passive pressure? Suppose you have the retaining wall okay or other on other side you have the soil that is your backfill now you this retaining wall is retaining some water okay.

This is some waterfront structure say for example. Now this water pressure will try to push this wall towards the backfill am I right. So, this pressure due to the wave or due to any kind of static hydrostatic pressure you will be getting some static pressure on the wall which will try to move the wall towards the backfill and at that time your pressure whatever pressure will be generated or exerted on the wall lateral pressure that is known as your passive pressure right.

So, these are 3 conditions, one is earth pressure at rest condition when there is no movement of the wall, wall is stationary; when the wall is moving away from the backfill at that time you will be getting active condition that at that time whatever pressure will be exerted on the wall that will be active pressure; and when the wall will be moving towards the backfill at that time that condition is known passive condition and the pressure will be the passive pressure. So, these 3 conditions we will be analyzing separately and we will be trying to find out or we will be trying to express the or determine the expressions to find out the pressures at different conditions okay.

Now let us go (()) (09:50)

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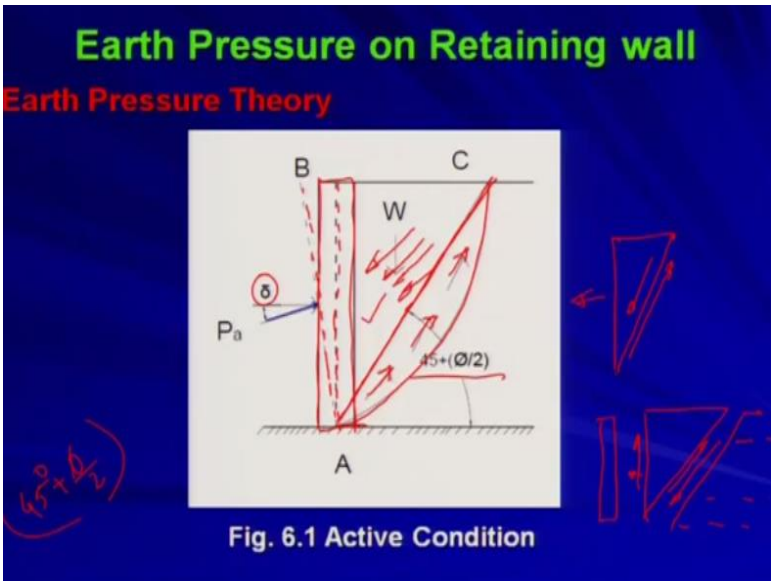

Now as I told you in the active condition you see this is the wall say AB is the wall so this is your wall okay. Now this is the center line of the wall as shown here. Now this wall if the wall is moving so there are several other several kinds of movement. Now this movement whatever is shown this movement is rotation with respect to the base. This is the center line after movement. So, this is the wall. Now it can move like this that means rotation with respect to the base.

It can move like this rotation with respect to the top or it can slide simply the whole thing is moving in the horizontal direction. So, any kind of movement will give you the active state or active pressure generation okay. So, due to this movement basically what will happen? Soil will try to move. This backfill soil will try to move in this direction. So, this is the direction of movement of the backfill soil right but soil resistance will try to resist that movement.

So, that is why you will be say this is the say failure surface you are getting actual failure surface will be curved one this is the failure surface but to idealize the problem we will be solving with respect to this failure surface that is the linear failure surface which will be making a triangular wedge right triangular failure block. So, this block so ABC this block will try to move along with the wall and the soil pressure or soil resistance what it will do it will try to resist that kind of movement okay.

That means this is the wedge, this is the triangular wedge. It will try to move in this direction. So, therefore this is the direction of movement and you will be getting the resistance which will be developed at the failure surface and this resistance is nothing but your shear resistance right as

we discussed in the last chapter that every resistance which will be which you generally get from the soil so that resistance is generally based on the shear resistance right.

So, this resistance will be developed and slowly gradually it will mobilize and when the complete mobilization of the shear strength is done then the wedge will move along with the wall right. So, this is the phenomena so that is why whatever pressure so now basically I mean if you look at the wall this is the wall this is the backfill wedge which is filling and this is the soil at rest condition right.

So, you will these are I mean free bodies now if you try to show the resistance so it will try to move in this direction move towards the wall so it will try to move in this direction so the resistance will be in this direction whereas the resistance on the soil which is under rest condition that will be like this okay. Similarly, the wall if you consider the wall is perfectly rough that means there is no slippage between the wall and the backfill wedge then the whole thing will be moving together.

If you consider the slippage that means the wall is not perfectly rough, it is partially rough that means some smoothness is there so therefore this wedge and this wall I mean that at the interface you will be having some relative movement right. So, the wall will be moving like this and wedge will be moving like this. So, there will be another resistance which will be acting on this side right. So, this is the free body diagram or this is the kind of mechanism okay which is happening during active earth pressure condition.

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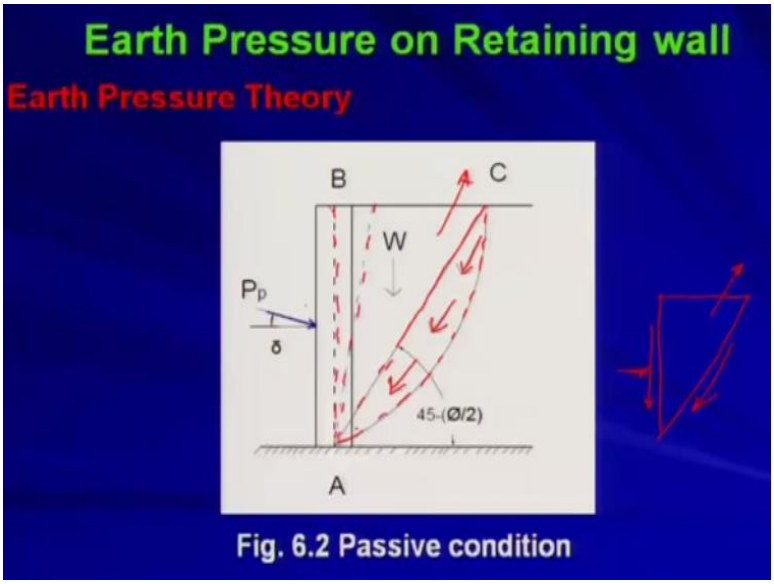

Similarly, in case of passive what I told that the wall is moving towards the backfill. So, this is the wall center line now this is the center line so that means similar way so you can have the rotation with respect to base, you can have the rotation with respect to top, and you can have the complete (()) (14:26) movement towards the backfill and due to that you will be getting the failure surface because failure surface means at the extreme point when the complete shear mobilization happen say complete shear strength is mobilized at that time you will be getting the failure that is on the verge of failure right.

So, when you push that and if you get if you reach the failure condition then basically your resistance shear resistance will be developed along this, this is the actual failure surface which generally develops but it can be idealized with say linear failure surface and now this wedge will try to move in this direction right. So, your shear resistance will be acting in this direction right. So, that means this is the wedge okay. You are pushing this wedge. It will try to move in the upward direction. This is the say directional movement.

So, you will be getting the shear resistance which will be developed at the surface at the interface like this and so this is moving in this direction so basically you will be getting the free body diagram of this wedge like this right. So, this these are the things we are going to analyze and we are going to obtain how we can quantify this pressure earth pressure at rest, earth pressure at active condition, earth pressure at passive condition. Now one more thing I would like to tell you that in this previous figure in the active condition generally it has been seen that this angle this failure surface angle or the failure surface which will be making an angle 45 + phi by 2 okay 45 degree + phi by 2 with the horizontal and it is not arbitrary.

Why it is like that we will be coming to that point later on. It depends on your Mohr circle representation and the shear line right. It is not arbitrary. Now this delta this angle is nothing but the angle of internal friction or angle of interface friction rather so that is the friction between wall and soil okay. So, if delta is equal to phi that means it is completely rough condition. If delta is 0 the wall is completely smooth condition. So, why I am calling smooth and rough. Now suppose you are talking about concrete wall which is having some rough surface. Now that surface is touching the soil on the other side that means on the backfill side.

Now that surface whatever shear resistance it will provide it will not be it may not be same if you provide some steel smooth steel, steel wall and that interface whatever resistance or whatever interface friction you will be getting that may not be same right. So, the steel wall will be acting

more like as a smooth wall. That means you do not have any kind of roughness at the interface whereas the concrete wall will provide some roughness and because of that you will be getting different values of delta and because of that you will be getting the angle if delta is 0 basically P a the if the wall is smooth then P a will be completely horizontal. If delta is not 0 then you will be having the P a which is inclined with the horizontal. Similarly, similar situation happens for passive pressure also.

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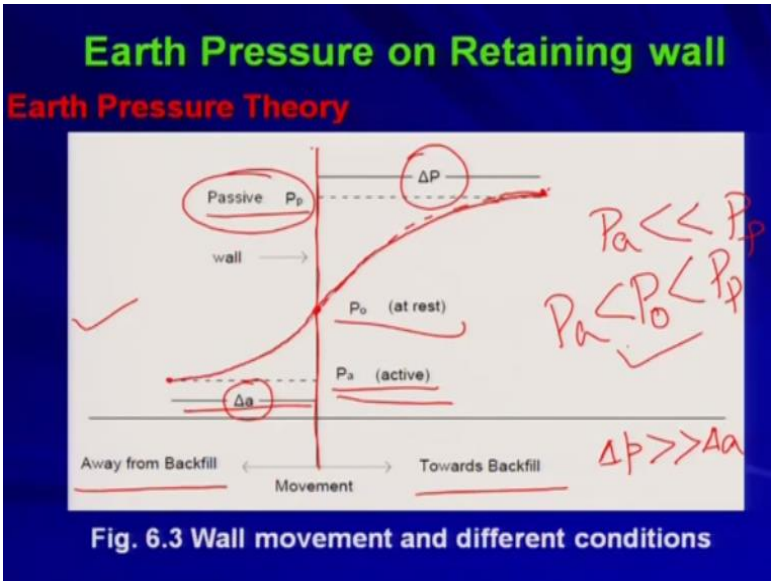

Fig. 6.3 Wall movement and different conditions

Now based on the wall movement we can have and we can see the different condition. So, suppose this is the wall okay this is the wall and at rest condition you are getting say P 0. At rest condition say pressure is P 0 okay total pressure is P 0. Now as I told you if the wall moves away from the backfill, moves away from the backfill, so this is this side is backfill say. This side is free. So, if the wall is moving away from the backfill so gradually your pressure is decreasing and at ultimate state you will be getting the active pressure that is P a and at that time this is the movement delta a is the movement required to get the active pressure.

So, what you are getting at rest condition this is the pressure and gradually you are moving the wall away from the backfill so gradually or slowly your shear strength is getting mobilized and at the ultimate state your when the shear strength is completely mobilized at that time whatever pressure you are getting that is your active pressure P a and to obtain this P a you need to have this much of wall movement away from the backfill. Similarly, if you start from the rest

condition and if you start pushing the wall so basically your earth pressure at I mean passive condition is going on increasing gradually increasing as I told u right.

Passive pressure will be gradually increasing and at the ultimate state you will be getting the ultimate passive pressure and that pressure is known as P p okay and to obtain P p you need to have this much of displacement delta P which is very greater than so delta P is very greater than delta a okay. That means you need to exhaust I mean a significant amount of displacement or the movement to get the passive pressure whereas at a very slow amount of or very less amount of movement of the wall away from the away from the backfill will cause the active state.

So, now this curve this S curve will define that how the pressure is getting built up right. So, this is the earth pressure at rest if you gradually start moving the wall away from the backfill so pressure will be decreasing and ultimately it will reach the active pressure. If the wall is moving towards the backfill then the pressure will be gradually increasing and ultimately it will reach the passive pressure.

I hope that you have understood. So, this is towards the backfill this is away from the backfill. So, in this movement in this process basically you will be getting the active pressure rest and passive pressure. So, from this figure it is very clear that P a is very less than P p right. The active pressure is very less than passive pressure and the P 0 say at rest condition P 0 is in between. So, P a is less than P 0 less than P p right so as you have seen here and now we are going to quantify this.

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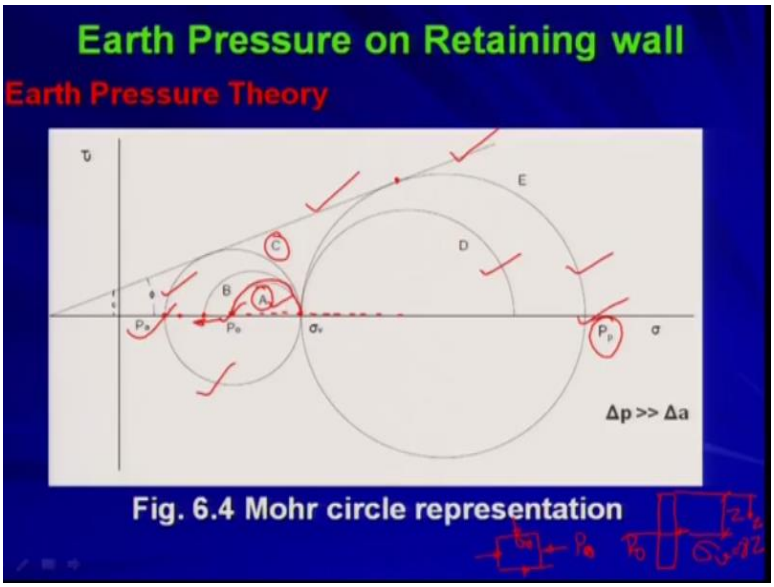

Now to understand this phenomena we need to see the Mohr circle representation. Now this is the Mohr circle representation. What is happening here? Now at any situation say at rest condition okay this is the rest condition we are considering and this is nothing but by sigma v. Now what is the sigma v? That is the vertical stress on any so if this is my wall so at and say this is the z direction at any depth z okay I can calculate sigma v that is the vertical stress.

What is that vertical stress gamma into z gamma where gamma is the unit weight of the soil and z is the depth right. So, sigma v if I consider and at that time at that location okay at which is z distance below the ground surface at that location if I want to find out the earth pressure at rest condition okay then say at that location I am getting say P 0. This is my earth pressure at rest condition.

So, this surface if I consider this surface so this surface is free from initial stress so that gamma z that is sigma v is nothing but the principle stress okay so that is nothing but the principle stress and that principle stress is causing this P 0. Therefore P 0 I mean this surface so if I if I consider a block soil block like this so this is your sigma v and this is your P 0 right. So, sigma v is nothing but gamma z that is your major principle stress because that is the action and due to that you are getting P 0 which is another principle stress which is nothing but the minor principle stress.

So, now if I want to show this is on in the Mohr circle representation so it will look like this. So, circle A so circle A this circle will be representing that condition that earth pressure at rest condition. Now wall is gradually moving away from the backfill. Now what will happen? Your gamma sigma v will be remaining same that is your major principle stress will be remaining same is it not? The major principle stress will be remaining same. Only thing is that you are gradually it is moving away from the backfill so the lateral pressure will be decreasing.

If the lateral pressure is decreasing that means your sigma 3 that is the minor principle stress is decreasing. So, minor principle stress is gradually decreasing right. So, from A you are getting circle B and at the ultimate state you are getting circle C. So, this is nothing but this circle okay. So, this circle will be telling you about the state of stress at active condition and at that time this point will be giving you the minor principle stress at active condition which is eventually P a which is nothing but P a right active earth pressure.

So, I hope that you have understood. So, this is your starting circle starting Mohr circle A that is earth pressure at rest condition. Gradually wall is moving away from the backfill. So, this sigma

v is remaining same because you are considering at a particular depth z so there is no question of changing sigma v. So, only change is happening in the lateral pressure and which is nothing but your sigma 3 and nothing but this point basically.

So, this point is gradually moving in this direction and ultimately it will be coming at this location where the Mohr circle will be touching the Mohr-Coulomb failure envelope okay. So, this is your active pressure circle. So, this circle, circle C is nothing but your active pressure circle. From this circle you will be getting the information about the active pressure. Now I am going to the passive state. So, in the passive state what we are doing? We are pushing the wall towards the backfill.

Still your vertical stress sigma v will be same that is completely unchanged right gamma z is completely unchanged you are not changing the depth. So, gamma z will be remaining there only thing is that you are pushing so that means you are increasing the pressure. So, from P 0 it will move in this direction so and so in the process you will be getting say circle D and finally you will be getting circle E which will be giving you the passive pressure P p which is touching the Mohr circle sorry Mohr-Coulomb failure envelope at this point okay. So, this is your P p this is your P 0 and this is your P a okay.

So, this is the Mohr circle representation of the active and passive pressure as well as earth pressure at rest condition. So, I will stop here today. In the next lecture, we will be talking about the expression of the active and passive earth pressure coefficients. Thank you very much.