Ground Improvement
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Lecture 54
Geosynthetics in Ground Improvement (Contd.)

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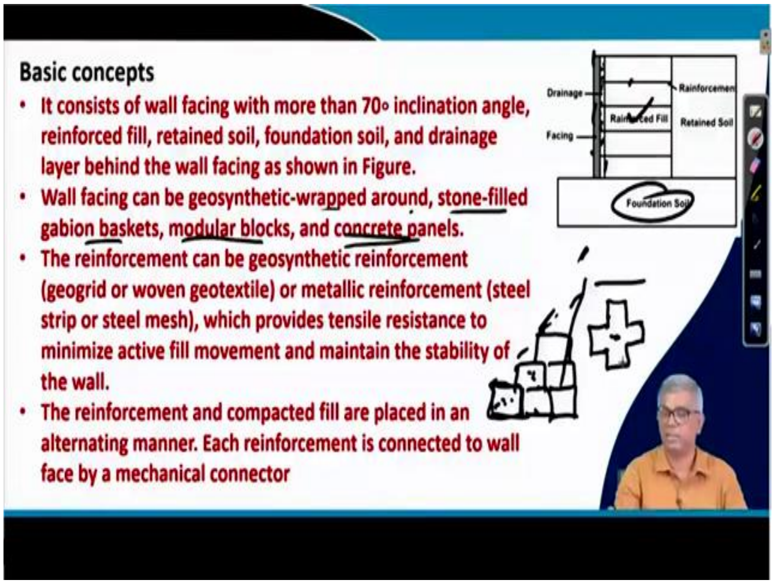

It will only provide to the falling of the soil actually it is only supporting the soil but it is not taking much force on the on the on this wall. So, what happens this is so, these consist of facing and that facing nearly vertical. It is about 70maximum 10 or 20degrees inclinations and the inclination will be like this towards backfill it will be little inclined.

This is the one so, facing will be with some 70 degrees inclination and reinforced field. This is called reinforced field and then there will be foundation soil and then the drainage layer, this is the drainage layer actually, this is the drainage layer behind the wall and so, all those things so, here and this actually retained soil finally.

The MSE wall, part of this foundation facing element drainage layer, this is reinforcement and the reinforced field. These are the different components in the MSE wall and wall facing can be geosynthetics wrapped around or it can be stone-filled gabion basket or it can be modular blocks and concrete panels.

Whenever you travel on the highways wherever there will be overpass and we will see that, that approach to the main crossing that some portion will be both sides, there will be a nearly vertical wall will be there and those vertical wall will have different designs. Those designs actually prefabricated and they are facing element. Most common facing element we use, the plus sign, many places we will see like this. So, it will be like that.

And a number of these actually connect, will connect each other to form this type of wall. And this facing element will have connection with the reinforcement which will be laid inside. And in between or soil filling will be there. So that is the one, so this is one that means concrete panels like this can be they are, modular blocks; there are some other blocks actually can be locked each other and one after another can be locked and wall can be form.

gabion basket; gabion basket means actually by wire mesh, we can make a like a big basket and inside there will be stone-filled and that is a one actually one gabion basket will be several ton rate and like that if there is a place somewhere here and we can put one gabion basket like this and then we can put gabion baskets like this, next layer gabion basket maybe like this, next layer gabion basket like this, so like this will make a wall like this.

So, these are all gabion baskets This is through wire mesh inside that we stone, that is actually gabion wall it is called, it is quite flexible hilly areas they are very much useful. That is also sort of gabion walls can be used for MSE wall and then geosynthetic wrapped around whatever I have shown the in the slope, that previous lecture, that wrapped around, the reinforcement will be late and then it will be wrapped like this.

Then again, soil will be, one layer will be laid then soil will be filled then it will be wrapped around and then like that mild slope wall can be made. So, those are all are comes under mechanically stabilized earth wall. Wall facing can be geosynthetics, this facing can be geosynthetic wrapped around stone field gabion basket modular blocks or concrete panels like this. So, these are the different types of facing elements can be there.

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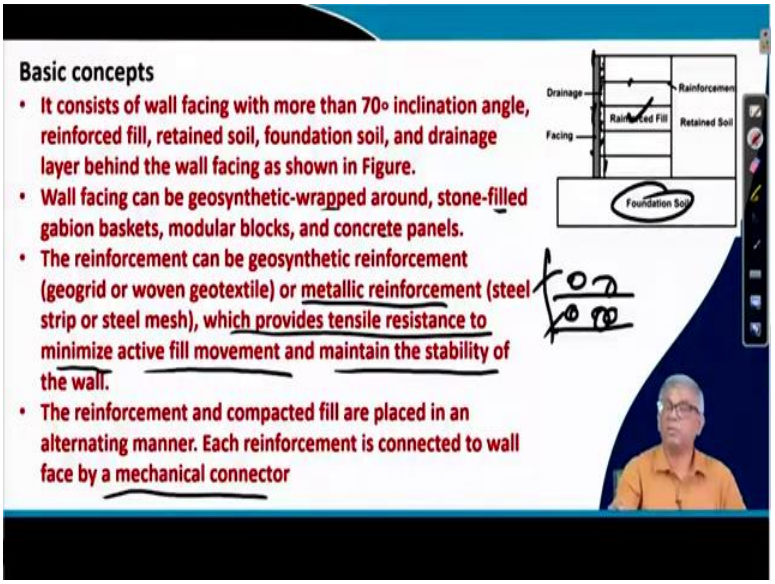

Next, is the reinforcement can be geosynthetic reinforcement, geogrid or geotextile. Whatever we are giving it can geo-textile or metallic reinforcement, sometimes, we can use steel metallic bar or metallic strip that can be used, this can be metallic strip will laid horizontally and that will have friction between the soil and the metal strip that will give the stability. And which provides the tensile resistance to minimize active field movement and maintain the stability of the wall.

These are the different types of reinforcement whatever is mentioned here and reinforcement and compacted fill are placed in alternate back that means reinforcement then fill then involvement then fill and they are connected ofcourse otherwise it will fall. Each reinforcement is connected to the wall faced by a mechanical connector. There will be some connecting, there will be some mechanism by which it is connected.

This is actually basic part or component of the MSE wall and how it works also briefly I could mention because the wall, because when the loading will be there it will try to have, will have tendency to move this direction, when this information will also receive, to come out and fill both side and the reinforcement will have the friction. Because of that, it will have some frictional resistance, these directions.

Pulling this side and this side they will be balancing, that is the mechanism in the stability of the MSE wall. Let me go to the next slide.

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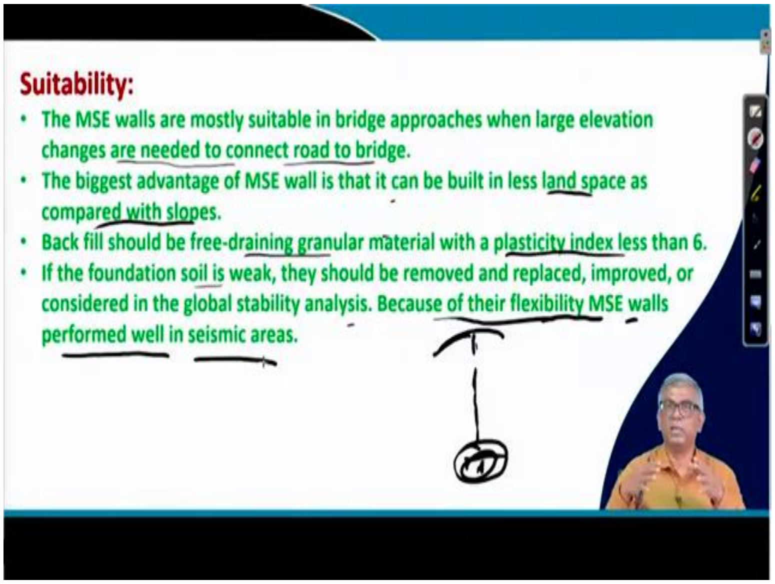

So, suitability MSE wall are mostly suitable in bridge approaches, as I have mentioned wherever there is a bridge, will be that, why we make bridge; because we may have underpass. So, the bridge will be at some height and actual road is in some level. To connect the bridge and to the road there will be sloping ground and that sloping ground, now that means there will be wall of varying height, up to the bridge can be made.

That is actually, can be made by MSE well. Most of the places now all bridge approaches are MSE wall. Particularly, if the height is more than 2meter, 1.5meter, 2meter the MSE wall will be more economical. And while large elevation changes are needed to connect road and bridge, so that is what road is suppose at level 100 and bridge is of 108, so that means the level difference is 8meter.

That 6meter actually change that wall the maximum height of the wall will be 8meter, somewhere it will be zero and it will start increasing slowly. So that is our application. Then biggest advantage of MSE wall that it can be built in less land space, as compared with slopes. Actually, the road map approach if I make a sloping embankment, then the land space required actually much more than MSE wall that is a biggest advantage.

And backfill should be free, right, that is a you can say drawback of it, but as suitability I mentioned that where when you use the MSE wall, that your backfield should be free running most of the backfill should be granular actually we have discussed in soil mechanism foundation engineering.

In addition to that MSE wall it is must, because that should be have enough friction that friction development between development of friction between the reinforcement and the soil material that is important which actually stabilize the system. So, because of that, free running granular material is required because free grinding is required because if there is a water logging that water pressure will be additional pressure which is not taken into concern in the design.

So, that may create some instability of the wall and if I use some fine material, then plasticity index would be less than that is a requirement. Other than that, if I use then it will be ineffective. If the foundation soil is weak, suppose the MSE wall will start like this from here then that means the wall, foundation will be somewhere here and if this soil is not good, and then if the soil because of this weight, it settles, then this wall also will not be stable. It will either fall this side or fall like this side, either way it will happen.

Because of that, if there is a weak foundation soil, then it has to removed, have to be compacted and it will prepare for this type of wall foundation. That is the requirement. If the foundation soil is weak, they should be removed and replaced improved all considered in the global stability analysis that means, there will be sliding through that, that also to be include because of their flexibility another important that MSE wall is a little flexible.

And because of that even because of some hard work loading also because of the flexible nature, it can sustain actually that quick loading. Because of that it is because of their flexibility MSE walls performed well in seismic areas, when there is a seismic prone area, this is actually sometimes better, it is economical most people are using, when there is a seismic area, when you use retaining conventional retaining wall, we have to take additional precautions.

Because of extra load you have to provide more thickness etc. Here actually that is not required. Because he flexibility sometime it is a good.

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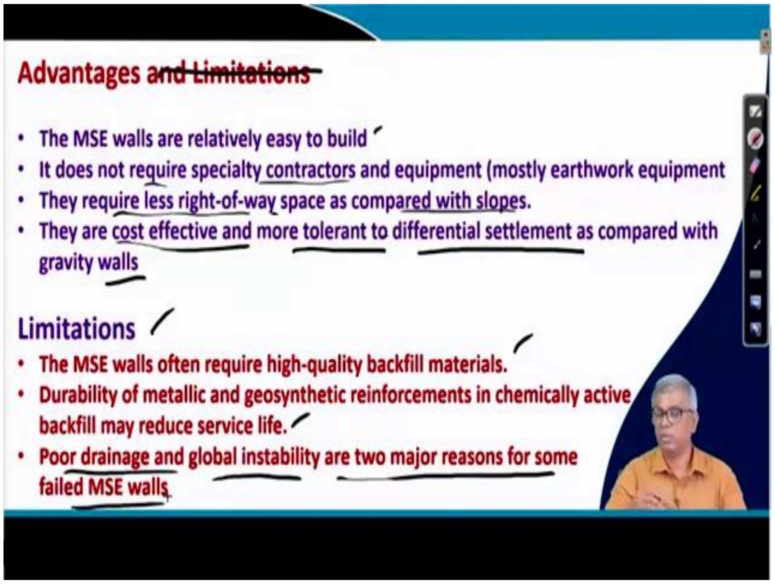

Then advantages and limitations, both should not be there. This is first; 3-4 actually advantages, what is that; the MSE walls are relatively easy to build, does not require specialty contractors and equipment, not much special equipments required, they require less right away space as compared with slopes. Already we have mentioned, they are cost effective and more tolerant to differential settlement as compared with gravity walls.

So, these are the major advantage why we go for mechanically stabilized earth wall, economic is a, economy is the biggest advantage in addition to that, the flexible, it is easy to construct and no special contractors or equipments is required and land requirement is less because it goes almost verticle.

And limitations; all the limitations are MSE walls often require high quality backfill, as I have mentioned that it should have plasticity index less than 6 and all. That is actually some requirement it has to fulfill. Durability of metallic and geosynthetics reinforcement chemically active backfill may reduce service life. If there will chemically active, so metallic strip will be used then it may erode and life will be reduced that is all, that has to be, that is that one limitations.

And poor drainage and global instability are two major reasons for more failed MSE wall. So, sometimes we know that drainage has to be provided, any proper drainage is not provided during construction. So that also sometimes (flaws) cause some problem and global stability also cause problems. This sometime create problems so, it has to be careful about that proper analysis has to be carried out and proper drainage has to be provided.

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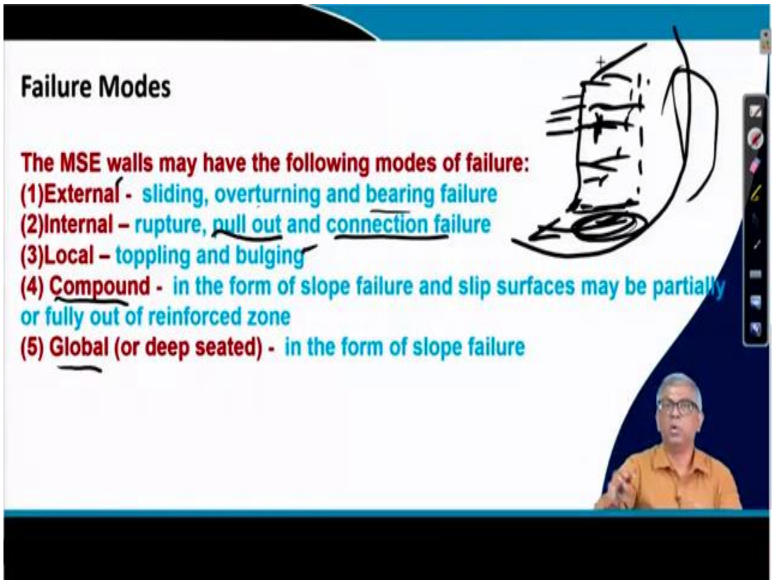

Now here actually failure modes like different other topics we have discussed like nail or anchors, they are also we had some nail means that our enforcement only because it is anchoring somewhere or remaining portion it is intention. So, here also soil and reinforcement that they are working together to provide the stability.

But it may become means unstable and what are the different, unstable means failure and what are the different ways the mechanical stabilize earth wall can fail; there are number of them. You can see the MSE wall can fail, external failure external failure can happen by suppose this is our mechanically stimulated earth wall well this is mechanical stabilize earth wall, it can fail by sliding that means, up to this reinforcement is provided and behind there is soil.

Because of the soil pressure and whatever resistance provided through the base may not be enough then enter reinforce wall can slide so, that is actually external failure. Similarly, if there is a because of these with respect to these if the moment is more then sometimes it may overturn, the entire reinforced soil system that has a blog can overturn that is also can help that is also external failure.

And bearing failure; whatever loading is their surcharges etc., and based on that you can find out the pressure at the base and if that pressure exceeds the bearing capacity of the soil, then also the entire wall may fail. That is also bearing capacity, these are all external failure. Whatever I have mentioned, sliding, overturning and bearing capacity failure they are all external failure.

Similarly, internal failure; internal failure means what? Actually, rupture can happen that means, the reinforcement can break okay, see if 2-3 reinforcement breaks then this because of this weight of the soil, this element will come out and they are only connected each other but slowly it will become loose and it will fall. Many places it happens so, rupturing of the reinforcement pull out sometimes entire reinforcement.

So, enough friction between the soil and enforcement may not occur because of that if the too much of loading, then it can come like this. It is pull out and similarly connection failure as we have mentioned that reinforcement and the wall facing element will have some connection arrangement, if that connection also failed that also comes under all internal failure.

So, what is that? Rupture, pull out and connection failure they are all internal failure. Then local failure actually I will show the figure also, local failure means it can be toppling that means one or two blocks may topple or sometime because of some insufficient compaction or during construction heavy rain or some other reason, sometimes there will be localized bulging and once bulging happens then finally, the panel may come out.

So, that will also create the problem. So, toppling and bulging become some of the local failure and some compound failure actually; sometime in the form of slope failures. These are the reinforcement and your failure surface maybe going out of that. I will be discussed that. That is actually compound failure can be there and there can be global failure.

Global failure means, there will be, so this is the wall, it may fail, failure surface from her like that entire thing like a as a slope way slide for that is global failure. We will discuss all those things one by, next slide we will have detail sketch for each and every one we can see here.

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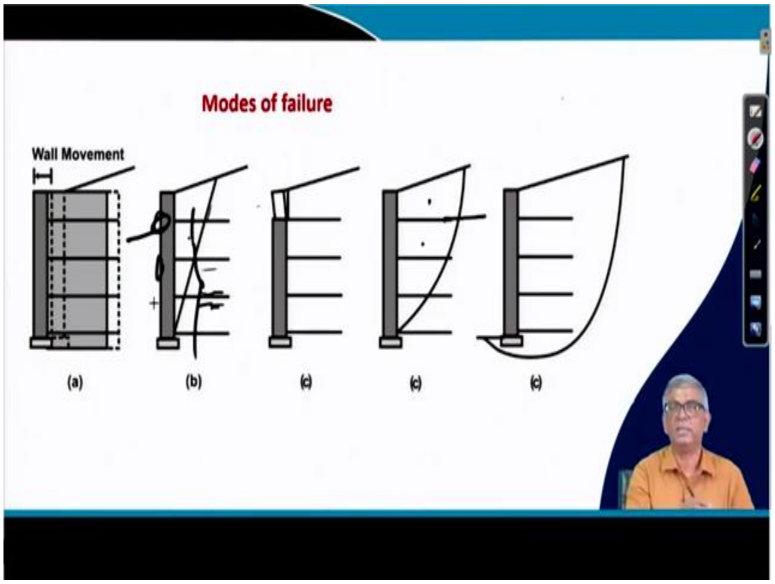

So, these are actually shown, your external failure you can see the sliding, the dotted original position was suppose the dotted and then because of sliding it is moved this direction that is sliding. And this is suppose your overturning can happen also and bearing capacity also failure can happen also. This is actually local that is toppling and then this is actually compound failure that means the sometimes you have provided enforcement.

Actually, reinforcement should be provided this is actually, when actually mechanically stabilized earth wall will form two zone; one is called active zone, another is called stable zone. Active zone actually moves away from the back and stable zone means were actually used in wide reinforcement where actually the fictional resistance will develop.

But you can see if you provide enforcement like this and below surface is here then it is a combined failure, because it is not provided here actually. Even is provided here then you have not failed and as I have shown in the previous slide that global failure that is somewhere else actually there, we plane from there it may failure surface may develop like this then entire thing like a it will slide that is also a global failure.

And here actually second level I have told rupture and all know, here actually reinforcement is provided this is the failure surface suppose and beyond that it is provided. Whatever frictional is develop and whatever pressure is coming there so, because of that, it will have some amount of tension. If that, because of that tension is more than the tensile capacity or the reinforcement then it may fail like that, it may fail like this.

That is one type of thing then because of the heavy load entire thing may come out and slide interpret that is pull out and then at the connection may fail that is connection failure. So, these are the different failures whatever we have mentioned as a given list these are the details in the form of sketch.

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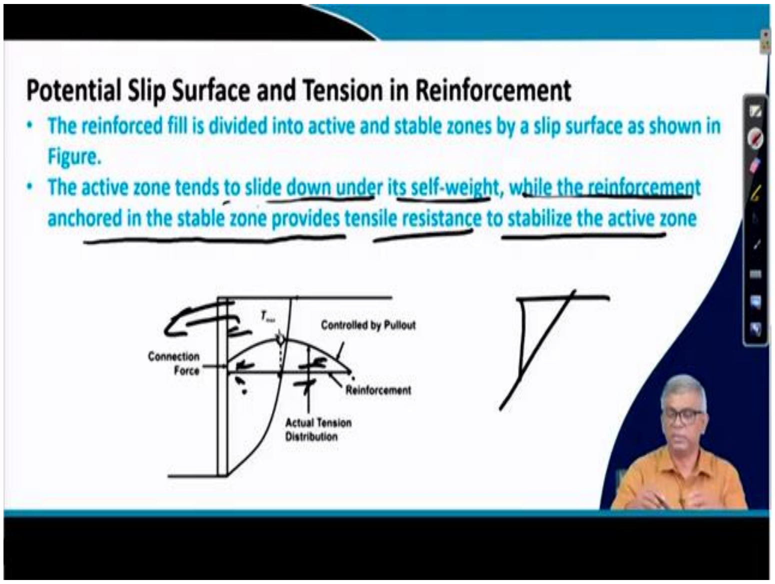

And potential slip surface and tension in the reinforcement how to you can see here that I already have mentioned the reinforced fill is divided into active and stable zone, you can see this portion this portion is called active, so, it is moving the direction. And this is a stable zone okay. The stable zone that is actually it will be having frictional resistance will be like this and this side actually since it is soil is moving this direction. So, here also reinforcement frictional will be like this okay.

when this reinforcement is provided like this, it has to be provided sufficient length in the stable zone to balance this, the active zone load and if I see the distribution of stress in the in the reinforcement, you will see that close to the failure surface this is the failure surface if I assume, close to the failure shop it will maximum added, decreasing towards the end and again decreasing towards the facing.

So, facing will have some value but entire T will become zero. So, active zone tends to slide down under its self-weight. That is what this way while the reinforcement anchored in the stable zone provides tensile resistance to stabilize the active zone. This is the mechanism actually whatever we are discussing.

This is actually when if this wall is there, this soil is there that will be in a retaining wall we have assumed failure surface like this and when there is no reinforcement, but when there will be enforcement, the failure surface is not exactly like this, it will be curved. Suppose this is the failure surface. Beyond left side of the failure surface is the active zone that when it is falling and beyond the right side of the failure surface that is actually stable zone.

And through the stable zone you have to lay the reinforcement sufficient length, that frictional resistance developed should be equal to the load because of this the active zone, that it will be stable.

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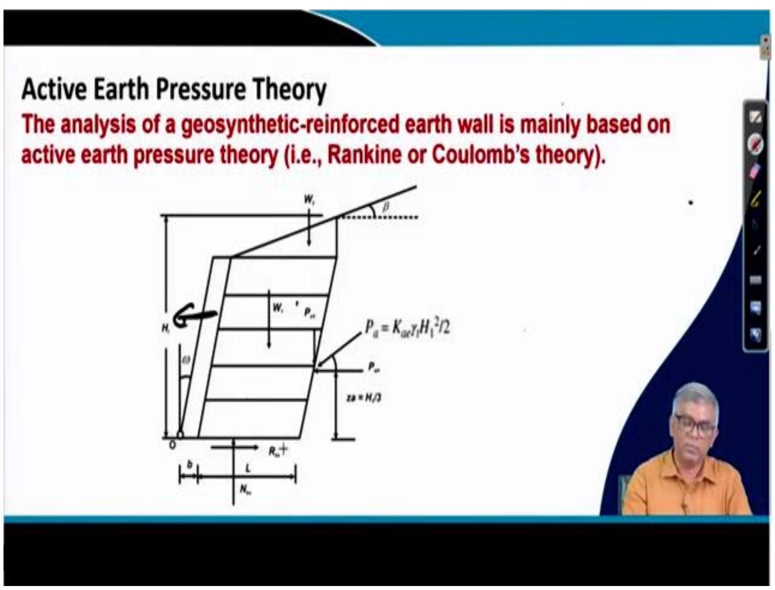

This is the buy enlarge mechanism of an active earth pressure theory you know that analysis of geosynthetics reinforced earth wall is mainly based on active earth pressure theory because it never we had actually retaining wall, we have defined three different types of earth pressure, activate earth pressure, passive earth pressure, earth pressure addressed. Active means wall moves away from the backfill.

Passive means wall moves towards backfill and when it is address when no movement, but here actually that our normal retaining wall sometime it can move towards backfill also some situation will be there and commonly move away from backfill. But here in reinforce retaining wall always movement will be this direction.

So, it will be active case always so, that is what so because of Rankine Coulomb's theory can be used and if I use Rankine Column theory and this is the wall suppose then, this is a reinforced zone, reinforced soil and then we can apply Rankine theory you can find out what is the coefficient of earth pressure and then what will be the earth pressure actually it is parallel to this and then you can make vertical-horizontal component, base resistance and etc. all those things and this is a free body diagram of the force acting in a MSE earth wall, actually MSE wall, mechanically stabilized earth wall.

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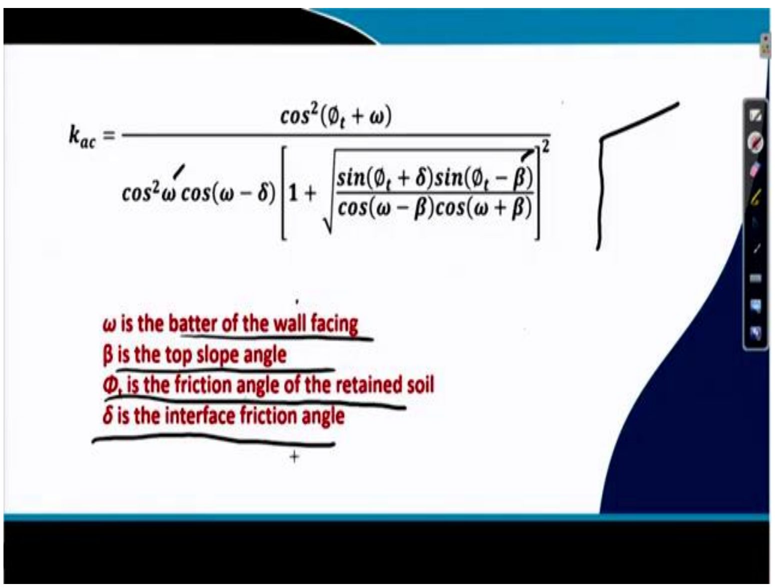

And then, the formula when we use friction angle and all, there then common formula will be this one that is Coulomb's formula where that your omega is the batter angle and beta is the like this is the wall, is the slope of the surface, Delta actually internal friction which is the wall and soil and then you have that is all, omega, beta and phi t is the frictional angle of the file soil, retain soil actually that is what is meant to.

Omega is the batter of the wall, beta is a top slope, phi t is the friction angle and delta is the interface friction angle. So, these are the things you can use this equation and find out the K_{ac} active earth pressure coefficient.

$$K_{ac} = \frac{\cos^2(\phi_t + \omega)}{\cos^2\omega\cos(\omega-\delta)\left[1+\sqrt{\frac{\sin(\phi_t+\delta)\sin(\phi_t-\delta)}{\cos(\omega-\beta)\cos(\omega+\beta)}}\right]^2}$$

ω is the batter of the facing wall

β is the top slope angle

ϕ_t is the friction angle of the retained soil

δ is the interace friction angle

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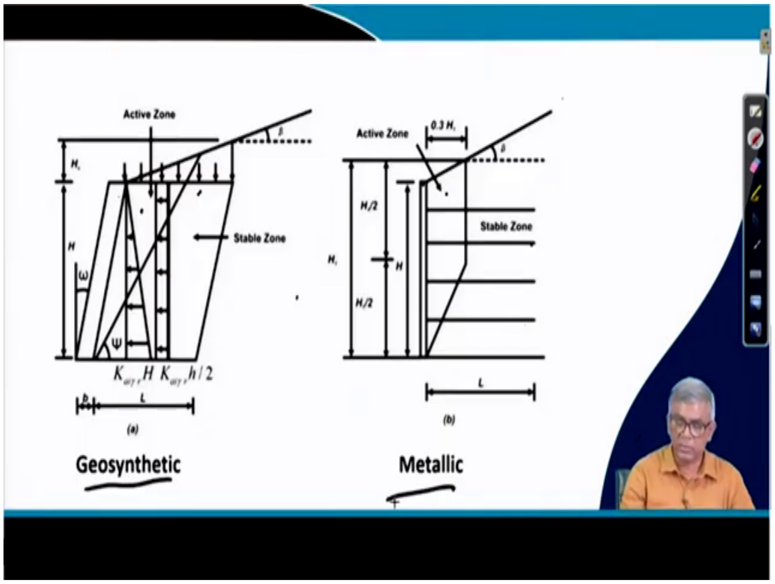

And when you will use geosynthetic then actually since, when geosynthetic is used it is less stiff and movement of wall will be little more compared to her use metal it will be less. So, when you use geosynthetics actually your failure surface will be towards little right and whereas, if I use metal, it will be towards little left.

So, it will be close to the wall and it will be away from the, failure surface will be away from the wall. It is geosynthetics use this is the failure surface when metallic is use this is the failure surface and the under these actually this is the stable zone and this is the active zone and under this, this is the active zone and this is a stable zone and you have to provide reinforcement like that passing through both stable and active zone.

And the different components are shown here. So not much to discuss in this figure, let me go to the next slide.

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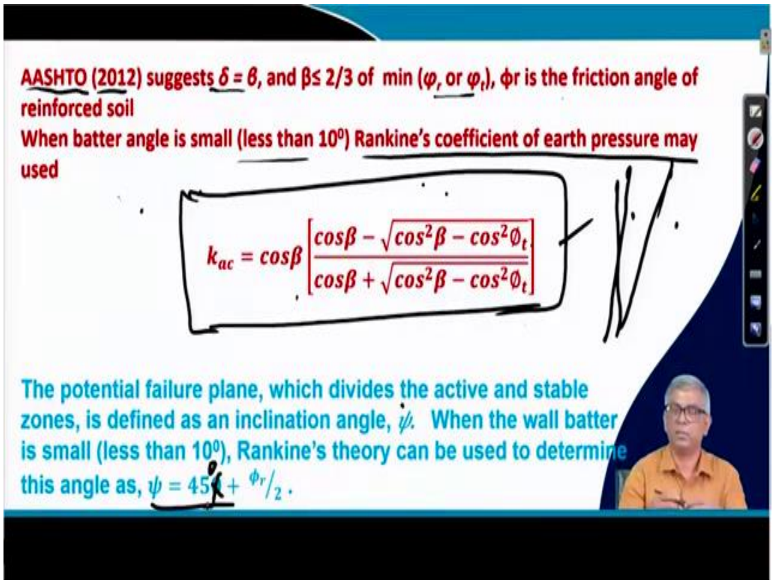

And this AASHTO; 2012, suggest data to be considered as equal to beta okay and beta should be less than or equal to two third of minimum or phi or phi t, friction of normal on retain soil or frictional on the reinforce soil. $\delta = \beta$, and $\beta \le \frac{2}{3}$ of min (ϕ or ϕ_t)

Out of that whatever minimum one is suppose 32 and one is suppose 35, so 32 to be taken and then two third of that at least beta should be two third of less than equal to two third of that. When the batter angle is small that it less than 10°, Rankin's coefficient of earth pressure can be used in this form. It can be taken that is actually less than 10° that the, if I calculate with it and without w the value is very close. So, because of that can we use this.

The potential failure plane which divides the active and stable zone is defined as the inclination phi, so suppose this is the wall and this is the active zone and this is a stable zone, the surface by which is divided that is actually can be defined by inclination Psi and when the wall batter is less again, the wall batter is less than 10 degrees or so, then this can be approximately calculated Psi equal to 45 degrees plus Pi by 2.

$$\Psi = 45^o + \frac{\phi_t}{2}$$

what we do, normally in the retaining wall, we always assume the failure plane equal to 50 this is 45 degrees not 450; 45 degrees plus Phi by 2 and otherwise, this can be determined there are some complicated equations I am not discussed here. I am taking the simplified one which I can take it in the example but if you want to do real design, you can refer the document and you can find out what is the exact inclination of the failure surface.

Otherwise, if I assume this, this then the other batter angle is generally less around 10 degrees or so 10-15 degrees so directly can use this and also the inclination of the failure surface can be taken 45 degrees plus phi by 2 without much NF.

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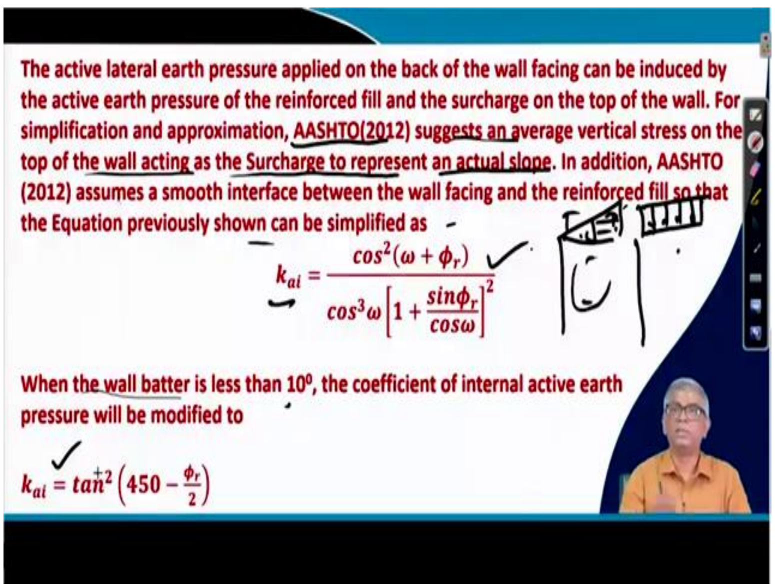

And then the active lateral earth pressure applied on the back of the wall facing can be induced by active earth pressure of the reinforced field and the surcharge, so that means, if there is a wall, so pressure will be because of this soil and this slope or surcharge. For simplification and approximation AASHTO suggests an average vertical stress on the top of the wall acting as the surcharge to represent actual.

$$K_{ai} = \frac{\cos^2(\omega + \phi_r)}{\cos^2\omega\left[1 + \frac{\sin\phi_r}{\cos\omega}\right]^2}$$

$$K_{ai} = \tan^2\left(45^0 - \frac{\phi_r}{2}\right)$$

So, if this is slope and then I can find out what is the value here at different places then I can provide equivalent to one average a surcharge on that and then I can make the wall like this, instead of wall like this I can make a wall like this. In addition, AASHTO assumes smooth interface between the wall facing and the reinforced fill so the equation previously shown can be simply, that means, when I use Delta that can be smooth, wall can be used zero then k can be used by this equation and when the wall batter is again less than 10 degrees then K_{ai} become 10 square 45 degrees minus phi by 2.

So, again this is the typical expression for coefficient of active earth pressure whatever we do for any retaining wall.

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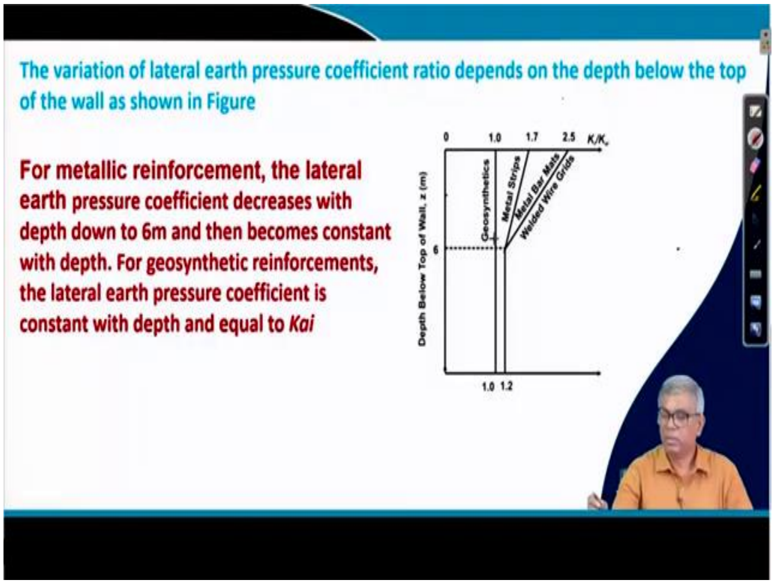

And then variation of the lateral earth pressure coefficient ratio depends on the depth below. So here actually you can see that up to 6meter depth from the surface that the coefficient of earth pressure actually varies. And in fact, if you use geosynthetics it can be taken cost and throughout the depth, but if you use metallic strip then it can be varying actually from some value to some constant value at 6meter depth. So, these are the when it is a metal bar is used when metal strip is using the different distribution are shown this is available in the literature.

Similarly, same thing can be taken, otherwise in the geosynthetics is use of the reinforcement, there will be throughout the layer, your coefficient of earth pressure will be constant whereas coefficient of earth pressure will be varying from surface, some value to some constant value at 6meter depth and then it will be remaining constant. So, that is the distribution shown.

That is what for metallic reinforcement, the lateral earth pressure coefficient decreases with depth down to 6 meters up to 6 meter and then become constant with depth, for geosynthetic reinforcement the lateral earth pressure coefficient is constant with depth and equal to Ki, that is whatever expression we have used directly we can use if it is a geosynthetics reinforcement is used, but if it is metallic earth pressure used then we can have this variation also.

With this, some more aspects, we have to examine for design of MSE wall. I will take one more lecture on various aspects of design aspect of a MSE well, and then, immediately after that, I will take you on design example to explain how to design a mechanically stabilized earth wall. And if we get time of course, we will take another topic like either reinforced slope, or reinforced foundation base something I will take. So that is all today. Thank you.