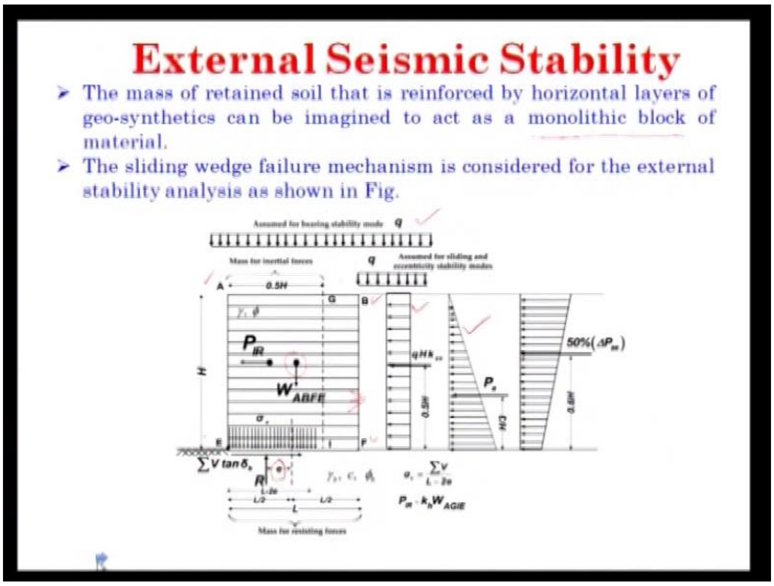
Application of Soil Mechanics
Prof. N. R. Patra
Department of Civil Engineering
Indian Institute of Technology, Kanpur

Lecture – 37

(Refer Slide Time: 00:20)

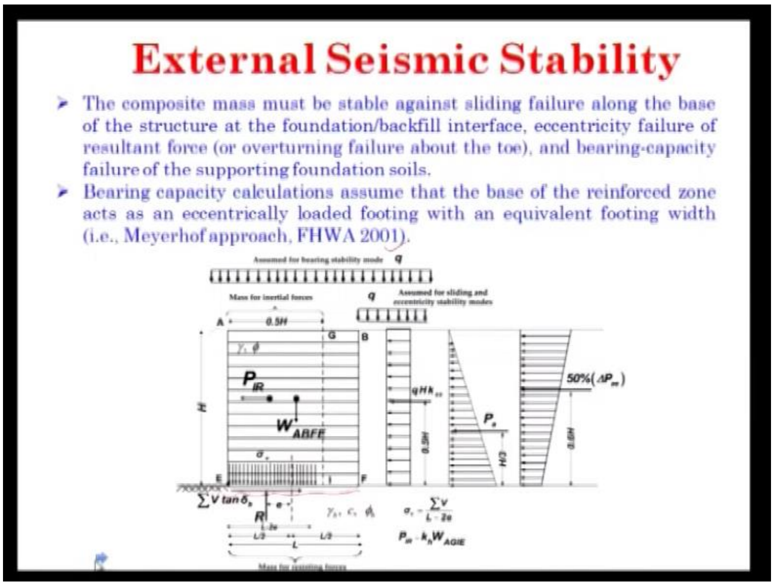
Earlier we have discussed about this design of this federal highway as given by federal highway administration f h w a for en post earth wall we discussed also.

(Refer Slide Time: 00:28)



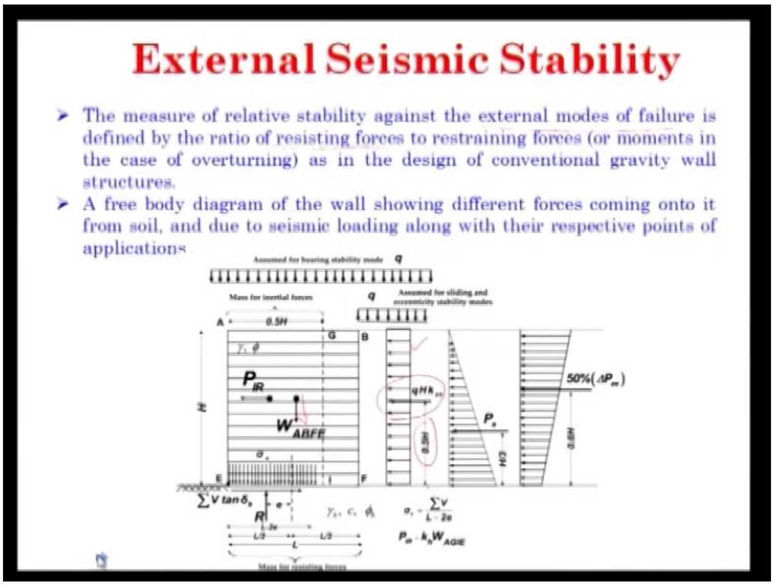
So, these are all review on a two slides external specific stability, these external specific stability has been considered taking into consider as a monolithic block of this material.

(Refer Slide Time: 00:45)



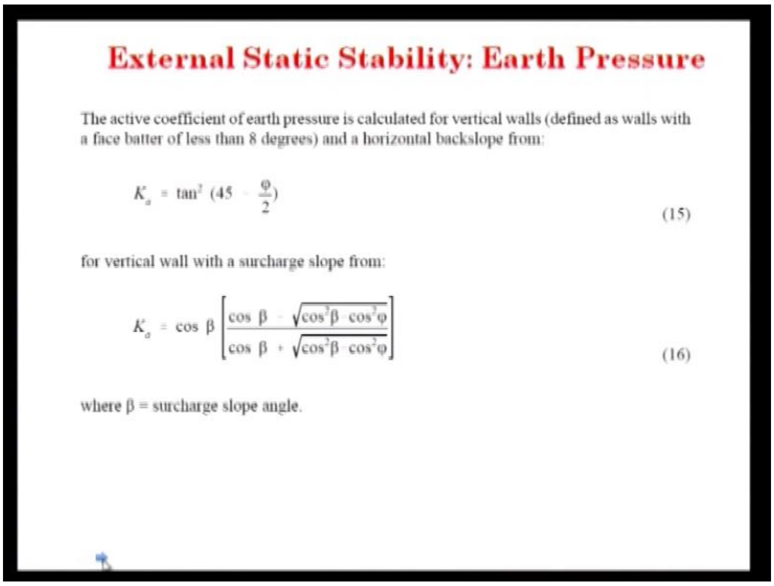
Then this approach bearing capacity calculations has resumed that the base of the reinforced zone act as an eccentrically loaded footing with an equivalent footing width of by taking this measure of approach.

(Refer Slide Time: 01:01)



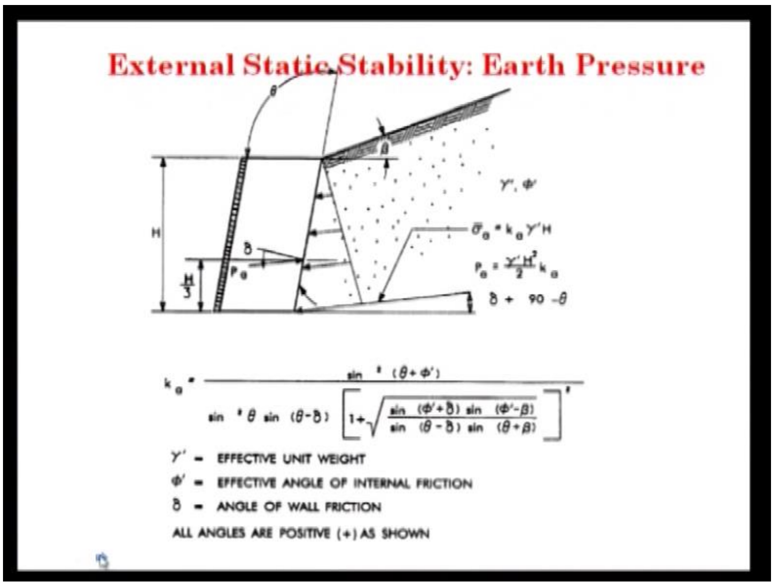
Then by considering this measure of approach, we can go for this past will find it out the pressure distribution diagram one has to one is a, then is a, because is a earth pressure, then, because of your seismic load all three will be combined will find it out the result, and earth result are pressure, and the and how for this result, and pressure from this center of gravity or c g of this entire soil mass as well as your en post earth walls, then based on that this stability annalist as been check.

(Refer Slide Time: 01:40)



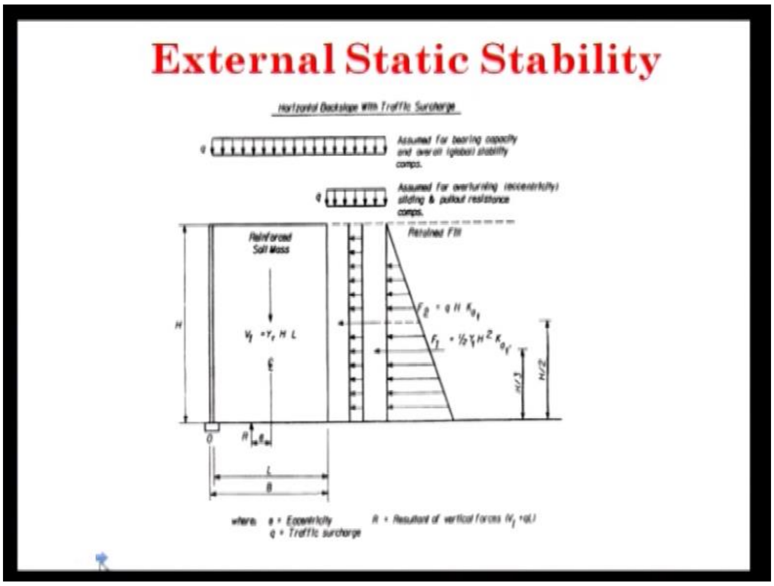
Earth pressure, as a we have these things we have discussed. So, k active earth pressure it is your time square 45 degree minus five by two with a vertical wall with a surcharge slope.

(Refer Slide Time: 01:54)



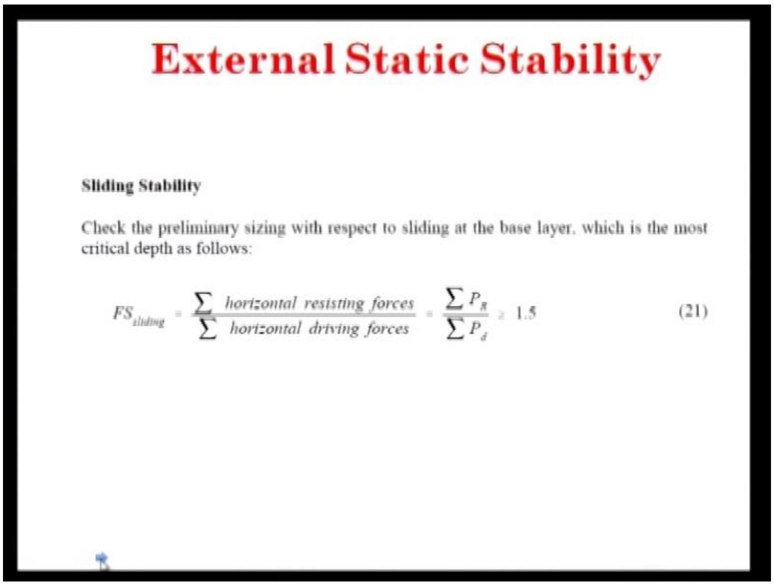
This kind of slope earth pressure, you can get it from these situations these also as discussed.

(Refer Slide Time: 02:00)



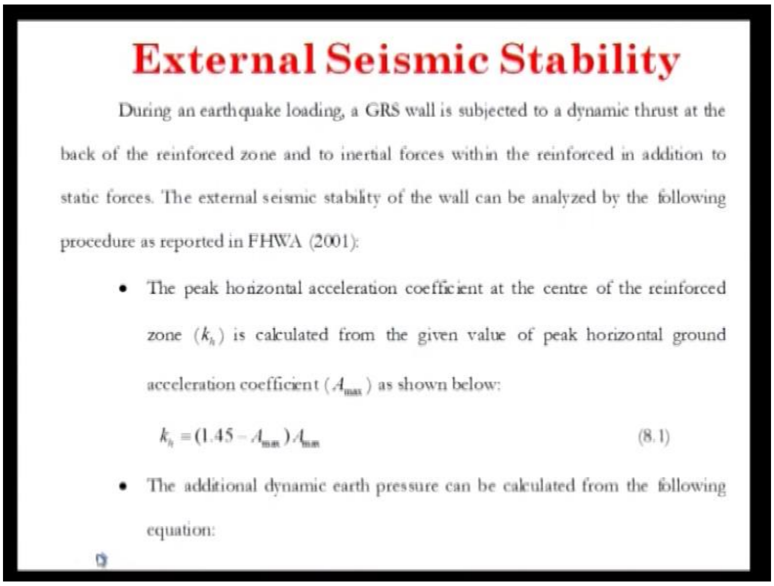
Then for externals stability analysis.

(Refer Slide Time: 02:03)



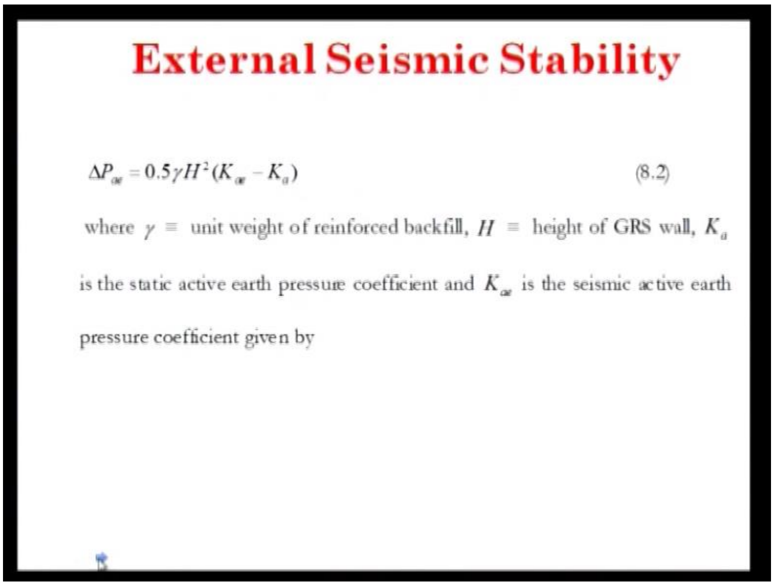
You can find it out sliding fact of safety against it should be horizontal resisting forces by horizontal driving forces; that means, p r by p d it should be greater than one point five. So, horizontal resisting forces, and horizontal driving forces. If you come back here this is your horizontal driving forces is the resisting forces could says, and there is a driving forces, because of your r pressures lateral r is pressure.

(Refer Slide Time: 02:35)



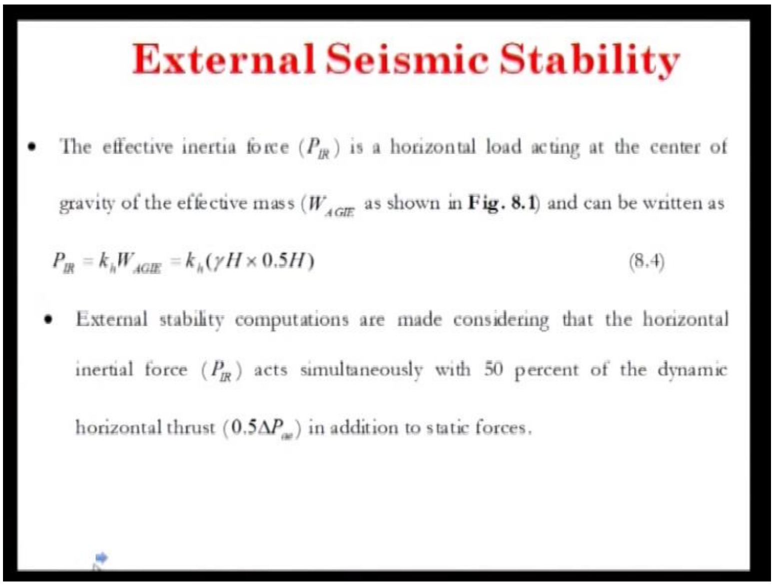
Then external seismic stability we have discussed also this speak horizontal acceleration co efficient you can find it out, then additional dynamic earth pressure can be calculated additional dynamic

(Refer Slide Time: 02:46)



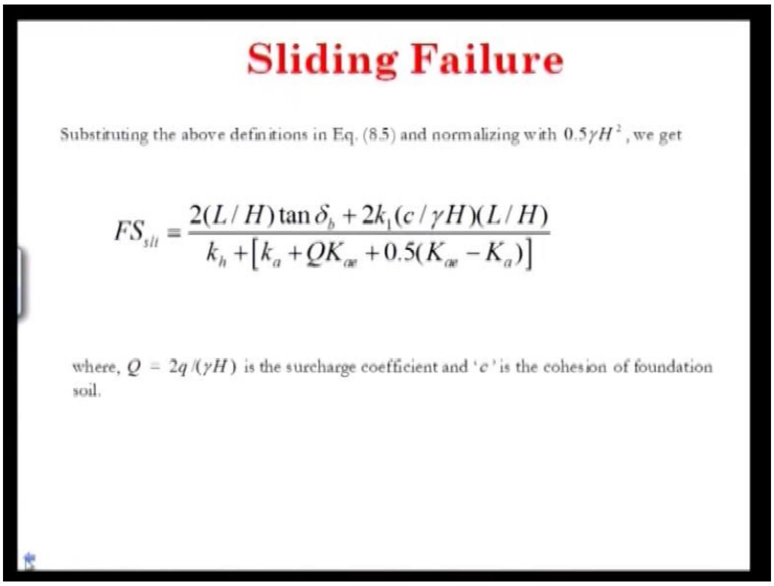
Earth pressure, because of your this. So, it is a zero point five gamma is k r k e minus k a, then based on that we can find it out k e which is your k a e is the seismic active as earth pressure co efficient, it is the seismic active earth pressure co efficient.

(Refer Slide Time: 03:11)



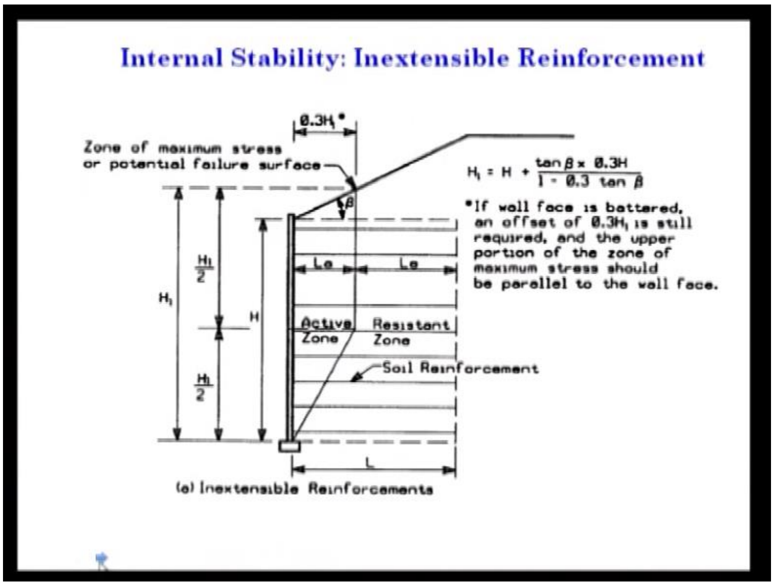
Then after finding out seismic active earth pressure co efficient b the effective inertia force p i r can be found out by k h w a g i e, then once we get this we can find it out for the pressure distribution, because of your this is your pressure distribution, because of your seismic course, and the resultant will act the resultant will act distance zero point six h from the base of the wall. So, by we can find it out by doing this we can find it out also factor of that against sliding failure.

(Refer Slide Time: 03:51)



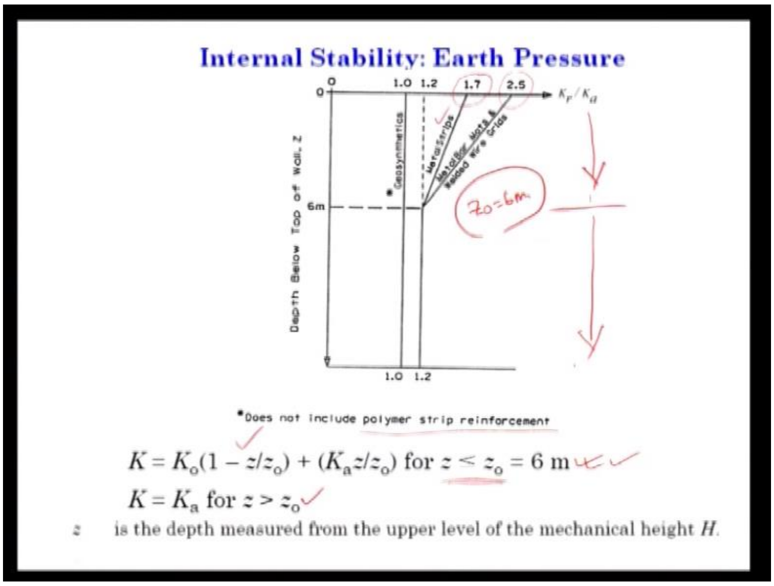
And we can check it taking into consideration of earth quick forces we can find it out against sliding similarly we can find it out factors setting against sliding similarly we can find it out factors setting against. So, what kind as a eccentricity failure, then we can find it out put in terms of these about finding as eccentricity failure terms of e by h e is your eccentricity, and h is your total height in terms of active earth pressure k a, and k e a e, then next is your bearing capacity failure this also we have discussed very factor seismic again is bearing capacity is your called ultimate bearing called capacity, this you can get it you can get it here of a distributions e n c zero point five gamma b l minus two e do in gamma sigma b we can find it out total vertical forces divided by a l minus two e.

(Refer Slide Time: 04:51)



Then next part is your of your internal stability that is your earth pressure these we are going to start earlier this after.

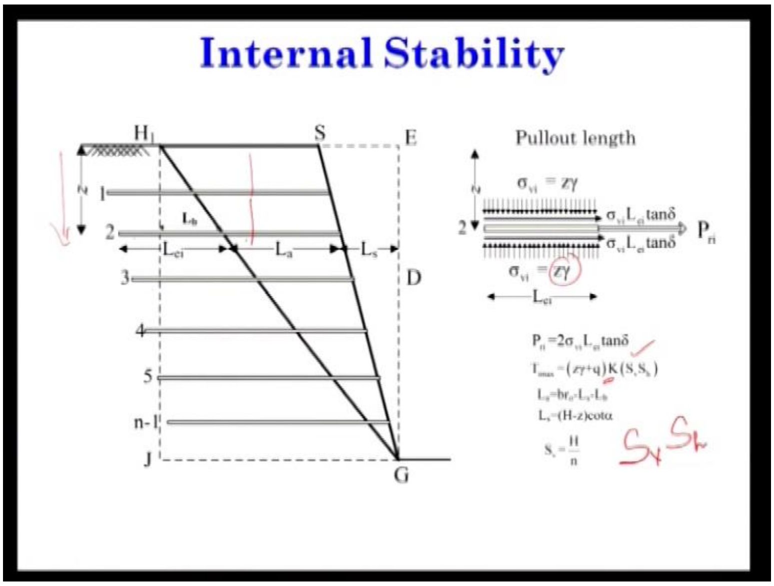
(Refer Slide Time: 04:53)



This we have finished your external stability as well as some part of your internal stability that is your extensible reinforcement. Now we will start the this internal stability; that means, of the earth pressure, if we look at this internal stability earth pressure it does not include polymer strip reinforcement it does not include this polymer strip reinforcement. Now you can look at this figure this is the total height, and at a height of the wall, and depth below the top of the wall j, and depth below the top of the wall j that is your geo synthetic; that means, it is your metals stiff.

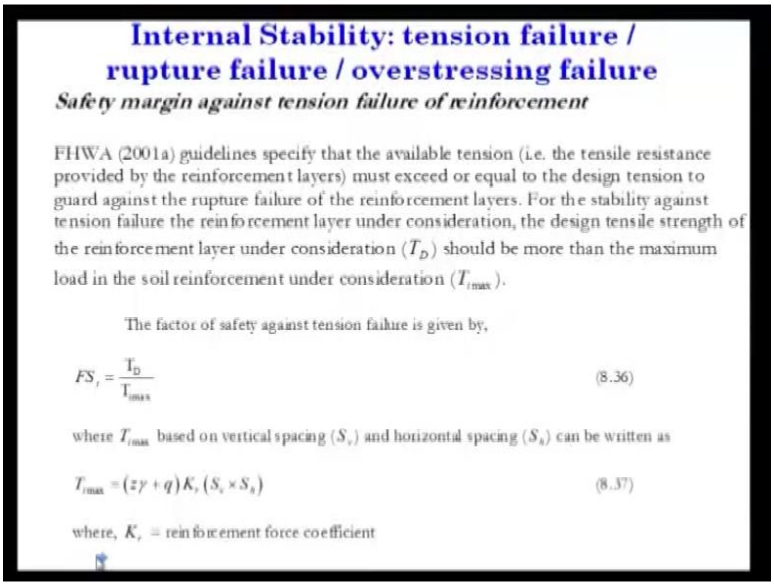
If it look at k a is coming about to be one point seven it is varying at a distance of six meter to zero to six meter it is going up to horizontal of one point seven, then metal bar metals, and well deed were grades it is coming up to two point five; that means, u can find it out K is equal to k zero one minus z d by z zero, then from there plus k a z by z zero for z is less than equal to z zero; that means, z zero is considered to be six meter, and k is equal to k a; that means, if there is a there is a wall height suppose say up to six, we can find it out are pressure k zero into one minus z by z zero plus k a z by z zero for a wall height of six meter this various we can find it out from this equations, and beyond these six meters k is equal to k k a it should be k is equal to k a z greater than z zero means z this is your distance z is greater than z zero z zero zero is your six meters is greater than z zero is a six meter greater than these it is is your k is equal to to k a z is the depth measured.

(Refer Slide Time: 07:11)



From the upper level of the mechanical height h internal stability is part is your pull out length oh pull out length we can find it out from your at at a distance of z at a distance of the distance z at a distance z these are the enforcing bar one two three four five up to j j number of bars. So, for this pull out length to the find it by taking into consideration of pressures of the soil that is your sigma b i at the top that is your gamma z sigma b i at the bottom gamma z to p r i is equal to two sigma b i l e i, and delta e i max is equal to gamma z plus q k into s b into s h s b, and s h is your spacing in vertical direction s is your spacing b is in vertical direction s is your spacing h for is your in horizontal direction spacing in vertical direction this is the wall height this is your spacing in vertical direction, then if i moved towards in plain strain or the length wise, then this spacing will be a in horizontal direction internal stability.

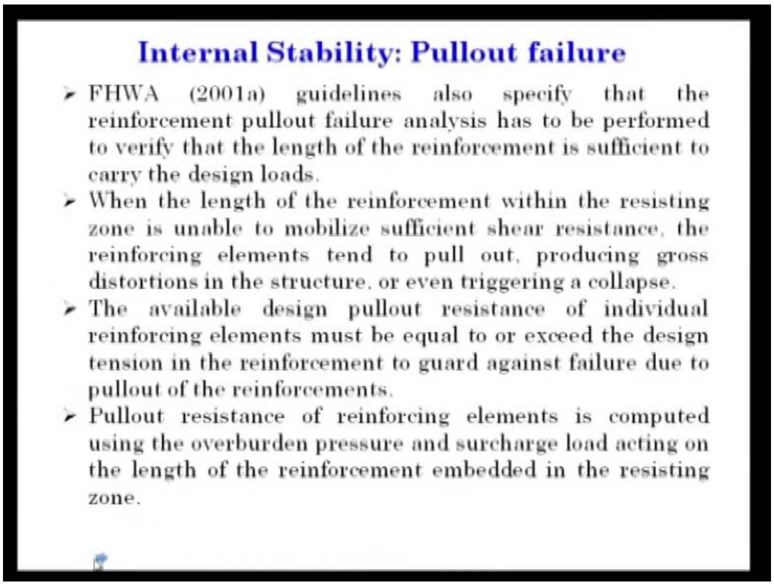
(Refer Slide Time: 08:27)



That means tension failure or rapture failure or over stressing failure safety margin against tension failure of reinforcement as per f h w a guidelines specify that the available tension; that means, tensile resistance provided by the reinforcement layers must exceed the look at here this available tension must exceed or equal to the design tension to guard against the rapture failure of the reinforcement layers for the stability against tension failure.

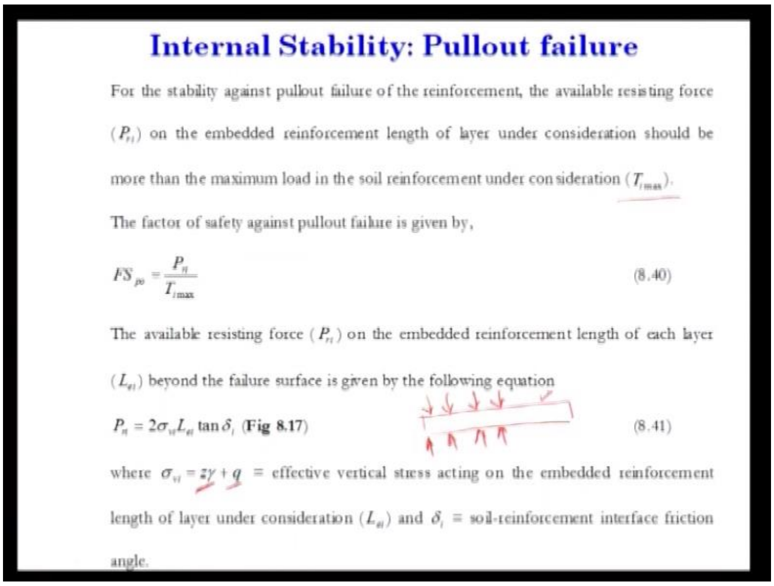
The reinforcement layers under consideration the design tensile strength of the reinforcement layer under consideration t d should be more than the maximum load in the in the soil reinforcement under consideration; that means, t d should be more than t i maximum the factor of safety t against tension failure is given by factor safety f s is be t for tension failure which is equal to t d by t i maximum t i maximum based on vertical spacing. If you look at here t i maximum is based on vertical spacing s b, and horizontal spacing s h can be written as t i maximum q plus gamma z q is your for z gamma z is your gamma z is your weight of the soil against the gamma z into a r k r is reinforcement force co efficient k r is reinforcement force co efficient in to s b into s h s b is your spacing in vertical direction spacing in horizontal direction.

(Refer Slide Time: 10:03)



So, f a f h guidelines of also specify that the reinforcement pullout failure analysis has to be performed to verify that the length of the reinforcement is sufficient to carry the design loads; that means, the length of the reinforcement should sufficient to carry the design loads one the length was he within the resisting zone is unable to mobilize sufficient shear resistance the reinforcing elements tend to pull out produce gross distortions in the structure or even triggering a collapse; that means, length of the reinforcement would be sufficient if it is not sufficient it will produce a grass destruction in the structure, and even triggering a collapse the available design pull out resistance of individual enforcing elements must be equal to or exceed design tension in the reinforcement you guard against a failure the available design the pullout resistance of individual elements, it should be equal or greater than the reinforcement pull out reinforcing elements is computed using the over burden pressure, and surcharge load acting on the length of the reinforcement embedded in the resisting zone.

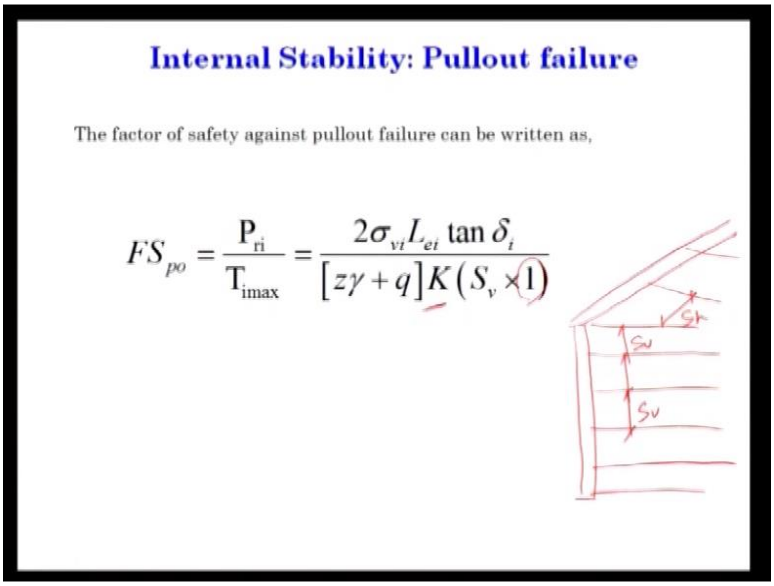
(Refer Slide Time: 11:59)



For stability against pull out failure of the reinforcement available resisting force p r i on the embedded reinforcement length of layer under consideration should be the more, then the maximum load in the soil reinforcement the consideration; that means, t i maximum pr i should be more than t r i maximum t i maximum the factors of the against pull out failure that is your p r i by t i maximum the available resisting force p r i on the embedded reinforcement length of each layer l e i beyond this elements of the given by the following lesson this is you p r i p can find it out this is your two time sigma b i, because this is the reinforcing elements made. So, this is your once site this your other site; that means, this is your two sigma b i l e i stand delta

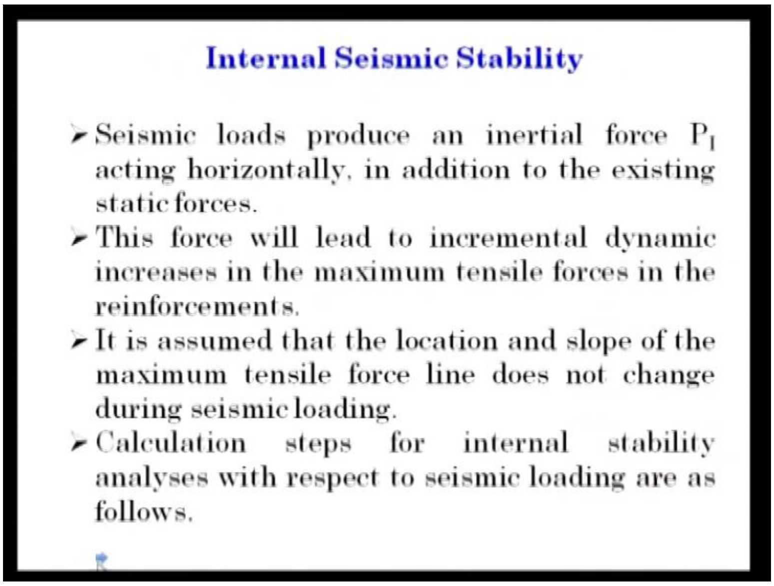
So, sigma b i is as is said this is your searcher plus over button gamma z, we can see and l e r i is you length stand delta is final force along one surface between in the wall, and in the soil to the both the side it will occur.

(Refer Slide Time: 13:20)



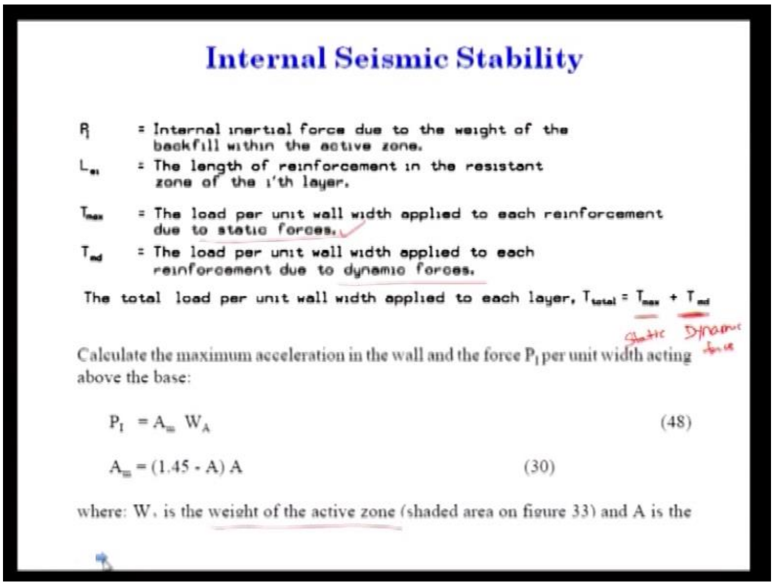
So, factors set the again is pull out failure if i write it interns of p r i, and t i maximum it should be two sigma b i l e i, and delta i gamma z plus q k s b into one why it is one this is generally if I take this the retaining wall if this is the retaining wall, and this is spacing in a vertical direction also you have this spacing also in line that also in length direction you have this spacing also to spacing like this have your spacing that is your s h generally in design are taking into consideration of four meter length is one meter one meter length is taking into a consideration by this s h becomes to be one.

(Refer Slide Time: 14:24)



Then internal seismic stability seismic load produces are inertial force p one acting horizontally this one two existing static forces as we have also earlier discuss the seismic load produces inertial force p one acting horizontally in addition to the existing starting forces these force will lead to incremental dynamic increases in the maximum tensile forces in the reinforcement, it is assume that location, and slope of the maximum tensile force line does not change during this specific load the this is the draw back or we can say that this is the assumption; that means, the location, and slope of much maximum tensile force line does not change during the specific loading; that means, it will same as during the static including conditions calculation steps for a internal stability analysis with respect to specific loading are these are like this.

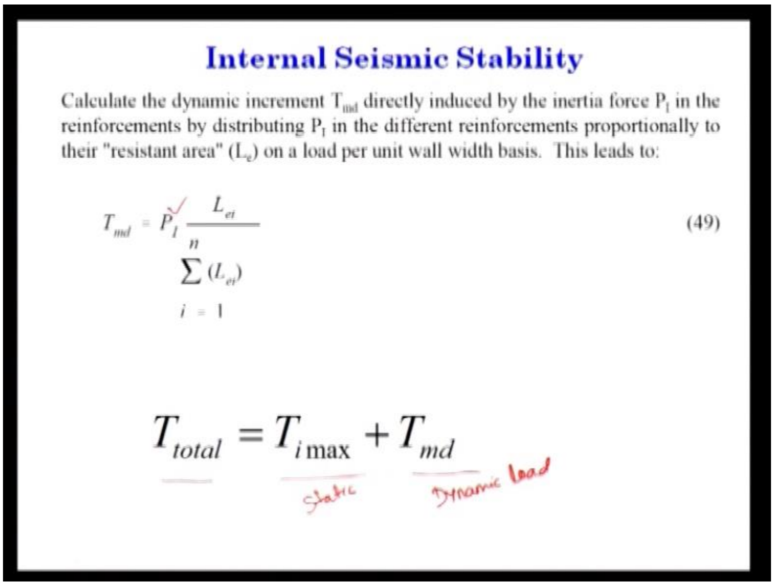
(Refer Slide Time: 15:25)



So, p i is your internal inertial force due to weight of the back fill within active zone this is your p i or p one if we look at here the this is your p i, because of specific loading in extensible force, then l e is the length of the reinforcement in the resistant zone l e i, then t maximum the load per unit t wall with the load per unit wall width applied to each reinforcement due to static forces he load per unit wall with the load per unit wall width applied to each reinforcement due to static forces t n d is your load per unit wall width per unit wall width applied to each reinforcement due to dynamic forces one is you have to static forces, and other is you have due to dynamic forces; that means, t maximum, and t n d t maximum, and t n d.

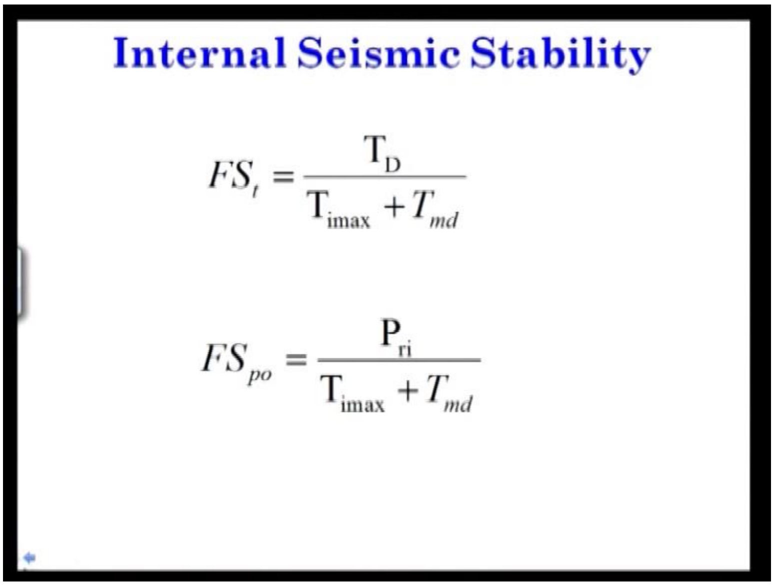
Now, the total load per unit wall width applied to each layer; that means, t total at each layer t total t maximum this is, because of you static t n d this is, because of your dynamic forces this is, because of your static this is, because of your dynamic forces. So, maximum lesson in the p one force for unit width about a base; that means, p i each you're a into w a a n is equal to one point four five minus a into two a where w a is to said it area in this figure a set up the active zone said it area in this figure this is the weight of the active zone these are the at the said this area.

(Refer Slide Time: 17:36)



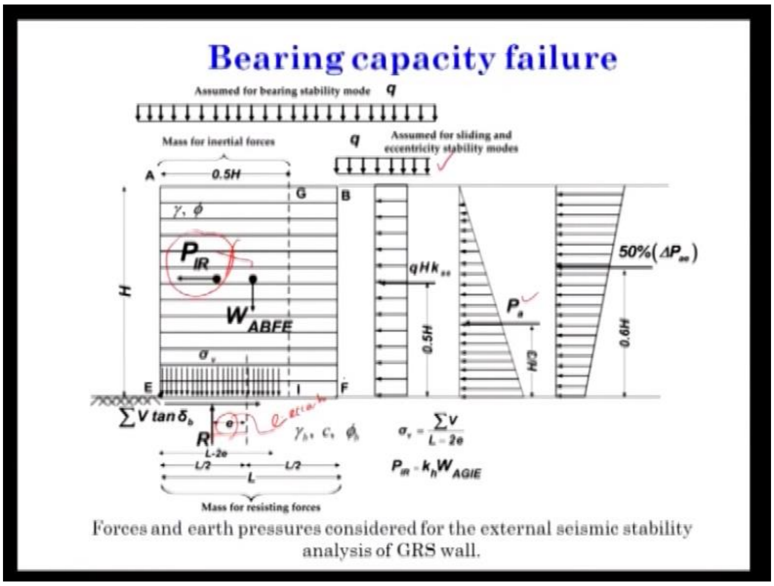
Now, dynamic increment we can will have to calculate t n d directly induced by the inertia force p i in the reinforcement by distributing p one p i in the different reinforcement proportionally to their resistant area l e on a load for unit wall width basis. So, t nd can be calculated p i into l e i by i is equal to one two n; that means, numbers of layers into l e i suppose this is a t m d. So, p i in a course. So, this is your l e i, then this is your the number of layer let this is one. So, if have to one three four five six seven like this a number of a. So, total t total if can we find it out t i maximum in to t m d this is, because of your static i say this is, because of your dynamic load.

(Refer Slide Time: 18:36)



This is, because of your dynamic load. So, factor of safety internals seismic stability factor safety t d by i maximum t i maximum plus t m d of factor of safety t in terms of t factor of safety in terms of p. So, p r i by t i maximum plus t n d. So, this is all about this seismic design, and post or reinforcement the earth design, if I summarize if I summarize looking at one figure, let me take out this one figure.

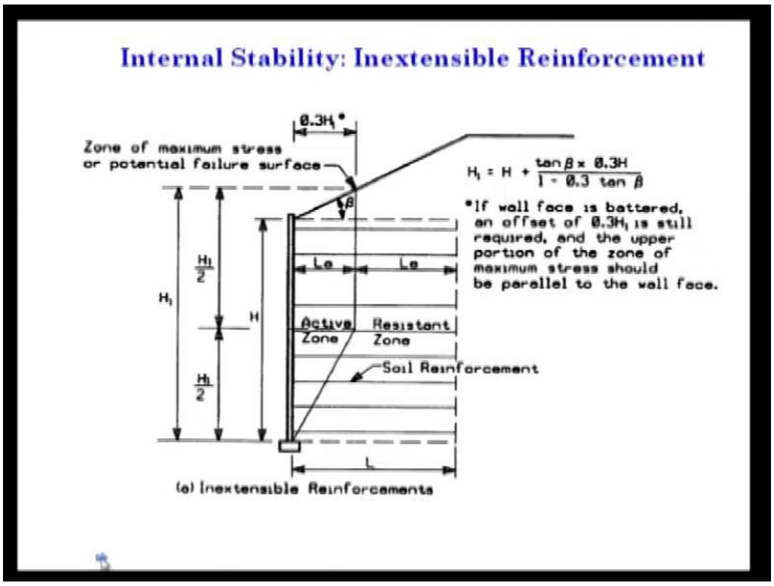
(Refer Slide Time: 19:14)



If this is the case this is the case forget about there are two parts one is your static part other is your dynamic part, if there is static part f; there is a only static part is has to be check this is, because of your their force, because of your dynamic loading this think has to be a neglected enter soil plus enforced earth wall to be consider as one unit; that means, it has two we constructed monolithic ally, then this weight of this earth wall it will occur this easy, then you will have to find it out this earth pressure earth pressure, because of your, and its result, and force is acted, and earth pressure, because of your soil.

And its result, and forces, and total will are end this total will give you lateral resistance forces, and with these with this w will we have to find it out what is the result acting a at the best, and how far it is how far it is from the sentro it is from the best, and that to find it out the eccentricity e is equal to eccentricity eccentricity, and based on this eccentricity one. So, get in the we can calculate the factors set be difference factors set be one is your factors set be against sliding there these will slide or not these greater than equal to one point five other is a, because of your over whether this will overturn at the top, and hearing capacity; that means, whether these soil below the means above the of this soil above the ground where this enforced they are below the a reinforced earth soil is whether this bearing capacity it is bearing capacity is within this limit or not, if have to check it.

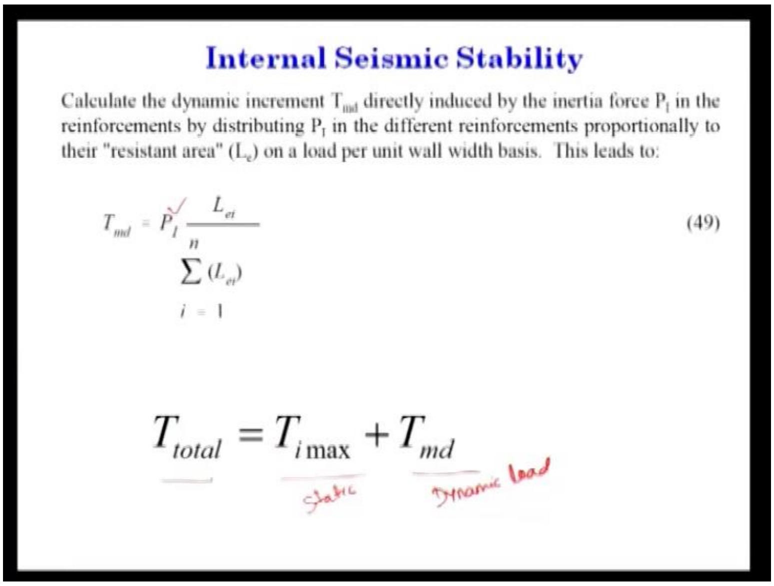
(Refer Slide Time: 21:05)



Then once it has a it will check, then we will go for, then will go for internal stability internal stability; that means, per in internal stability to consider for rapture stability against a rapture stability against pull out, and stability against excessive department in the séance. So, pull out length there are two parts one is active zone other is resistance zone. So, this resistance zone a least should be sufficient. So, that its took second it should take care of your additional ten sail force ten sail force, because of your enforcing one force earth wall, then if you are going to do it both static, and dynamic load conditions both static, and dynamic load we condition in that case dynamic load condition is the sense, because of a dynamic loads has to be considered the assumption is that this in your force, because of a dynamic load it will last g of this enforcing are earth mass.

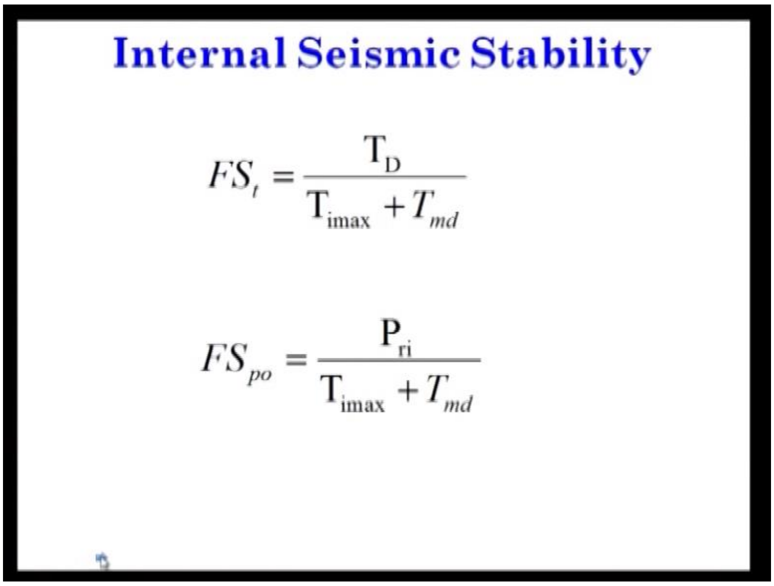
And this pressure distribution, because of a earth force p r i it should be find it out, and this pressure distribution diagram is given when, and with this pressure distribution diagram you will have to find it out the result, and at the result, and the large at zero point six from the base of the ground, and r this three plus pressure distribution diagram pressure distribution diagram, because of a pressure distribution diagram, because of a soil pressure distribution diagram, because of a inner shear forces add all of these three, and find it out this total pressure distribution diagram, then you calculate, then up to taking into consideration, then check the stability considering over turning sliding as well as well as this sliding, then bearing capacity, then as well as also internal stability; that means, pull out resistance up to check it the for pull out you have considered you have considered pull out resistance.

(Refer Slide Time: 23:08)



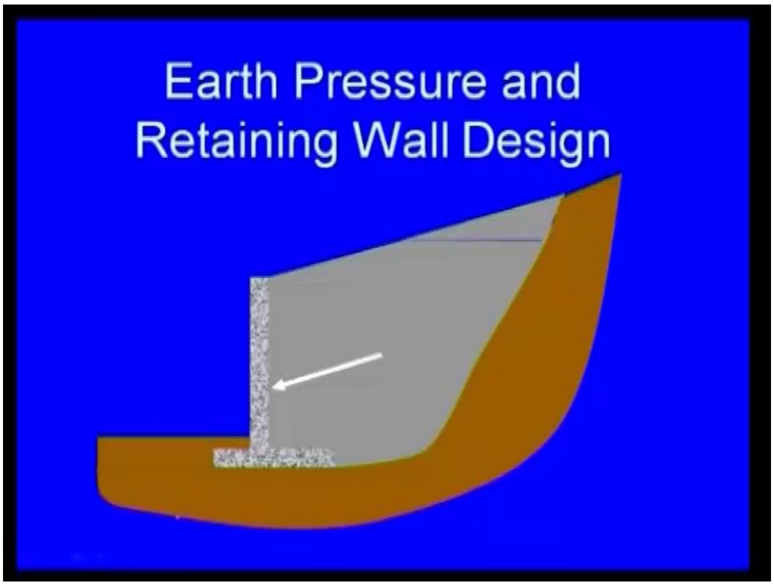
There are two parts you have considered as I said total total t total is t i maximum, and t m d t i maximum is your, because of static t m d, because of your dynamic load.

(Refer Slide Time: 23:19)



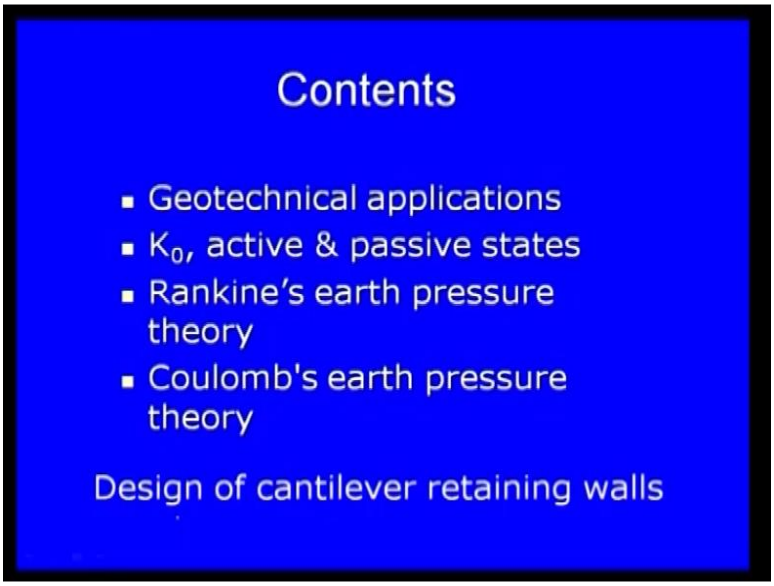
Then find it out each, then check whether this would be this factor safety is satisfied or not, then these completes your complete design methodology or procedure for your reinforced earth materials or reinforced are structures or reinforcing materials reinforced as structures, then one part is still remaining I will go for these this is about your rent forced are design.

(Refer Slide Time: 24:03)



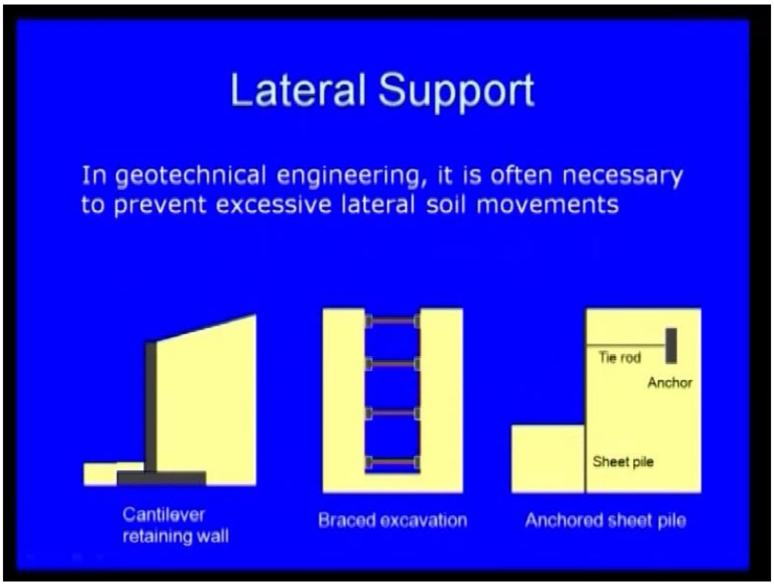
So, one parties left that basic earth pressure to start with this something some part of this retaining structures introduction to retaining structures, and what are the earth pressures comes into picture; that means, earth pressure, and retaining wall design.

(Refer Slide Time: 24:06)



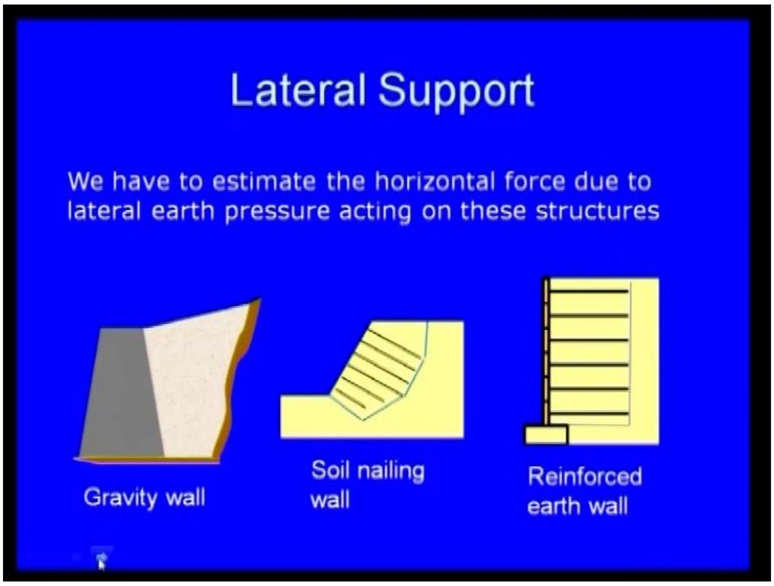
If you consider that is your this is in addition to these, because you should first know what are the different earth pressure acted, and how the retaining wall has been design, then once you know it, then for reinforced e earth wall you can go for both static as well as dynamic loading just geotechnical application k zero; that means, what is k zero means earth pressure, then active, and passive states ranking earth pressure, then coulomb's earth pressure theory is your this is just a brief view of this retaining wall earth pressure theories in geotechnical practice.

(Refer Slide Time: 24:43)



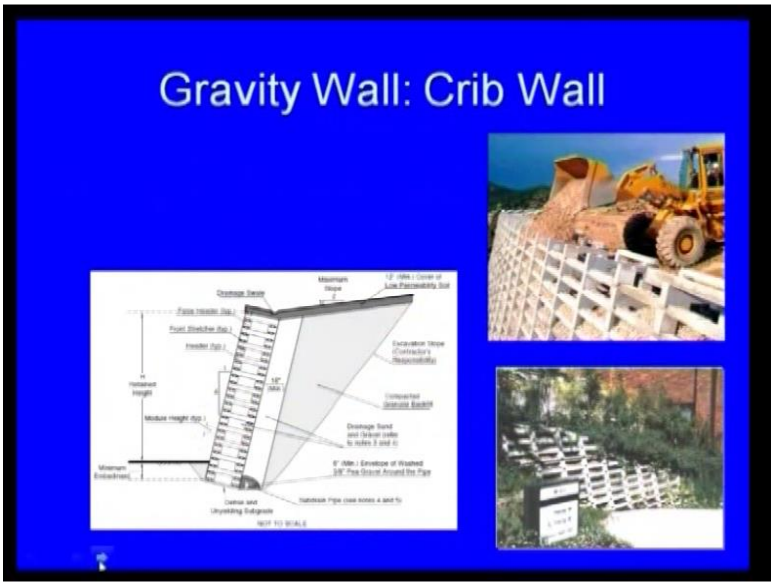
How this lateral support talker particularly cantilever retaining wall if you look at here this cantilever retaining wall this cantilever retaining wall; that means, it will retain this wall mass, because of your cantilever action. And braced excavation generally this excavation has been down below the ground surface to support to support these vertical cut, then anchors sheet pile also this, I have discusses also anchors sheet piles this anchors sheet piles has been provided to anchor a sheet or legible legible piles.

(Refer Slide Time: 25:23)



Now, lateral support this retaining wall, if you look at there is a gravity wall soil nailing wall, and reinforced earth wall. So, these reinforced earth wall, we are discussing this reinforced earth wall already we have finished. So, this is your reinforced earth wall soil nailing wall, and gravity wall. So, you should know little bit about your retaining wall.

(Refer Slide Time: 25:47)

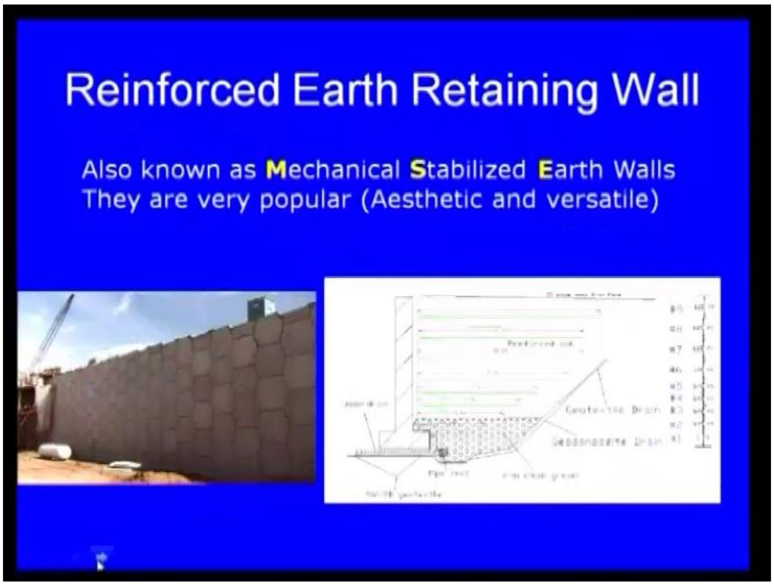


Now, gravity wall gravity wall, if you look at it will entire load will be taken by means of gravity actions gravity actions, and some photograph I have shown this gravity wall crib wall one of the crib walls some photographs as been shown good drainage it allow crib wall it is a good drainage allow plan to grow.

(Refer Slide Time: 26:11)

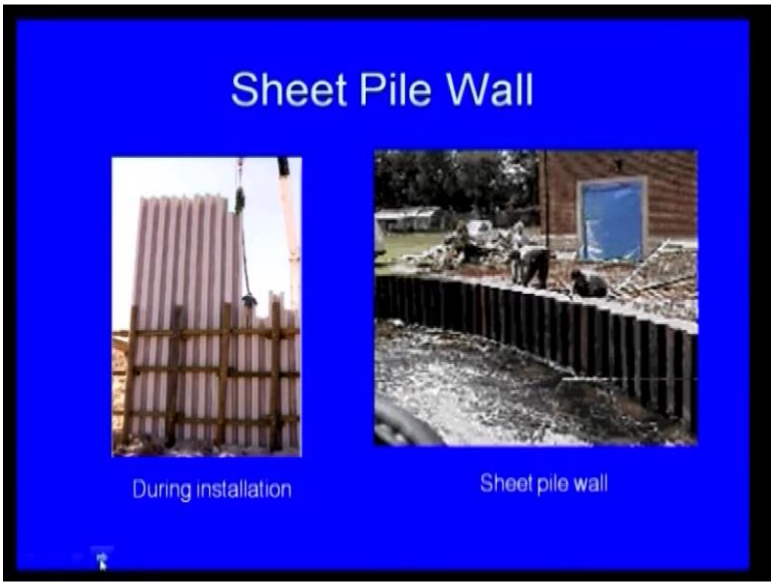
Then soil nailing wall, if you look at this soil nailing wall; these are all reinforced wall you can say it will look at this soil nailing wall this is your slope along this slope the soil nail has been provided if you see this is of, then reinforce soil nail walls if you see once again soil nail wall soil nail wall this nails how this nails as been provided.

(Refer Slide Time: 26:23)



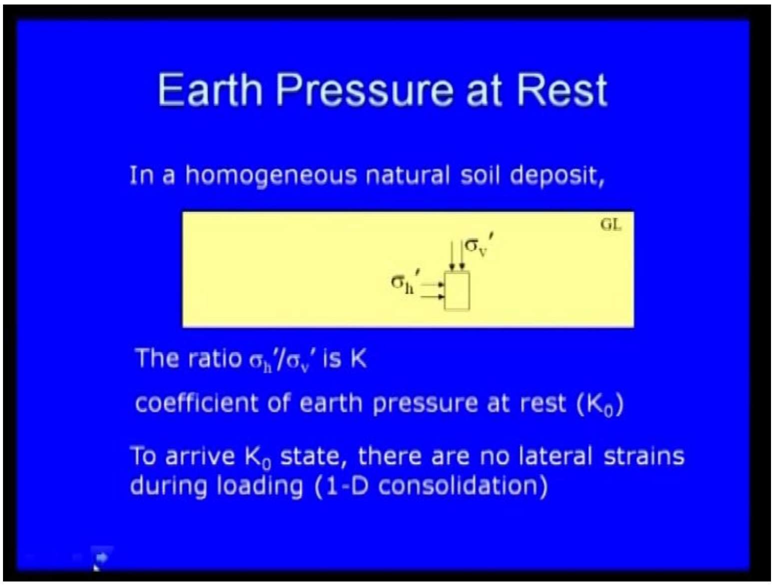
Here this nail here one nail here one nail along the length of the wall. So, this is again reinforced earth wall you can say that by means of soil nailing, then second is your third is you reinforced earth wall. So, layer of reinforcing material layer of reinforcing material layer of reinforcing material has been provided in the reinforced earth wall. So, mechanical stabilized reinforced earth wall it is called m s e mechanical mechanical stabilized earth wall; that means, mechanical it has been stabilized.

(Refer Slide Time: 27:16)



So, this is reinforced earth walls, then sheet pile walls how it looks earlier in the beginning, we are finish this sheet pile walls in this applications of soil mechanics, how the sheet pile walls has been built up one by one how been construct in constructed during the installation, and sheet pile wall how it looks one side.

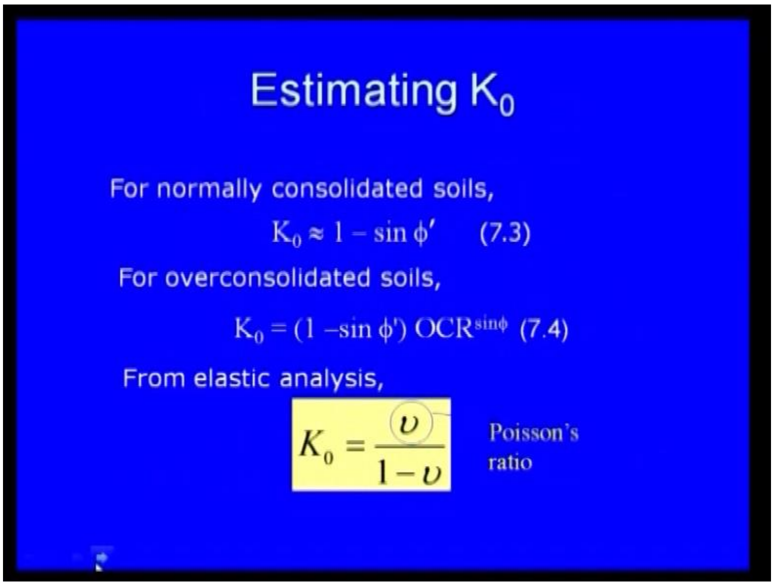
(Refer Slide Time: 27:37)



How it looks, then look at this earth pressure a rest if there is ground level, if you take a soil mass. So, there are we can say that sigma b, and sigma h. So, so the ratio of sigma h prime by sigma b prime is k that is called coefficient of earth pressure at rest that is your k zero to arrive k zero state.

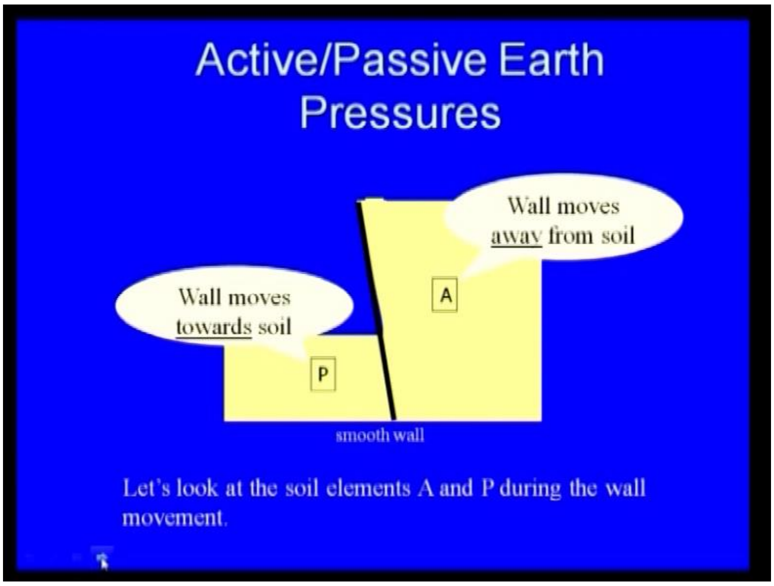
There are no lateral strains during the loading; that means, in earth pressure at rest condition there are no lateral strain during the loading; that means, one d consolidation only in vertical direction there is no lateral strain.

(Refer Slide Time: 28:16)



So, you can find it out k zero k zero is equal to one minus sin phi for normally consolidated soil for over consolidated soil k zero is equal to one minus sin phi into o c r sin phi for elastic analysis k zero for elastic analysis k zero is equal to mu by one minus mu.

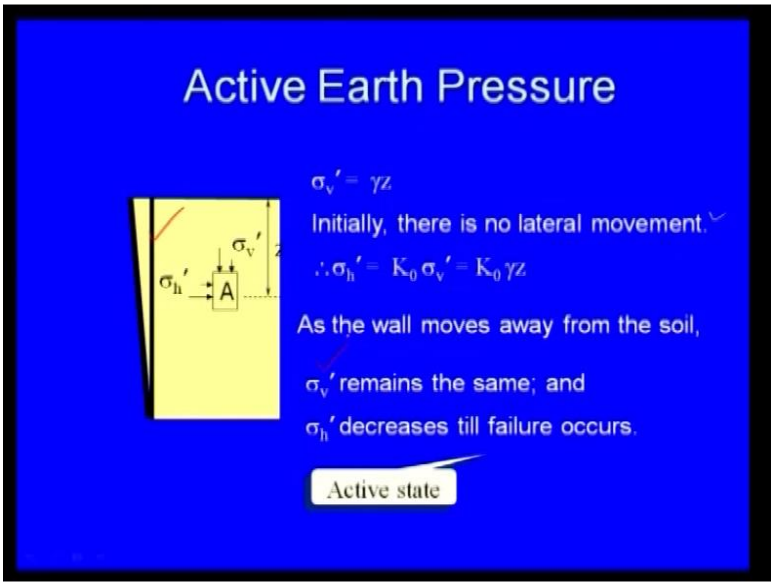
(Refer Slide Time: 28:44)



This is your collisions ratio mu by one minus mu this is your collisions ratio, then we will discuss little bit about active pressure earth pressure, and passive earth pressure if you look at active passive earth pressure by animation.

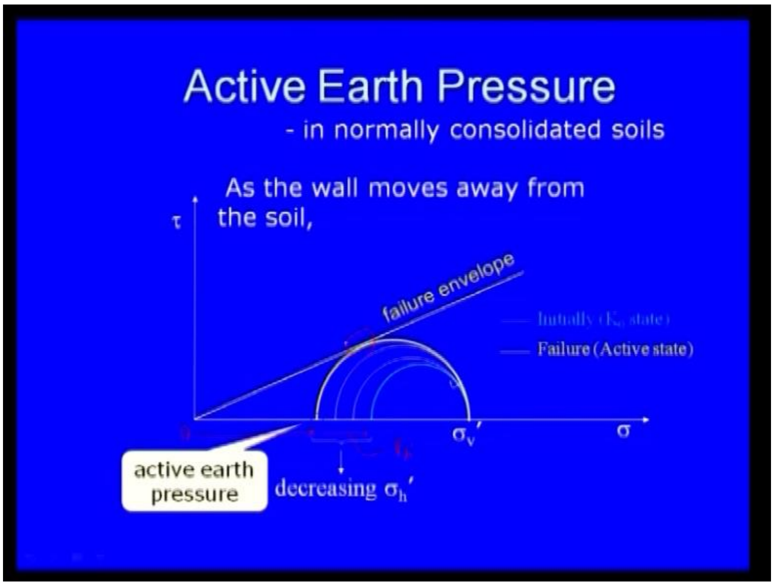
I will show you once again active passive earth pressure this is a soil mass there is a retaining wall this is a retaining wall, and this is a smooth retaining wall, and now because of a earth pressure it rotates it rotates or may be translate it can be go by means of translation; that means, this soil pressure soil will act pressure on the wall; that means, if this is the wall wall will move away wall will move away from this from this soil in that case it is called active state look at this, this is your active state in this condition wall is moving away from the soil; that means, it will act as a active state in this case wall is wall is moving towards pile wall is moving towards pile; that means, it is in the passive state.

(Refer Slide Time: 30:03)



If you look at this active state active earth pressure, if this is the sigma b prime initially at rest, and sigma h prime initially there is no lateral movement initially there is no lateral movement initially; there is no lateral movement, and sigma h prime is equal to k zero sigma b prime, that is your k zero gamma z as the wall moves away from soil. If this is my wall it moves away from the soil what will happen? Sigma b prime remains same sigma b prime remains same sigma h decreases steel failure occurs.

(Refer Slide Time: 30:52)



This is called active state for normally consolidated soil; that means, at k zero conditions.

If you see this is at this stage, then walls moves away from the soil walls moves away from the soil. Now for failure envelope develop; that means, decreasing value of initially from if this is the origin these two this will your sigma h prime. So, sigma b is not changing. So, sigma h is decreasing decreasing. So, it is coming the failure envelope mean this more circle touches your failure envelope that is called active sate. So, this is all preliminary or may be review of this active state, and passive state in diagrammatically or p p t form. I will discuss tomorrow for passive state also some of the review of this slides, I will stop it now.