Geo synthetics and Reinforced Soil Structures
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Lecture - 9
Different Types of Soil Retaining Structures

Hello students, so far we have been discussing about the fundamental properties of the geo synthetics and various applications, and so on. And from this module on let us look at the practical applications in particular in this module, we will study about the design and construction issues of the reinforced soil retaining walls.

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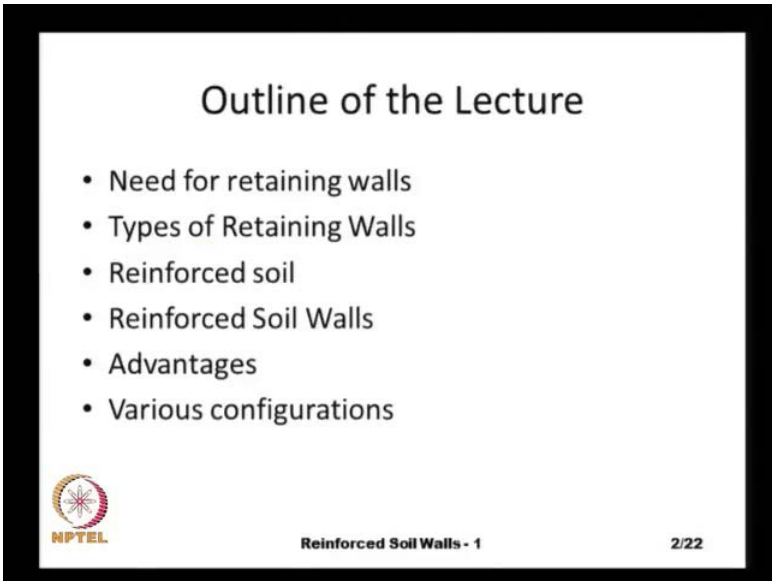

Brief outline of this lecture is we will look at the need for the retaining walls, and then the different type of retaining walls that we can have, and then what is reinforced soil, and what is a reinforced soil wall, and some of the advantages and various configurations that we can have with this type of construction procedure.

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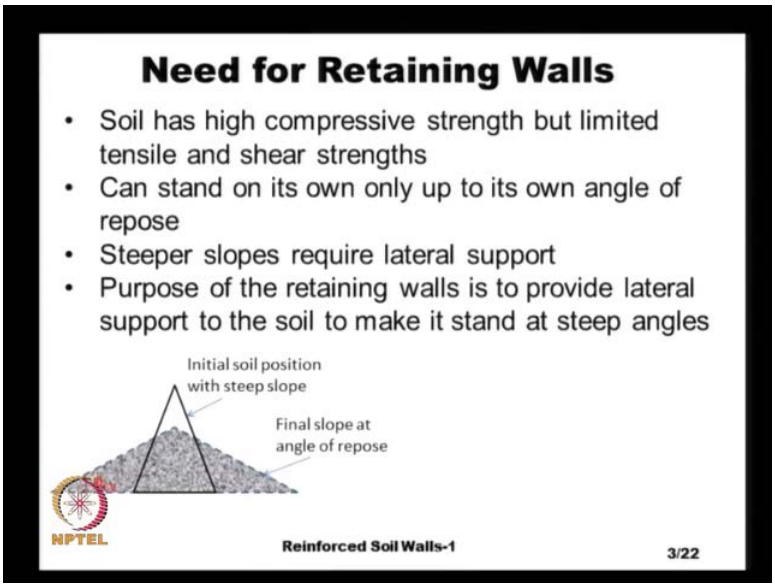

Well let us look at the need for the retaining walls, if we apply a pure compressive stress on the soil, it can take as much as you apply. But if you apply a normal compressive stress, with a free edge on the sides, then it can deform, because of the poisons effect. And in the process of deformation, it will undergo some tensile stresses and shear stresses. And unfortunately although the soil has very high compressive strength, it has very limited tensile strength, and then the shear strength.

And because of that reason it will undergo some failure and we all know that a soils can only stand, in stable condition, when they are placed at an angle less than or equal to their angle of repose. So, for example, let us look at the case here, let us say that by some means, we place dry sand at a very steep angle like this. And once you remove the confinement, this is what happens, the soil collapses to a more stable configuration. And that, this particular angle we call as the angle of repose and in variably this angle of repose will be equal to the friction angle at very large strains or at constant volume state.

So, we can say that, whenever we want to place the soil at an angle steeper than it is own angle of repose, we require some lateral support. So, that the lateral spread of the soil is arrested and we give some support and the purpose itself of the retaining walls is to provide lateral support. So, that it can stand at a steep angle.

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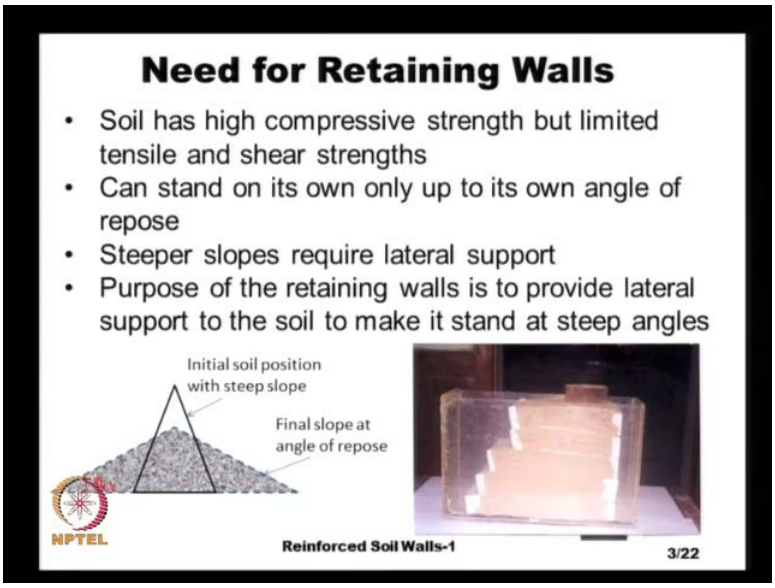

And one simple example is shown here. Here, we have a small retaining wall or the soil the dry sand, retained at vertical angle by supporting it with some paper, it is a computer printout paper and each tier is about 10 centimeters that is 100 millimeters. So, these 3 are 10 centimeters each and this one is 20 centimeters and one side, you see a vertical slope where as on this side, you see you have steps, number of steps we call this as a tiered wall. And this particular configuration, although it laterally supported by paper it could take 100 k g's weight without any deformation.

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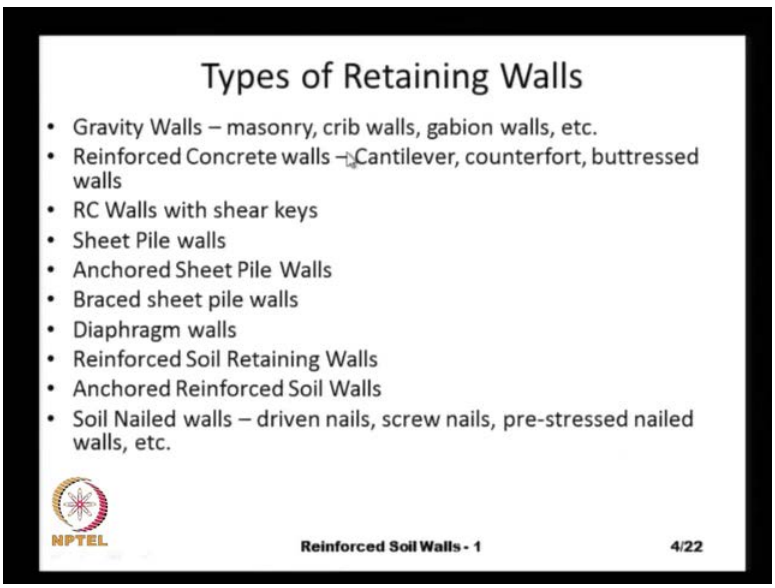

And number of retaining walls are possible using different types of materials. And let us look at some of these, the simplest one that people have been using for centuries together is the gravity wall. These gravity walls they derived their stability based on their mass or the weight that they have their own self weight and some of the materials, that we can have is the masonry, either bricks or stone masonry and so on.

And gabion walls, gabions as we have seen earlier, they are nothing but ire-mesh baskets and they can be filled with stones, to increase their mass. And we can use them for construction of retaining walls and then the crib walls. The crib walls are one simple way of explaining them is just imagine, used tires and just we lay them horizontal and fill them with soil and that becomes like a crib wall. And of course, we have number of these reinforced concrete retaining walls, different possibilities are the cantilever wall, counter fort wall, buttressed wall and so on. And in case of very high retaining walls, we also provide a shear key at the bottom. So, that it is lateral stability is improved and then we have the sheet pile walls.

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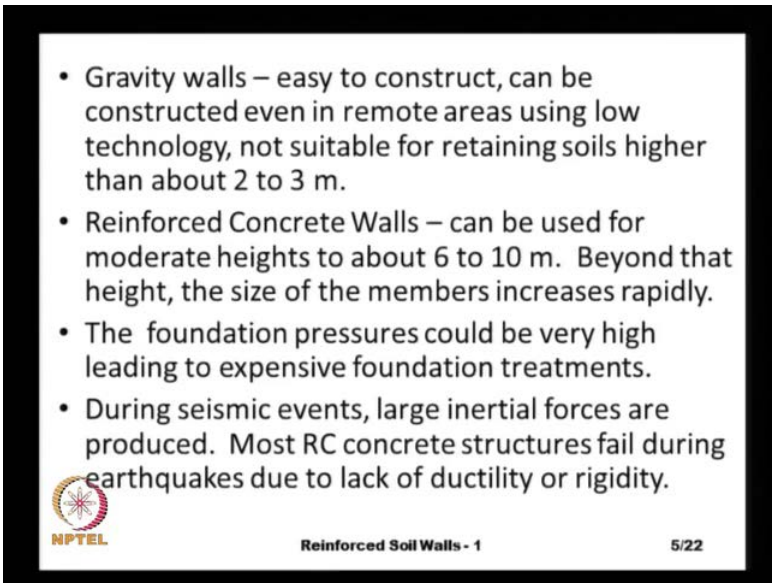

Especially for water French structures or at locations, where we cannot build retaining wall. We can just simply drive some sheet piles, that could be either made of plastic high strength plastic or steel channels, and so on.

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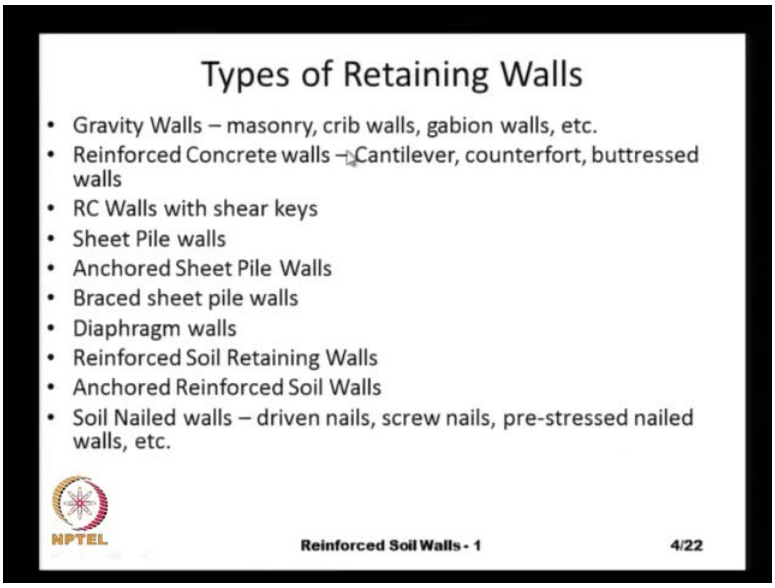

And then we can, if the soil to be supported is very high, we can have anchored sheet pile walls and this anchor itself can be provided in several manners. Then we have the braced sheet pile walls, especially for laying of conduits or pipe lines just by the road side, we have the sheet pile walls that are driven parallel to each other at very short, very close spacing. Then we put some braces in between to support them and then we can lay the pipe lines and after the construction work is over, usually these sheet pile walls are removed.

Then, we have diaphragm walls especially for very deep excavations in highly congested area, we can have a diaphragm wall that is constructed by using a different methods. Then coming to the topic of this course, the reinforced soil retaining walls they have become very popular. And in fact, all the highways in India are constructed using the approach roads are built, using reinforced soil retaining walls, and small modification of that or these anchored reinforced soil walls. And then soil nailed walls different types of nails that we can have that the driven nails screw nails pre-stressed nails and so on, we will see some examples of these as we go along.

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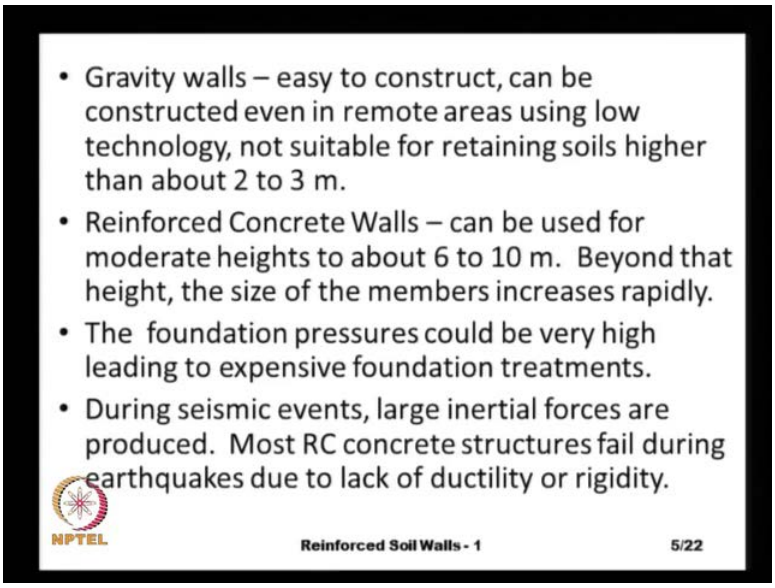

These gravity walls which is very old concept, these are easy to construct and can be constructed even in remote areas, using low technology. And we do not need much of skilled manpower to build these because it is basically assembling of meson units either bricks or stones and so on, they can be stacked, one and top of the other to retain the soil. And because this type of walls they derive their entire stability because of the self weight, they cannot be used to support soils to very great height.

And usually we do not prefer, using the gravity walls the pure gravity walls to support soils to more than about 2 to 3 meters high, beyond that it becomes very difficult because the size of the gravity wall increases tremendously. Then we have the reinforced concrete retaining walls and these can be used to moderate heights about 6 to 10 meters or even 12 meters and beyond that height, the size of the members increases rapidly. And because of that this type of walls they become uneconomical or it becomes very difficult to construct them because the size of the members become, So, massive that is not possible to construct.

And then one major disadvantage with both gravity wall and the reinforced concrete walls is that, the foundation pressure could be very, very high. Because, of the self weight and other features of this type of retaining walls and so we need very expensive foundation treatment in variably depending on the foundation soil. The foundation soil is not capable of taking the pressures applied, then we have to going for expensive pile

foundations, to safely transfer the load to a deep stratum where the soil is strong enough to carry the loads.

And another major disadvantage with these reinforced concrete retaining walls is that during the seismic activity, when the structures are subjected to large lateral deformations, repeated deformations. We produce lot of inertial forces because of the heavy mass. And once the inertial force is high, then they tend to destabilize this walls and it is common knowledge, that after every major seismic activity we have number of collapses of the reinforced concrete buildings, reinforced concrete bridges and so on. Whereas just next to them, if you have any reinforced soil retaining walls they stand perfectly well whereas, the reinforced concrete structures they undergo lot of failures. We will some examples of these, basically the failure is because of their rigidity or because of lack of ductility.

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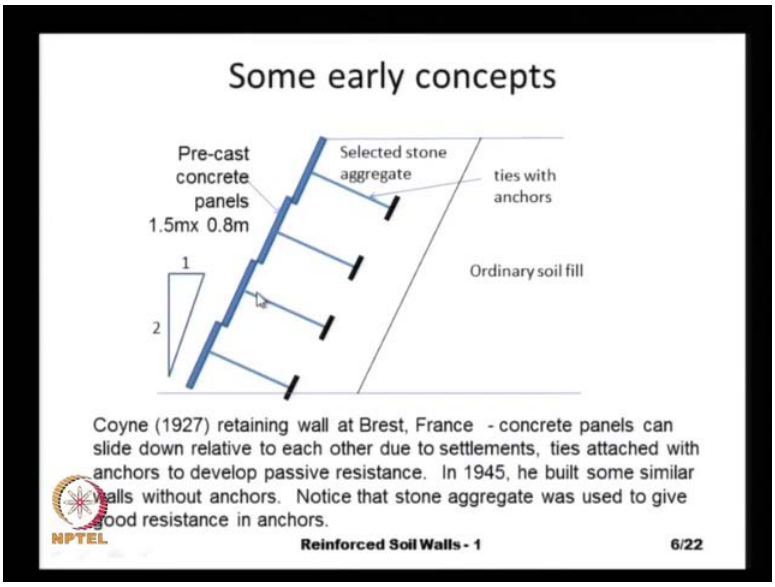

These retaining walls, they have been used for several centuries or even 1000 of years, as we have seen earlier even some 3000 years back our ancestors have built very, very high structures, as temples and other type of structures. And here, we see one example of a retaining wall, that was built by a French engineer by name coyne in 1927. They actually conceptually the wall that he has proposed is not very different from, what we are using now, currently you using, what he proposed is that, he proposed using a pre-cast concrete panels to stabilize the surface soil.

And these panels they are about 1 and half meters to 0.8 meters, and they are connected with an anchor rod and then a supported with a passive anchor at the back and in order to promote a good passive resistance, to some depth behind the facing panels, he suggested that should be filled with stone aggregate, and this always possibility for any construction that is built on the soil to settle down, because of the compression of the soil.

And, he suggested this type of arrangement where in each panel is laid slightly behind the bottom panel. So, that in case of any settlement, this panel can safely come down without damage in this panel and after gaining lot of experience, with this type of walls in 1945 he suggested that, this passive anchor can be removed because after gaining a lot of experience he has seen that, these ties themselves they are strong enough and they can, mobilize adequate frictional resistance to keep these front panels in place. And then this you notice that, this stone aggregate that he has suggested it has become. So, ingrained in the civil engineers that even in the present construction, we recommend the use highly permeable stone aggregate just behind the retaining walls.

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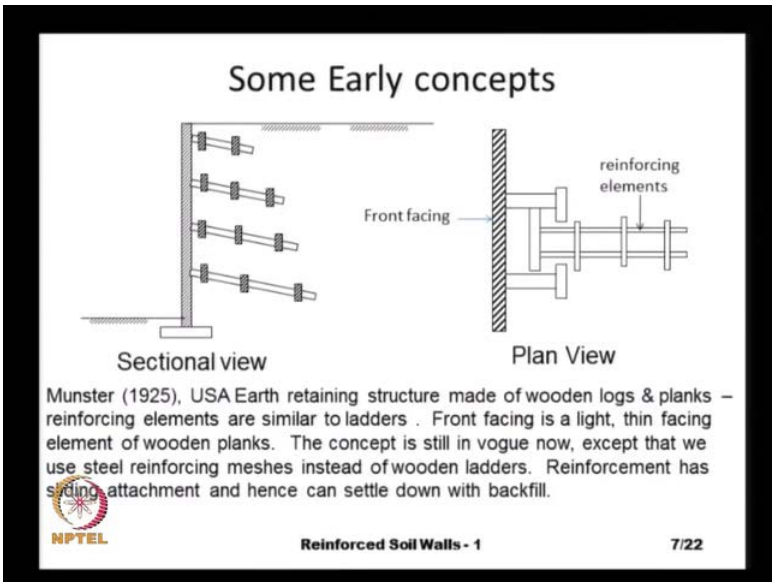

And one of the other early concepts that is quite significant was proposed by Munster in 1925 in the US and what he suggested, is that he suggested the use of timber and wooden panels and he suggested that, the surface soil can be prevented from erosion by using a light wooden panels. And then inside the soil is supported by a system that is very

similar to a ladders. That we normally use for climbing the walls and other things, just imagine that a ladder is placed in the soil horizontally, that itself could become like a reinforcing element.

And the wall that he has suggested is like this, in the sectional view it has a front facing, vertical facing and number of these ladders that are laid either horizontally or slightly at an inclination into the soil. And the arrangement of the front facing is that there is sliding arrangement and he did not recommend, connecting the reinforcing elements rigidly to the front facing mainly because in case of any settlements, if there is a rigid connection of the front facing, there could be very large connection stresses. And then if one member is trying to settle down whereas, the other member wants to same position there will be some stresses and there could be breakage.

And, so this wall concept was highly successfully applied, but unfortunately the material that is suggested is wood or timber, which has only limited life. So, it has not become very popular, but then this concept itself is very much invoke and now, also we use the same concept, instead of this a timber reinforcing elements we use polymeric type or steel reinforcement mesh's and so on.

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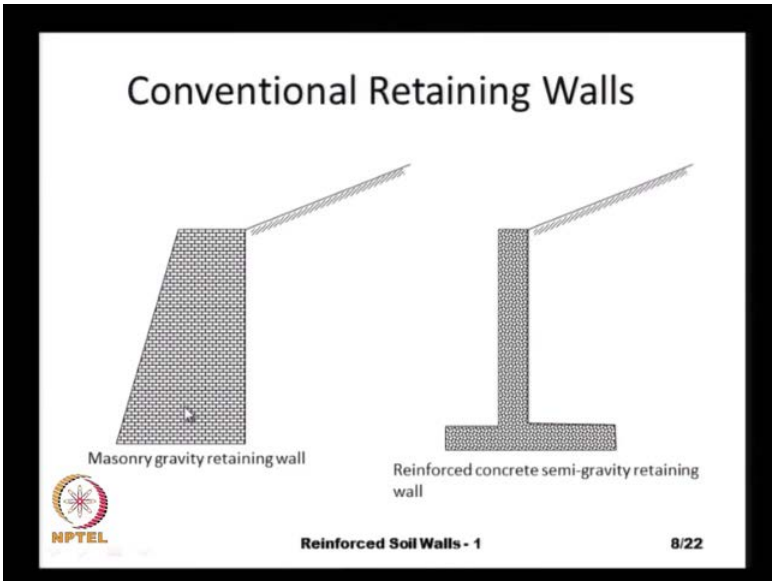

And let us now, look at the reinforced concrete retaining walls and so on. And the left hand side we have a masonry gravity retaining wall that derives, it is entire stability just based on it is weight and the advantage that it has is, it does not use any steel

reinforcement and it is basically, just arranging some stone, blocks and other things and if it is built with a very light weight material like bricks, we need to use some cement motor to bind all these bricks together.

And if we use heavy mass, like stone blocks or gabion units we do not need to bind them together, on the other hand we have this reinforced concrete retaining walls, these are also called as a semi-gravity and they depend on their structural action. So, all these reinforced concrete elements, they are structurally designed. So, that they can take up the bending stresses and the shear stresses that are applied by the soil and some part of the soil, that is resting on the heal portion he also supports the also gives the necessary support reaction. So, that the soil does not move laterally.

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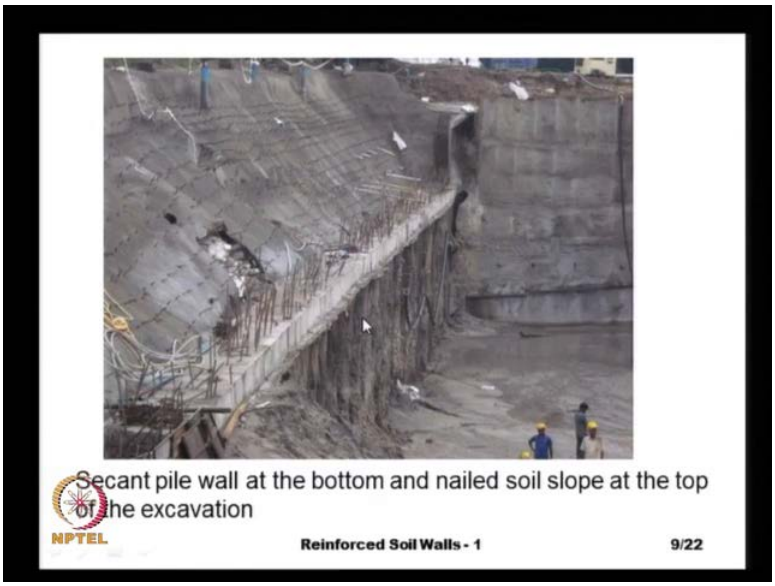

And here, we see a deep excavation that is underway in Chennai and this deep excavation is supported by, secant walls, secant piles at the bottom this is actually this is what we call as diaphragm wall. But, here the diaphragm wall is not made continuously, but it is made of the secant piles, that touch each other up to some height the excavation is supported by secant piles. And after this the top part is supported by nails, and the surface itself is protected by spray concrete and here, you see that these are all projections are all the steel nails that are driven. And here we can see the spray concrete, that was placed in placed there.

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And here is another example of a deep excavation, that is supported by some other method that is by using pre-stressed anchors, is actually these anchors are just steel rods that are driven in and their anchored in the soil, by means of some cement ground at back and then as after we drive them to the necessary depth, we place a cement panel at the front. So, that when we pre-stress this, when there is lot of a stress applied on the soil, there should be some we have distributing this compression over a very large area.

And, so this is what we do, we here you see this rod is attached to this concrete panel and then several of them could be connected by means of some steel members. And here you see, a pre-stressing force that is applied on this nail and the purpose is, once you apply the pre-stress the entire soil is kept in compression. And we know that, the soil is very strong in compression. And in the process of in the during the service life because of the self weight of the soil, it tries to apply some lateral force to deform the soil, but then this pre-stressing force will counter at it and keep the soil in stable position.

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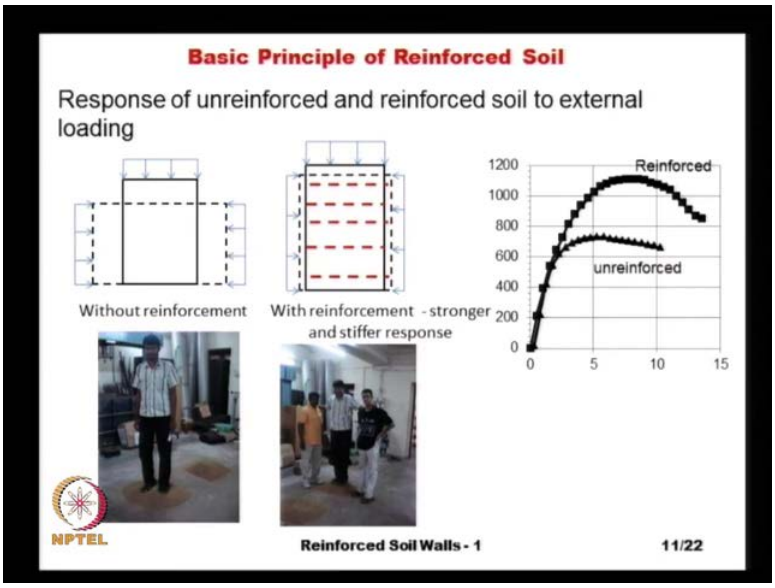

Well, now let us look at the principle of reinforced soil itself. This we have discussed a few classes back, few lectures back now let us briefly look at them, this is just imagine that this is an unreinforced soil and it is supported by, some confining pressure and when we apply some vertical stress or the deviator stress, it starts deforming. Once we apply, the pressure greater than it is capacity, it stars deforming.

And if you take the same soil and but reinforce it internally by some means, by putting an some reinforcement layers, the soil becomes more stable. And we can apply very large stress, much more than what we had applied on reinforced soil, without failing the soil or deforming the soil too much, this is what happens like here, the stress that, we can apply is much higher and then the deformation that we get would be also much smaller.

And here, we see an example of an unreinforced soil under track cell compression, it has developed some stress and then a reinforced soil which, develop much higher stress and sorry and the stiffness is also higher, for the reinforced soil. And the example is shown here, is actually these are the two soil pyramids that we had seen earlier, on the unreinforced soil when a student's stood, just immediately the unreinforced soil has given way and it has failed. Whereas, the reinforced soil, it is able to take the load without any lateral deformations.

So, that shows that, the interaction between the reinforcement that we place inside the soil. And the soil is the synergetic combination of these two materials, produces a

composite that we call as the reinforced soil that is able to take the load that is applied on the soil. And we can use this concept for constructing different type of soil structures like the retaining walls or embankments or pavements and so on.

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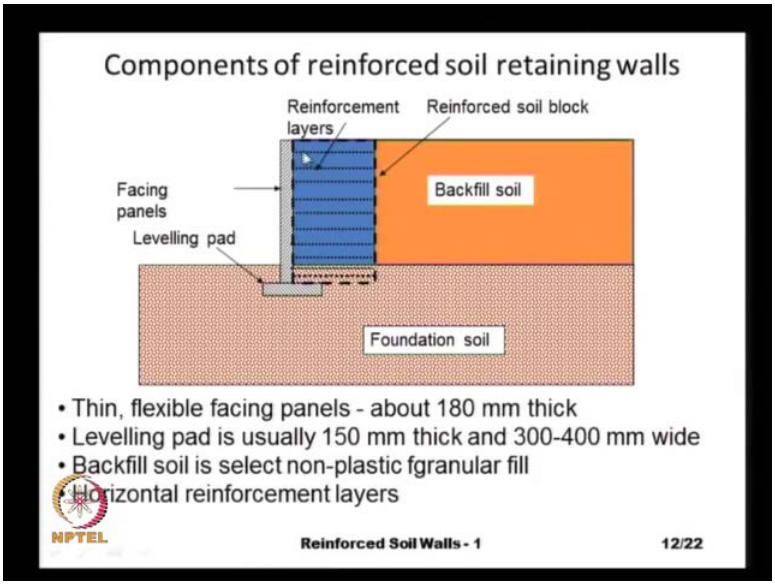

Well, now let us look at the reinforced soil. And once again, we have a vertical facing and then to support the soil and to transfer the load, we have a different mechanisms. And in all these reinforced soil, we have number of layers of reinforcement that is laid horizontally and the length of these reinforcement layers. And then the vertical spacing is actually that comes out of the design.

Depending on the type of foundation soil that we have and the type of the backfill, that we need to support and then the type of loading that we apply. The length of the reinforcement and then the vertical spacing goes on changing. And on the front face, in order to prevent the erosion of soil either because of wind or water we need to confine it by some means and there are different concepts originally when Henri vidal started it he suggested, the steel panels.

Now, we use only reinforced concrete panels and modular blocks. And even these panels, the maximum thickness is only 180 millimeters, we do not use anything more than that and these walls because they are highly flexible, they can tolerate any amount of deformation. And there is no foundation as such and there is only some leveling pad,

this is not to be confused with the foundation, that we provide on the or below the normal retaining walls.

This we call as a leveling pad, this is usually 150 mm thick and the width could be anywhere from 300 to 400 mm depending on the type of the panels that we use either panels or modular blocks and so on. And this is just a plane concrete PCC without any reinforcement. And they are called as leveling pad because mainly they are laid to a maintain the levels for construction.

So, that it becomes easy like once you take the levels at a along the length of the road or along the length of the wall, length of the retaining wall it becomes easy for people to go on placing the blocks and construct the wall. Then we have of course, the foundation soil and then the backfill soil. And the main component of these retaining walls, these reinforced soil retaining walls are these horizontal layers of soil and even without, the front facing this soil can remain in stable condition. But, then the soil will subject erosion because wind and water and to prevent these erosive forces, we need to provide some confinement.

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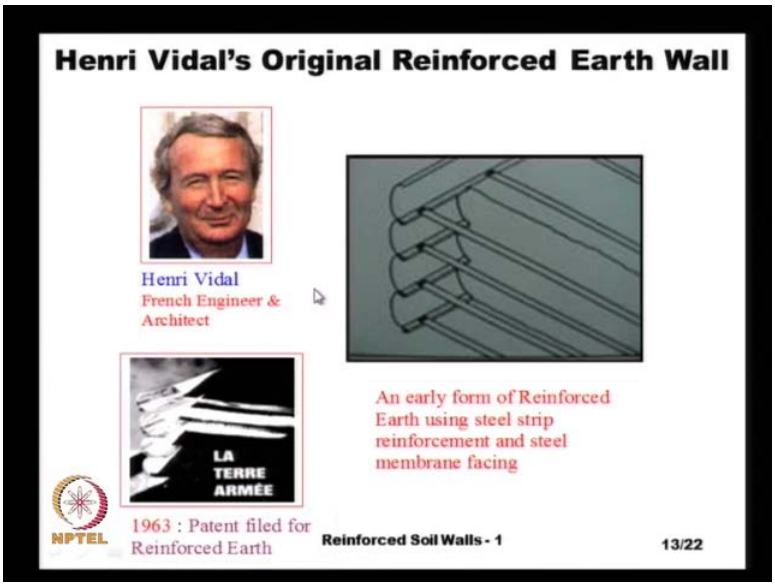

And this was the, original Henri vidal's proposal that we have seen earlier, and what he suggested is that, for the soil reinforcement he suggested using steel strips, which are about 50 mm to 60 mm wide and thickness is hardly about 5 to 7 millimeters thick. And

then the front facing is made up of steel membranes is actually slightly curved. So, that they have good esthetic finish.

And this was the original proposal that was given by Henri vidal in his patent application he has taken out a patent in the name of reinforced earth. And. In fact, we should not use the term reinforced earth because it infringes the patent rights of the company called reinforced earth and so we call it as a reinforced soil.

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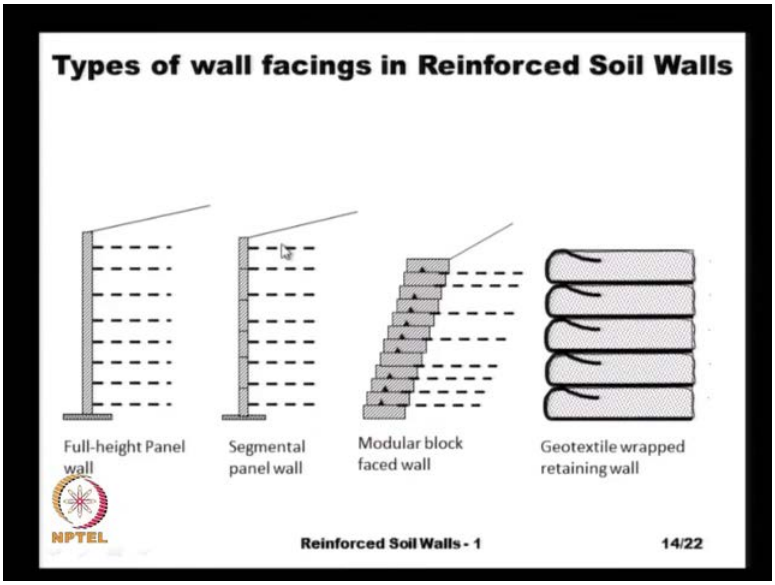

Different type of reinforced soil walls that are conventionally used are like this, we can use a full height panel wall. And usually when the soil height to be retained is very small, say about order of about say 3 to 4 meters and maximum 5 meters, we can have a single panel that is cast at the site. And then supported by some means externally, during the construction, we can have this type of full height panels. But, we normally do not prefer because handling such a large size panel is become it is very difficult.

And we have the segmental panel walls, each panel height is about 1 meter to 1 and half meters, on the thickness is in some companies use very thin facing panels about 140 mm and some companies use is 180 mm and so on. And these panels whether is full height panel wall or the segmental wall, they are connected to reinforcement layers. So, that there is these panels are prevented from lateral deformations.

And we have, these modular block walls, wherein each of these is very small block, the segmental panel wall each of these panel units could weigh as much as 1 ton 1 to 1.5 tons. So, we require a small crane to handle these panels whereas, the full height panel walls, depending on the height of the wall the weight could be very high. Modular blocks, these are very small in size and each of them they may have weight of about 25 to 30 k g's or maximum 30 k g's and these can be easily handle, by individual people and they will have a small shear lock.

So, that when these blocks are placed one on top of the other, it is easy for placing the upper block because we just try to align the shear lock and also we get, a small batter about 3 degrees batter backwards batter for esthetic appearance and for stability. And we can also have, what is known as a wrap around facing and usually when we have geo textiles, we can just nicely wrap them around, at the front facing. And fill the backside soil and we get facing which is known as a wrap around facing.

And usually, we do not leave them like this because geo textile this being a textile it is subjected vandalism, anybody can come with a knife and just simply cut the geo textile and then you can imagine what will happen to the structure. And so although it is given as a wrapper round, the front side is usually protected with rigid material, like a spray concrete or a detached retaining wall, that is made of modular blocks or panels and so on.

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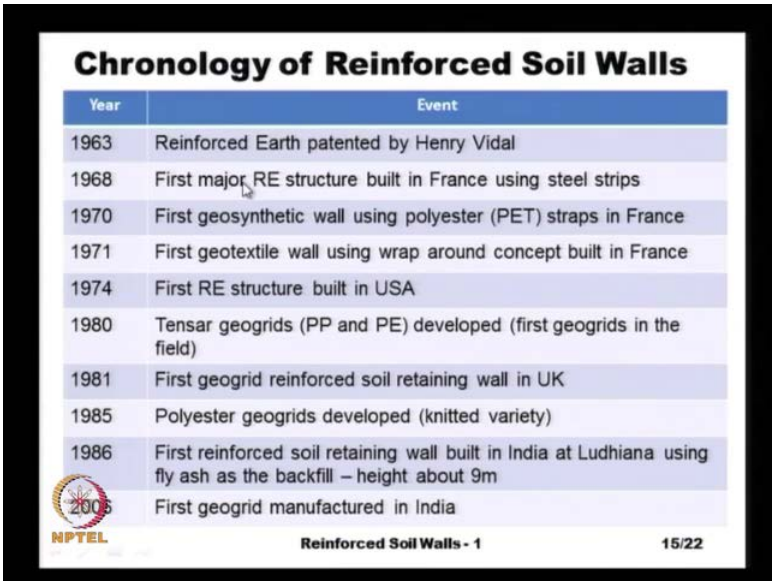

Is actually it is very interesting, to look at the chronology of the reinforced soil walls, in the year 1963 the reinforced earth was patented by Henri vidal. And it took almost 5 years for the company to convince the government to employ this technology for actual construction. And the first major reinforced earth structure was built in France using steel strips, which are 50 mm wide and about 6 millimeters thick, and 1970, the first geo synthetic wall using polyester straps in France.

Once again in France most of the early walls that, were built were in France because that is where most of the major developmental work started. And then 1971 the geo textile wrapper around wall was built once again in France. And it took almost 60 years for the technology to sorry almost 11 years for the technology to spread to the US, and in 1974 the first reinforced earth wall was the built in the US.

And 1980 the tensar company, they have come out with polypropylene and polyethylene geo grids, which are stressed the stretched type, this was in the UK, and in 1981 these geo grids were used for constructing of the construction of a retaining wall, that is once again in UK. And in 1985 the polyester geo grids, the woven and netted type they are brought out and in 1986, only we had the first reinforced soil retaining wall built in India, this was built at Ludhiana. And the maximum height of this wall was 9 meters, and the backfill that was used was fly ash pond ash. And in 2006 India has produced the first geo grid that is polyester geo grid.

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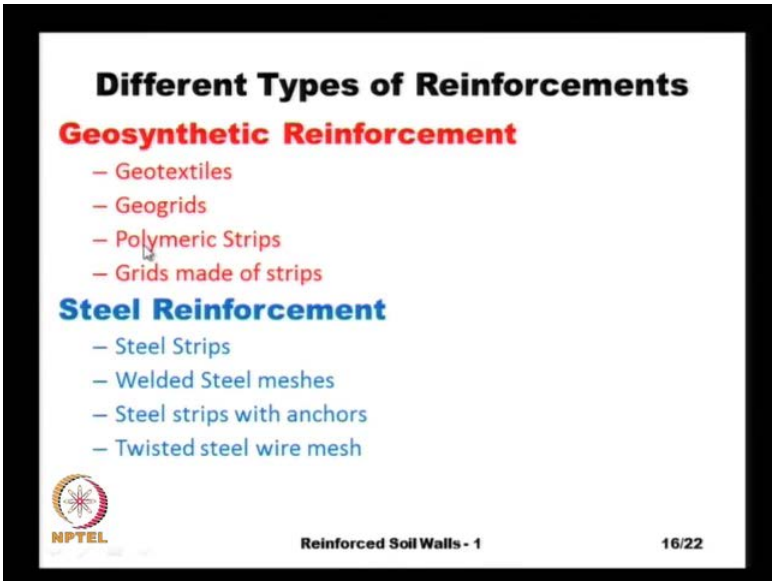

We use very large varieties of materials, both polymeric and also the metallic. And let us look at some of them, the geo synthetic reinforcements that are commonly in use in the industry, they are geo textiles. And then geo grids, polymeric strips and then the grids made of these polymeric strips. And then the steel is used in the several ways, the first application of the steel was in the form of steel strips. And then we have the welded steel meshes or welded wire meshes and then we can have the steel strips with anchors. And then we can have the twisted steel wire mesh that itself can act like a reinforcing element.

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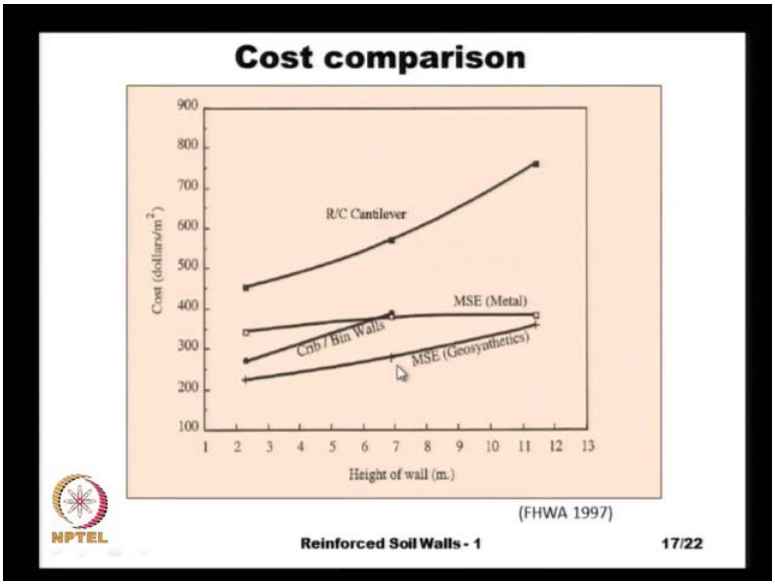

In 1997, the federal highway administration in the US. They have, then in extensively comparing the costs of different type of retaining wall systems and they have published this chart. And in all the they have published this chart, in terms of the height of the wall and the maximum height of the wall that is, the data was collected was up to 12 meters. That was in 1997, but in the year 2012 the height of the retaining walls as increased more than 50 meters.

Some of these walls, are as high as 100 meters, see even at small height of 2 meters, the cost of the reinforced concrete retaining wall is about nearly 450 dollars per square meter. Whereas, the MSE that is the mechanically stabilized earth wall, with polymeric reinforcement that is the geo synthetic it is hardly about 225 dollars whereas, the metallic reinforced wall, it costs about 350 which is, still less than reinforced concrete retaining

wall. Even at very small height of 2 meters, there is a significant reduction in the cost of the these walls.

These, costs are given in square meters, then as the wall height increases the cost of this reinforced concrete retaining walls, it increases exponentially. Mainly because in these reinforced concrete retaining walls as the height increases the bending the moment increases as a square of the height and as the bending moment increases the requirement of the steel increases. And the major cost of any reinforced concrete retaining wall is in the steel, whereas in the other structures like the reinforced sorry the reinforced soil walls.

The steel quantity that is used is very, very little and the cost comparison for crib and bin walls is something like this, these crib walls they are not used for very, very high heights about 5 to 6 meters. And we here we see that, at wall height of about nearly 11 to 12 meters, the cost of the metallic wall metallic reinforcement on the cost of the geo synthetic reinforcements, they are very close together. But, at very short heights it is more economical to use polymeric type reinforcement rather than, the metallic type reinforcement.

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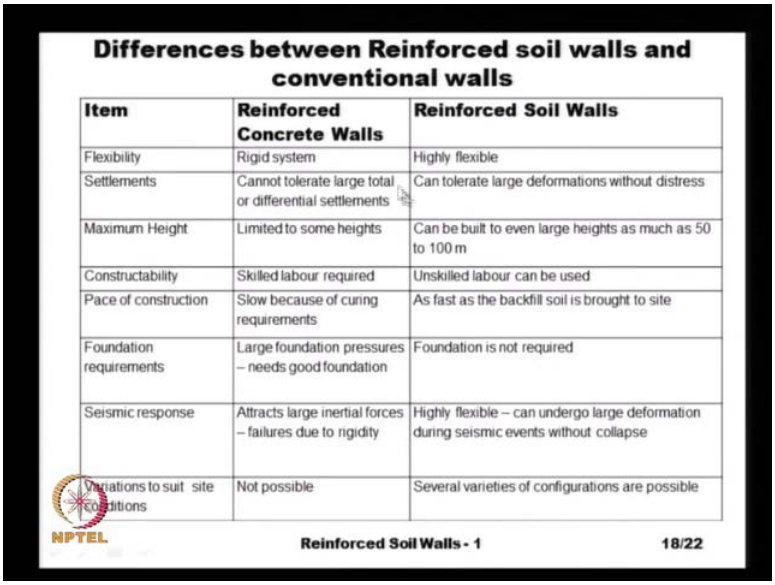

Let us look at, the major differences between the reinforced concrete retaining wall and the reinforced soil walls. And for different qualities of this behavior, lets look at the flexibility, the reinforced concrete retaining walls they are rigid by nature because they

have heavy sections and then heavy reinforcements. And because of that their nature of behavior is rigid, the reinforced soil was their nature is highly flexible because we use very soft, reinforcement materials.

Either grids or textiles or even the steel that is used, it is not used in very large quantities and the steel employed is, so small that the soil is predominant material that is, in the retaining wall and because of that the entire system is very, very flexible. Then let us look at the, tolerance to the settlements or deformations. Reinforced concrete retaining walls they cannot tolerate large total or differential settlements. Because, once there is settlements there will be some shear stresses developed or bending moments developed and because of that they crack.

Whereas, the reinforced soil retaining walls, they can tolerate large deformations without any distress. In fact, as they deform the reinforcements, reinforcement layers they develop or they mobilize higher tensile forces and then the wall becomes more stable. And all these reinforced soil retaining walls, they had designed. So, that they can deform a little bit, either during the construction or during the service life to mobilize their tensile forces.

Then, lets look at the maximum height to which these structures can be built and the reinforced concrete retaining walls, their height is limited to some height may be about 10 meters. But, beyond that their cost increases and the dimensions of the size the members, increases and it becomes very un uneconomical or practically impossible to build this type of structures. Whereas, the reinforcing soil retaining walls, they are easy to build even to very large heights. In fact, in India itself the walls that were built are nearly 50 meters.

And now, there is a steep slope that is under construction in Sikkim, the height is about 110 meters. And these can be built without any problems because of the flexible nature of this material and then the constructability, we require skilled labor for the construction of reinforced concrete retaining walls because we need to produce concrete in a factory, bring it. Then once it is brought it has to be placed and then vibrated under compacted,. So, that there is a dense concrete.

Whereas, the reinforced soil retaining walls they wee can use unskilled labor because basically we bring some precast elements and assemble them at the site. And the pace of

the construction that is, the speed at which we can build up the wall, it is the reinforced concrete retaining wall the pace is slow because we need to cure the concrete. At each and every stage, we need to cure and we cannot just simply go on constructing the wall in the height direction.

Whereas, the reinforced soil wall the pace of construction depends on the speed at which you bring the backfill soil, the faster you bring, the faster you can construct because the reinforced soil walls, they employ only precast elements, they just simply brought to the site and then assembled. And the foundation requirements, the reinforced concrete retaining walls, their foundation pressures are very high. And because of that they require a very strong foundation in the form of very large, mats or deep foundations like pile, appears and so on.

And the reinforced soil was, as such they do not require any foundation, they do not require any foundation at all. The seismic response it is the reinforced concrete walls, they attract very large inertial forces because of their high mass. And the reinforced soil walls because they are highly flexible and because their mass is only predominantly soil and some plastics, their mass is much lower compared to that of the concrete and because of that the inertial forces are much lower.

And let us look at, the major difference between a reinforced concrete retaining wall and the reinforced soil wall is the ability of the reinforced soil walls to be adopted, we can depending on the site condition that we have, we can come out with very large number of variations, in the way we apply the reinforcement. Whereas, in the case of reinforcement concrete retaining walls that variation is not possible. Because, the form is very simple or straight forward in the case of reinforced concrete walls and you cannot change it much.

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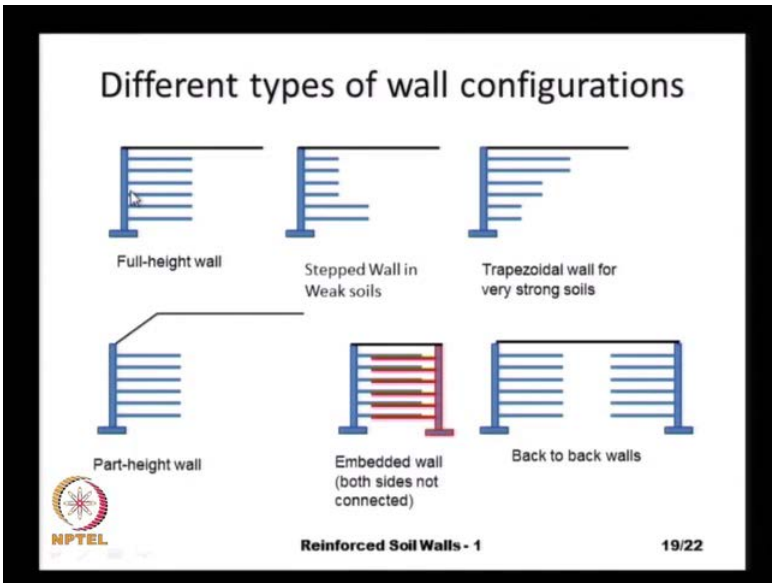

Let us look at these varieties of these possibilities, the simplest wall configuration for the reinforced soil wall, is a straight wall like full, we call it as a full height wall with some length of reinforcement. Is actually here, I have shown equal length and equal spacing, but it is not necessary, we can have variable lengths and then variable spacing, usually the spacing of the reinforcements reduces as we go into the soil with depth, because the lateral pressures are higher at deep depths, as compared to the soil at shallow depths.

Then, we have a stepped wall, is actually if we employ this type of full height wall with say equal reinforcement layer and say, we have at the bottom, we have a weak foundation soil, the entire structure can settle down. And to prevent, to restrict the settlements what we can do is, we can increase the length of the reinforcement at the bottom layer. So, that the pressure that is coming from the wall, it is distributed over a over a larger area.

And, so this is actually that is the advantage because the entire thing is assembled at the site, and the length of the reinforced block, we can control. And so by increasing the length of the bottom reinforcement layers, we can spread the weight of the retaining wall retained soil or wider area. And this is usually, used in the case of weak soils and we have water known as trapezoidal walls whereas, in this case the length of the reinforcement layers increase, as we go up.

This type of configuration, is used when we have very strong foundation soil, like for example, at a very shallow depth we have rock, and so there the requirement of the reinforcement is very small because the foundation soil is, so strong. But, then as you go to the top, you may require longer length because if you plot the rankine failure surface it may be something like this. And we need some anchorage, into the stable soil mass that is in the passive soil mass.

So, usually we increase length of the reinforcement as we go up, then we have a part-height wall whereas, we have some height of the soil, supported by soil reinforcement. And the other path could be either unreinforced or reinforced depending on the slope, that we provide then we have embedded wall. So, especially when you are constructing retaining walls on both the sides of a narrow road. And with very high height, the length of the reinforcement layers may be, so height that the reinforcements coming from both the sides they overlap each other, this we call as an embedded wall.

And you may think why not we just simply connect this wall to this wall that, should not be done. Basically because the reinforcement layers that design by considering only the friction that is developed between the soil and the reinforcement layers. But, then when we connect the two walls and because the both are independent walls, one of them may be settling down more or deforming more because of the variations in the soil the foundation soil or because of the variations in the applied load.

In that case, it will be a disaster because the reinforcement will simply rapture and that may lead to problems. In the stability of the retaining wall and because of that we just simply embed the reinforcement with some overlap and with some height difference between the, different reinforcement layers. And then there is another possibilities back to back retaining walls that is, this happens when you are constructing approach roads of very, very large width, let us say some 24 meters or 30 meters. And the height of some 10 15 meters, the reinforcement length is not sufficient to cover the entire width, this we call as a back to back wall.

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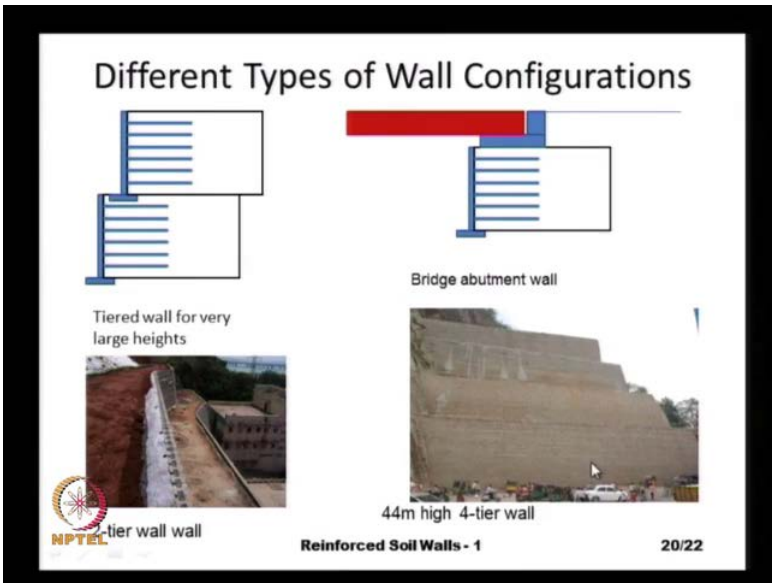

And we can also have tiered walls, especially when you have very high height of soil to be supported let us say some, height of the soil. And it is more easy to construct with some offset at each level. So, that we have good esthetics and constructability also becomes easy. And in this case, we build what is known as tiered wall or a piggy back wall, we construct some height of the retaining wall and we have an offset, then we construct another retaining wall we give some offset and we give, we construct another retaining wall and so on.

Some examples of these tiered walls are shown here, is actually this is a two tier wall and you can see, this is the bottom wall there is some bum. In this case this is 5 meters and then after this offset, this wall is built, the bottom wall the height was 12 meters whereas, the 10 the in the upper wall is 10 meters, total height is 22 meters. And the right hand side, you see a 44 meter wall and the bottom wall is about 12 meters and the remaining is spread between these 3 wall these 3 tiers.

And we in variably, we can support even the bridge abutments directly on the reinforced soil. And one example is shown here, is actually this is called as a bridge abutment wall, the soil is highly reinforced and directly on top of that, we can place the bridge abutment that supports the slab. So, these various configurations can be easily adopted to suit our own requirements, based on the foundation conditions and based on the loading conditions.

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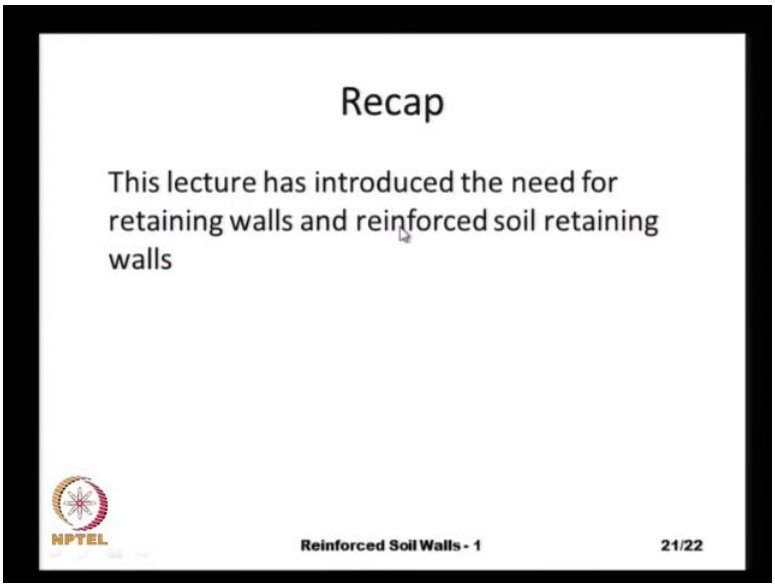

Just recap this lecture, we have introduced the different type of a retaining walls, we have compared the reinforced soil concept, with that of the earlier concepts. Like the reinforced concrete retaining walls. And then we have seen the different configurations and how we can adopt the reinforced soil technology to suit our specific site conditions.

Thank you.