**Geosynthetics and Reinforced Soil Structures**
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**Lecture - 10**
**Construction Aspects of Geosynthetic Reinforced Soil Retaining Walls**

Hello students, let us continue our discussion on the Reinforced Soil Retaining Walls. In the previous lecture, we have seen the different varieties of geosynthetics materials, and then the steel materials that we have for construction and the various configurations that we can have with the reinforce soil walls. And then their advantages and disadvantages as we saw we the reinforce concrete retaining walls and now lets continue our discussion on these walls.

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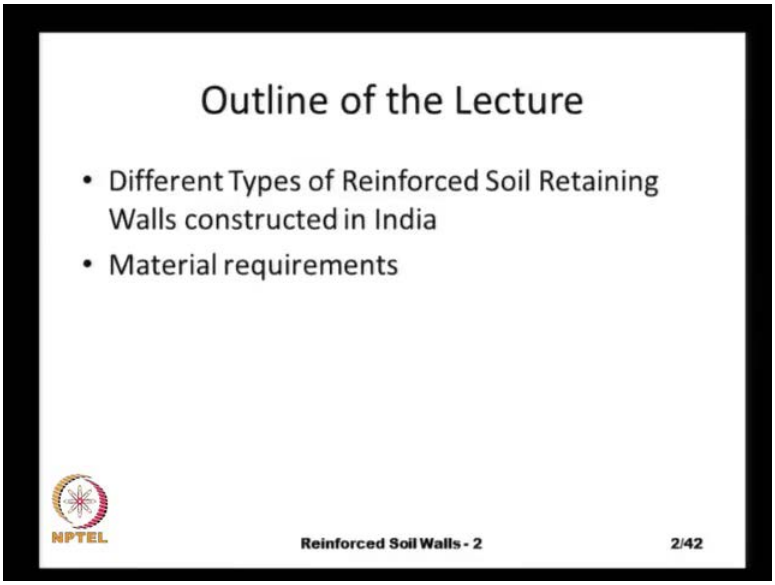


And the brief outline for this lecture is we will go through the different types of retaining walls, that are built in India as we go through we see some construction aspects and some material requirements and so on.

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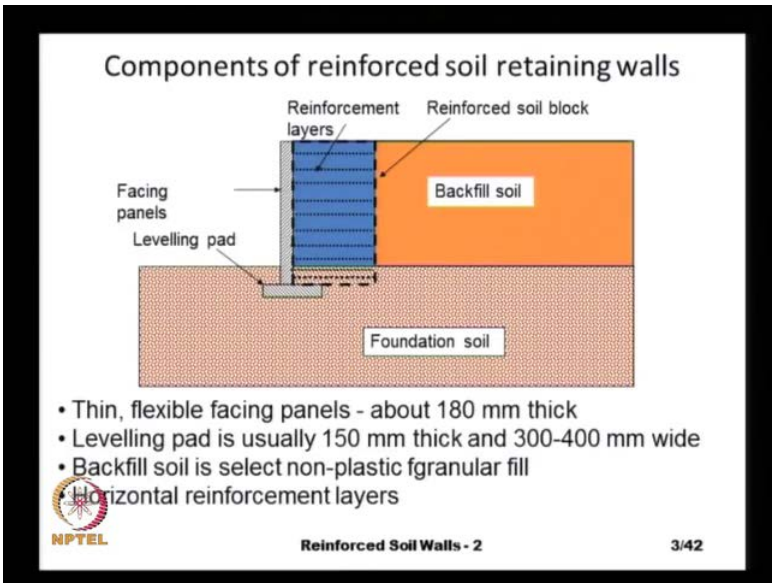


Just recap reinforce or retaining all consists of facing panel and then number of horizontal reinforcement layers that could be their geosynthetic that is polymeric or metallic in the form of steel. And then we have good granular re back fill that we have within the reinforce block then the back fill and the foundation then of course, leveling pad to maintain our levels.

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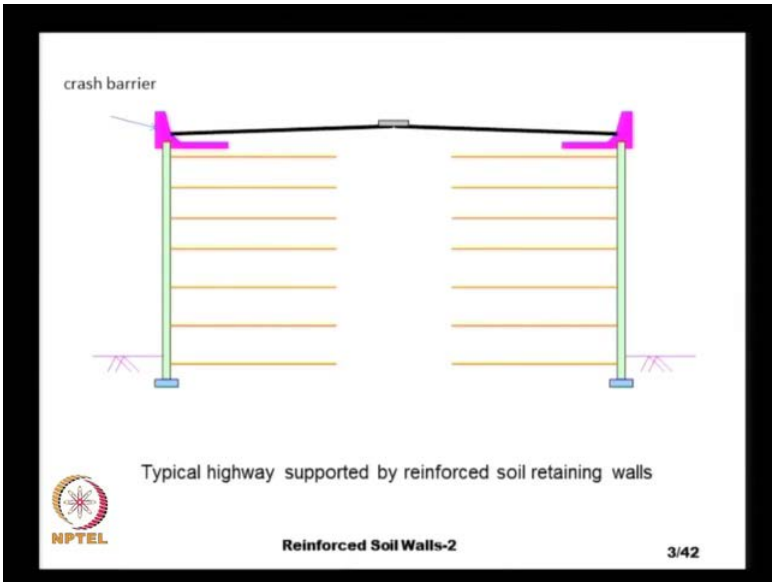


And here you see a cross section of a typical highway approach role and both sides you have the reinforced or retaining walls, then on the top you have a crash barrier, crash

barrier is a small structure to prevent any small accidents from happening. So, that people do not overturn then this is the mean this is this median, and as we have seen earlier this is called as the back to back wall, because the two walls are far away from each other. And there is no overlap in the reinforcement and there is a clear space in between the two reinforce zones.

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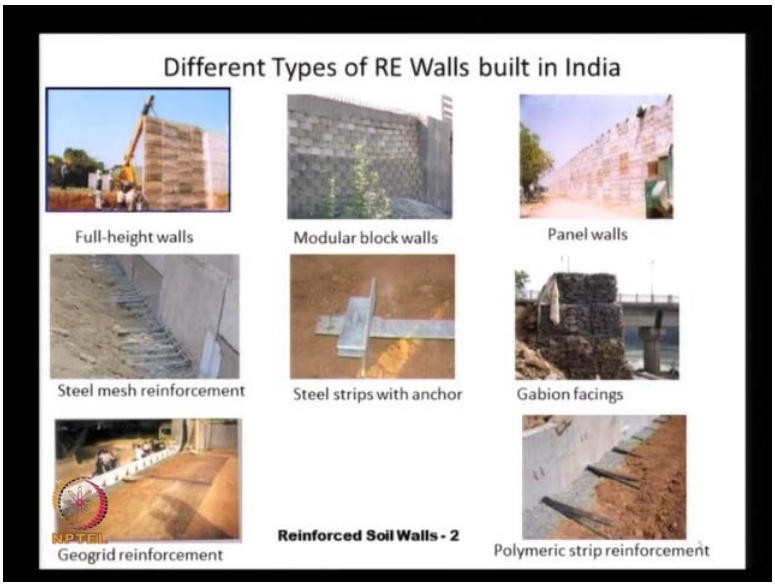


Well, just to give you an overview of the different type of retaining walls that are built in India, some walls were built using the full height concept and some walls were built using modular block walls then panels. And then once again panels and these walls these two walls were built using polymeric reinforcement whereas, here we have steel mesh and here we have a steel strip with an anchor. And here we have a gabion faced wall, then we have a geogrid reinforcement here, we have polymeric strip or strap type reinforcement.

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Well, as I mentioned the full height panel walls the advantage is there is no assembly required of individual modular blocks or the individual panels and when the height is limited to about 3 to maximum 5 meters. We just simply crust one full height panel and the bring it to the side and then by means of a crane and then support it, and then actually as we cross this panel some short lengths of reinforcement or embedded in the in the concrete.

When, the concrete is still fresh and once the concrete is set and when the panel is put in place, we attach the longer length of the reinforcement for the short length through some type of plastic bodkin and so on. And we actually these are all the different panels that are there, and the main problem with them is handling, because the weight of each of these things each of these panels could be anywhere from 10 to 15 tones depending on the on the height and then the size and other things the width of the panel. So, we need a very heavy crane and then during the handling the panel should not undergo any distress in the form of cracks or breakage and so on.

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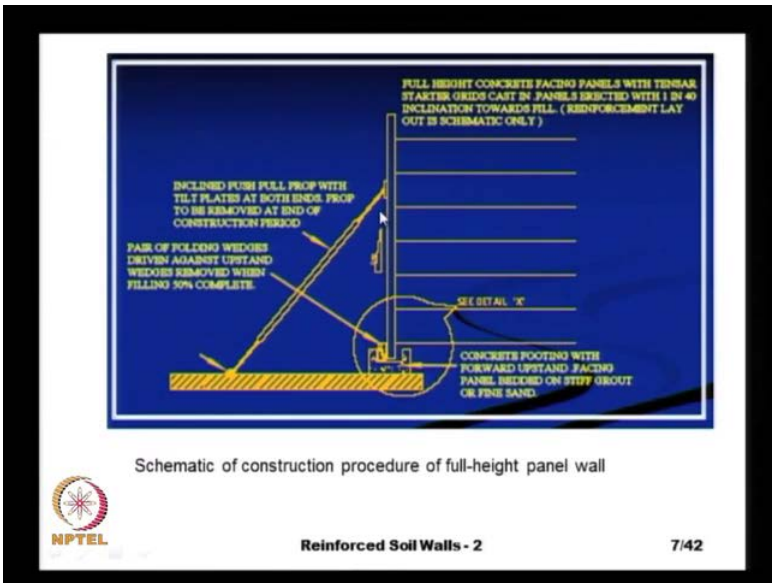


And here we see the a cross section of the full height panel wall a schematic sketch, it needs to be supported by means of some external props, and during the construction what we do is here at the bottom we have the leveling pad, we place it carefully. And we give some inward batter all these walls they are given some inward battle, that is their incline into the soil, the reason is as they are inclined into the soil and when the during the construction the soil is placed in layers.

And then after the full height of soil is constructed gradually, because of the lateral forces that are acting the wall becomes stable and in a vertical position. And it might even have some outward batter depending on the type of reinforcement, and the type of connection that we have and the reason why we want to do that is we need to mobilize some deformations. That will create some strains in the in the reinforcement layers, so that they can develop their force, and the these connection details are I will show them in some other lecture when we are doing the actual design, and here you see a far off picture the same thing.

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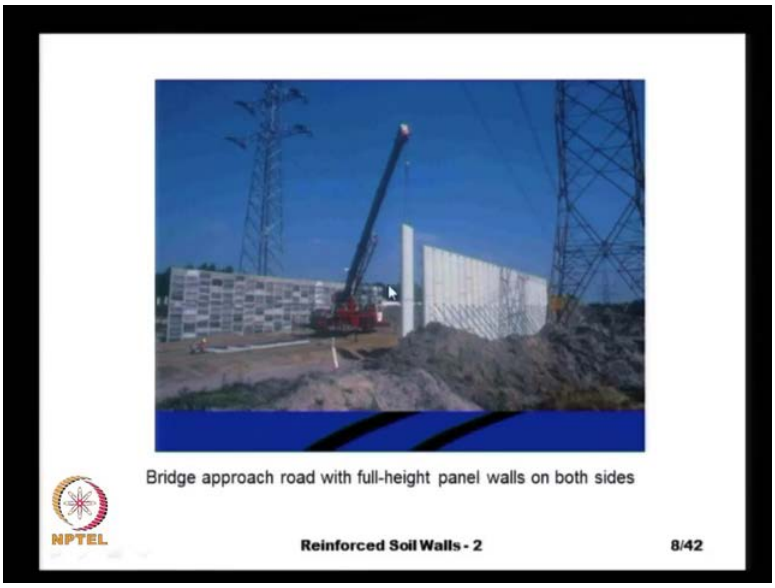


These two retaining walls, they are built as part of approach road to a approach ramp to a bridge to a flyover.

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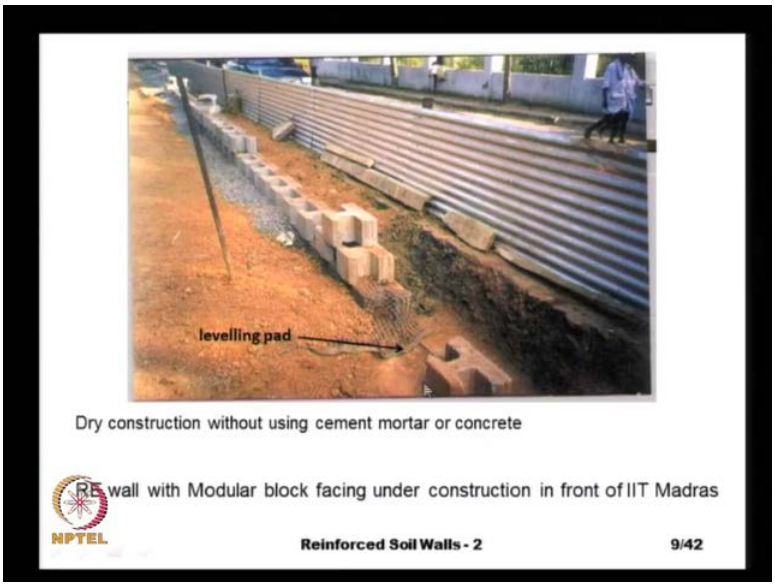


And this particular wall that was built right opposite to the IIT Madras campus, in the 1996-97 period, this was built using modular concrete blocks and these are so small that each of these blocks weighs only some 25 to 30 Kg's. And they can be handled very easily and this particular wall was constructed as part of a an approach road for a road

over bridge, built just next just in front of the IIT campus in fact, this is the compound wall of the IIT campus.

And the construction especially in the city areas should be such that the normal traffic is not obstructed, and because of the technology that is applied here the road traffic is allowed and both sides of the construction. And here you see the leveling pad is actually this the there is no such foundation only about half a meter of the existing road was cut, and then they the construction started with a small leveling pad.

And here you can see the leveling pad with a small notch in between and we assemble these modular blocks the depth of each of them is nearly 250 millimeters the height is 200 millimeters and the length along the length of the wall is nearly 400 millimeters. And we call this type of construction as a dry construction, because we do not use any cement water or concrete to join all these blocks together, and these modular blocks they are made by pressing by cold pressing in a in a factory and they are brought to the site.

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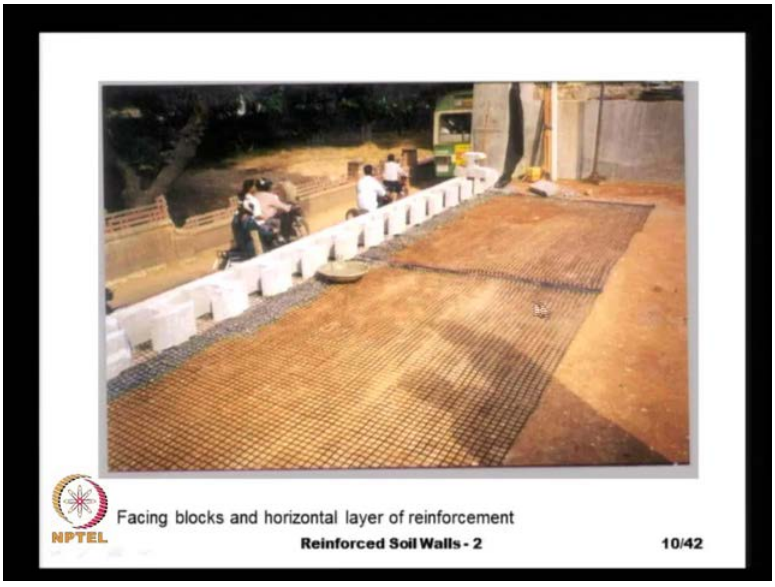


And here you see the other side of the wall during the construction and that are appropriate places we place the reinforcement layer. And here you see one construction scene and the seem is given not in the direction of the load, because in the retaining walls, you know that there is an outward pressure acting into the wall. And so the scene is given in the length direction in this direction, because there is a if we had given the seem along this length and if the seem is weaker than the reinforcement material, then

the failure may happen and with result that the reinforcement that is provided may not be able to generate adequate force to for the stability of the wall.

And here you can see the aggregate that is placed just behind this facing block, the purpose of the aggregate layer is to filter the water to prevent any fine soil particles from disappearing, from the back fill. And another reason specially in the context of the city roads is that if there is any loss of the fines, we form one streak of dirty soil along the along the length and height of the wall that becomes not, so good to look at. It becomes Nisor and we to prevent that also we require a filter layer and as per the ministry standards we decide the gradation requirements and then of course, the thickness is anywhere from 300 to 500 millimeters depending on the wall height and then the rainfall and so on.

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And here we see a close up of the same thing of these modular blocks, and then we see these reinforcement layer and then the aggregate.

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And this wall is also similar modular block wall that is built just behind the IIT Madras, campus in Velachery, this is for a level crossing there is a there is a railway line going like this. And this is to this is the approach road to that to that level crossing and this is the railing that is under construction at that time.

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And is actually this construction of this approach road took place in an extremely soft clay and they did not do any ground improvement at the side, so there were quite a lot of settlements. And if the entire length of the wall was uniformly supported on the

foundations all their would not have been no noticeable deformations, but here the then this is the reinforce concrete bridge abetment.

And some part of the some length of this retaining wall is resting on the pile cap that is below the below the bridge abetment whereas, the rest of the wall is supported on the normal soil, and this part of the retaining wall that is supported on the pile cap did not settle whereas, the rest has settled down. So, we can see these lines the joints between the horizontal joints between the different blocks they were originally horizontal, but now they have become curved.

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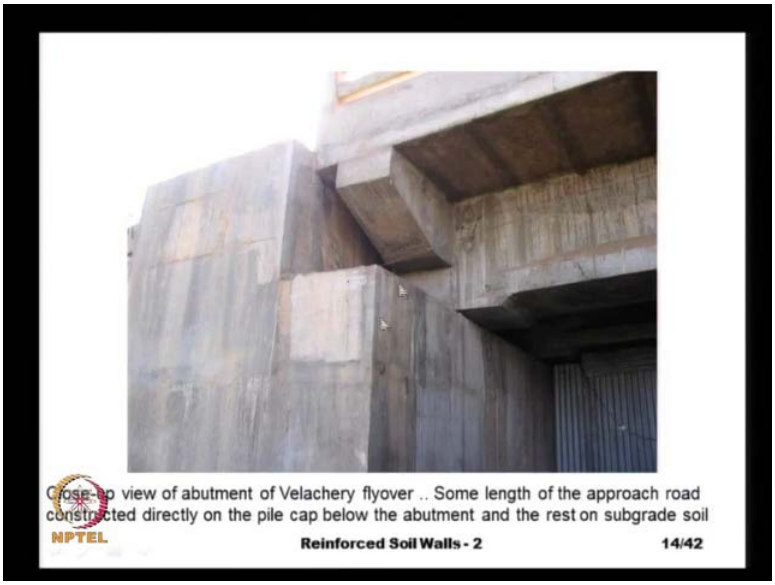


And so this is the close up of the this bridge abetment and because of the soft soil the bridge abetment was supported on number of piles and; obviously, when we have the piles we have a pile cap large pile cap.

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And that has led to some problem in the reinforced soil fill, so there were some cracks in the in this modular blocks, and this some difference in the alignment of these blocks, but nothing has happened to the soil itself. Because, the soil is stabilized not because of the blocks, but because of the horizontal layers of the reinforcement that we place in the soil and these the facing is mainly given for aesthetic purpose and to prevent any soil erosion.

And as long as these blocks do not fall off the we will have good protection to the soil, and this particular wall has been in service for almost 12 13 years, this was built in the 98 99 time, and this year is already 2012. So, it has been there for a long time without any problem in spite of some cracks in these blocks.

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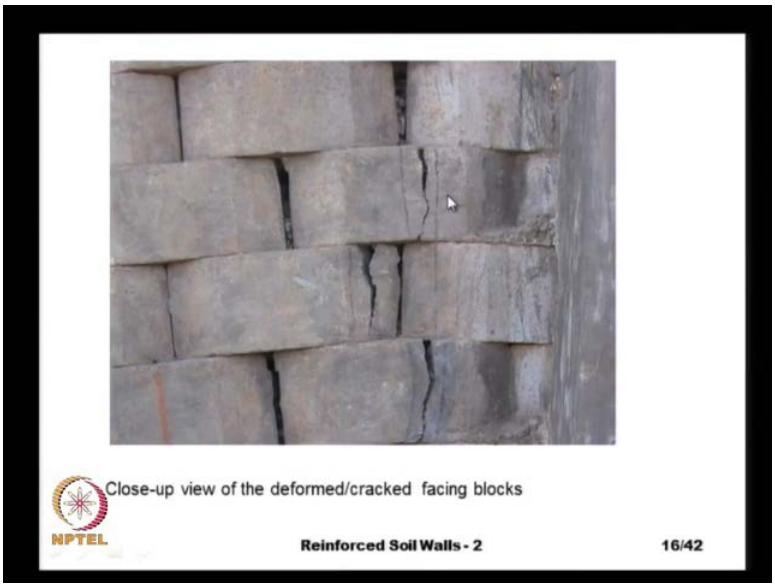


And here is the close up of the cracked blocks and not only the cracking, but the gap between some of these these blocks it has widened, and because the aggregate layer is placed just behind this modular blocks nothing has happened. If it was just a plain soil behind this modular blocks, the soil would have started coming out, but because large sized aggregate particles were used nothing has happened.

So, in fact, this is one of the advantages of these reinforce or retaining walls, and because none of these blocks is reinforced with steel, there is no problem of corrosion because of the cracking. And because of that this cracks they will not go on widening unlike the reinforced concrete, if there is a small crack and if they are exposed to elements like rain water or sea breeze and other thing. The inside steel reinforcement starts corroding and it expands in volume and the crack gets further widened, and then we have the distress, but such problems will not happen with the reinforce or retaining walls.

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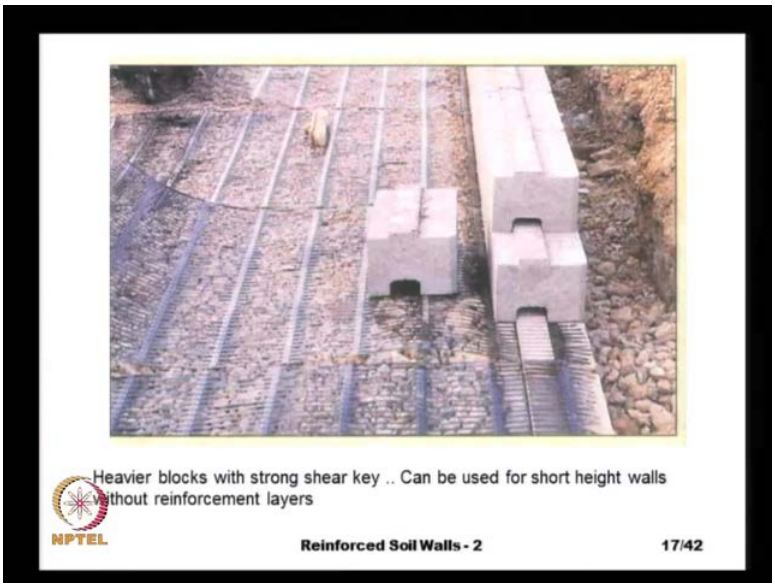


And here we see one heavy block this actually it was used in the 80's, but not very popular anymore the actually, it is a very heavy block with a very heavy sheer key. And this particular block was developed for use along with a tensor type geo-grids, it is very heavy this tensor grids themselves are very stiff, and so because of that we need heavy blocks. So, that there is a compatibility between the grid, that we have and these facing blocks, and here we see this the geo-grid laid on top, and then we have a sorry then we have a good bond between the geo-grid and the facing blocks through this sheer key.

And when we have very short height retaining walls like for example, when we are doing landscaping or something, this type of blocks can be used even without the reinforcement layers. Especially, when the height of soil to be supported is only say about half a meter to one meter we do not need to use any reinforcement they these blocks can be directly used.

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Even these modular blocks they can be used without any reinforcement layers for short height, because there is a good bonding between the different blocks through the sheer key that comes in between, well actually I do not see it here, but I will show it to you in some other lecture later on.

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And another popular method of construction is in India is using concrete panels, which are much wider and much taller, and these this particular flyover is also built near to Chennai in Kanchipuram and the facing is made up of one 80 mm thick facing panels.

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And here you see one approach road, that is under construction this is for a level crossing, the bridge deck is going to come up at this level and this height is nearly 9 to 9 and half meters. So, the approach road is going to come, and then that is on both sides this approach road is vertically supported by reinforce soil retaining walls. And here you can see this, the crane that is handling the facing panels and this lorry is watering the soil.

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So, that this soil can be compacted and here we see the close up view of the retaining wall the with the facing panels, and the when this facing panel is cast we provide some hooks. So, that the reinforcement layers can be connected, and the size of each of these panels is 1.5 meters by 1.5 meters and the thickness is 180 mm, so the weight of each of these panels is about nearly one ton, so we require some light cranes to handle these panels they cannot be handled by normal people.

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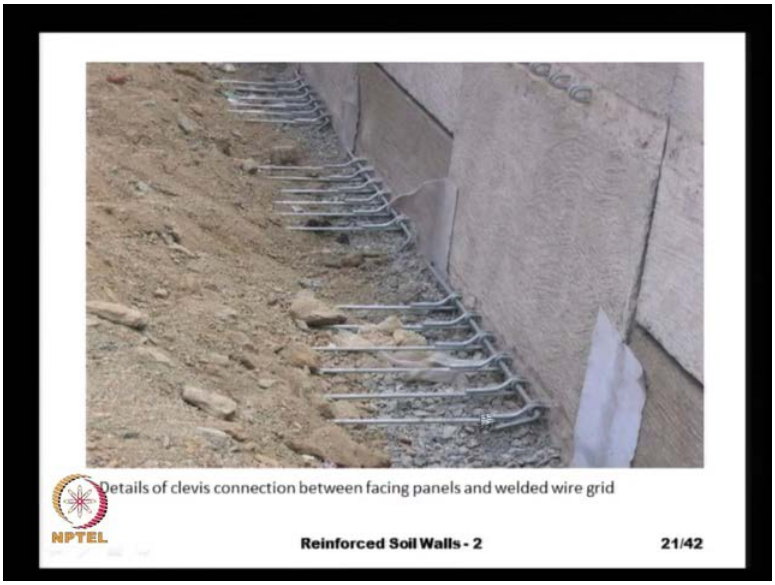


And here we see a detail on the connection we have the panel facing panels and this is the welded wire mesh reinforcement, and on the front side we connect the reinforcement by means of a cross bar. And this cross bar is a 16 millimeters diameter and these hooks they are anywhere from 9 mm hooks to 12 millimeters depending on the company, different companies use different grade of steel and different diameters.

And this cross bar is 16 mm diameter high strength s by s d bar 425 grade steel, and this steel is also this longitudinal reinforcement bars there also 425 grade, but the diameter is anywhere from 6 mm to 9 mm. And then the they are welded along the lengthened about 300 to 500 mm spacing depending on the design.

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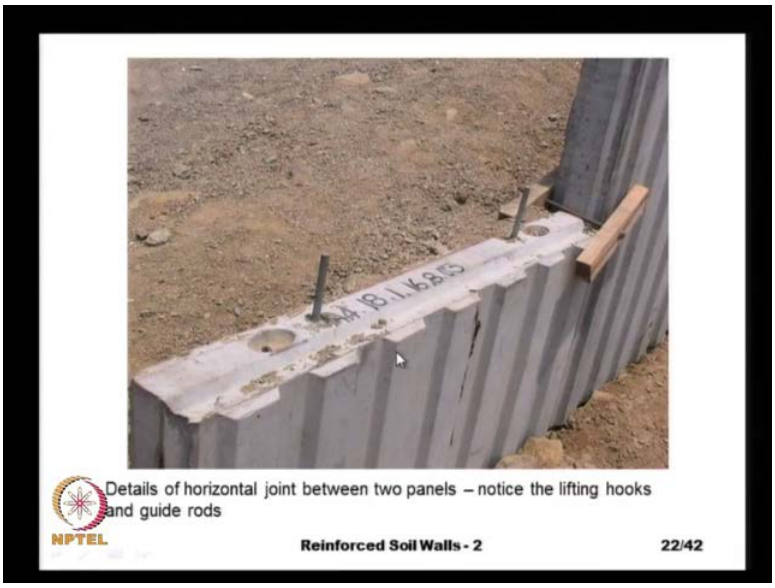


And here we see the close up of these panels and because these panels need to be handled by a crane we need some hooks lifting hooks, and here we see one hook here and then another hook here and the we need some guide rods. So, that these panels are aligned properly and then there is some bonding between the different panels, and here we see these guide rods that are pre cast in these in these blocks. And you can see the date that is 16 August 2003, that was cast in 2003 August.

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And here we see the leveling pad, is actually leveling pad is basically to maintain the levels along the length of the wall, because the length of these approach roads is about 400 meters, and along the length the road itself may not be of the same grade. So, we need the some level based on previous measurement, so that the height of the wall that we build is of standard height, and here we see this the leveling pad in place which is 300 mm wide and the thickness of this leveling pad is about 150 millimeters. Then directly we place these blocks, the actually there is a junction here because this is the length and then here we have this abetment wall that is coming up, because it is not in place now, but it will come.

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And these are the details of the facing panels made, this is the mould and the top left side is the mould for making the panels, and we can give different finishes, and this particular company uses very simple pattern the longitudinal strips. And here we see this um the strips in the mould, and we have to give some small reinforcement in these panels, because they are very heavy and they are handled by means of some cranes.

And they are subjected to lot of handling stresses and to take care of those stresses, we put in some reinforcement, some nominal reinforcement. And then because each of these panels is very heavy, and they are very hot surfaces we need to cushion in between these panels. And here we see a seating pad that is placed between each of these panels and in

the background, we see number of these precast panels that are stacked, and once these precast panels are stacked they are just simply taken to the site for construction purposes.

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And here we see the view of the support that we give for these panels, some temporary support and as the wall height is increased we raise the level of the support that we give them to the particular row of panels behind which we are placing the soil.

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And these are the details of the corner is actually, this is the corner between the longitudinal wall and this lateral wall that is coming up and this is called as the corner

block. And corner block it has the grooves to receive the wall from two different directions, and because of this corner we have different reinforcement detailing, because we cannot provide the normal reinforcement term here, because of the intersections that we have. And here we see this reinforcement detailing that we have at this corner, and once again even for the corner block we have the lifting hook and this guide rods.

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Here, we see another detail of the of this facing panels, and apart from the stone aggregate that we have because the joints they are much wider in these facing panels. We give some geo textile cover, so that they act like a filter to prevent any fine soil particles from coming out of the back fill, and here they are glued together, so that they are in position. And once the soil is placed behind and are compacted, there is no need for any other support the geo textile will be in place.

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And here is a picture of a light roller half a ton roller the compaction of the soil should be done carefully, normally we try to achieve about 95 to 98 percent compaction of the back fill soil. So, that any future settlements will be very negligible or minimal, but then during the construction the facing panels, they do not have adequate support, because we are react to place the reinforcement layers.

And because of that reason very near to the facing panel, the compaction that is given is usually by using light weight rollers. Here, you see a half a ton vibro roller that is used for compacting soil up to 3 meters behind the facing panel and beyond the 3 meters we use the normal 10 vibro rollers for compaction of the soil. The direction of the compaction is very important, we always compact the soil along the length of retaining wall because when we are compacting the soil gets pushed in the direction of the compaction.

And if it is done in the length direction the soil moves parallel to the wall, that if you do the compaction perpendicular to the wall the soil gets pushed and then the facing panels they could undergo large deformations, because there is not much reinforcement that is available to hold it in place. And so the drivers of this compaction equipment they should be instructed properly, so that this type of damage does not happen.

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And here we see an example of that type of damage that has happened, because of the compaction into the wall, and here in this particular case this wall was built near Delhi. And here we see these two rows of panels that are bulging out and we can see the we can see the curvature is actually also indicated that through this dark line just for visual purpose.

This is this happened because the driver of this compaction equipment was not instructed properly, he started compacting into the panels and because of that this bulging has happened. But, then this is only an isore to look at because of the defect in the appearance, otherwise the performance of the wall is not affected, because the reinforcement inside is, so flexible that it can take the strain and it can keep the soil in position.

So, in this particular case because the soil is not placed to much height, the entire height of the soil was removed and then recompacted, because this is part of a national highway. And if we do not correct this mistake at the beginning stage itself, the it will remain there and it will it is not harmful for the structure itself. But, then it becomes an isore for the people to look at, or it will it will not give confidence for the people to use the highway like, they might think that there's something wrong with this bridge and they should not use it.

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As I mentioned earlier we also use reinforced earth tankers and in this case when we have the steel strips like this one here, this particular retain wall is built in Chennai on the highway leading from IIT Madras to the airport. This particular steel strips they are 50 mm wide and thickness is 6 millimeters and as we discussed earlier the reinforced force is mobilized through skin friction.

That is acting between the surface of the reinforcement and the soil, and of course, the tensile strength and the governing design factor is minimum of these two either the pull out force or the rupture. And because these steel strips, they are relatively smooth although they are given some notches to promote the interaction between the steel surface and soil. Still the surface friction that is developed is much lower than the tensile strength of the these strip, and in order to promote higher tensile forces, some companies they attach an anchor at the back.

And here just simply l angles are used to make this angle and here we see this another small plate that is welded to the strip to make it stronger, is actually this has come out of our full scale laboratory testing, where we saw that. If this plate is not welded, this reinforce the failure was taking place at the connection, so to in order to make it stronger this we recommended a plate welded here and then because of the passive force that is generated against this anchor. We develop much higher forces in the reinforcement

layers and the connection to the front facing is by bolt and nut, as we see here is actually here we see the corner detailing.

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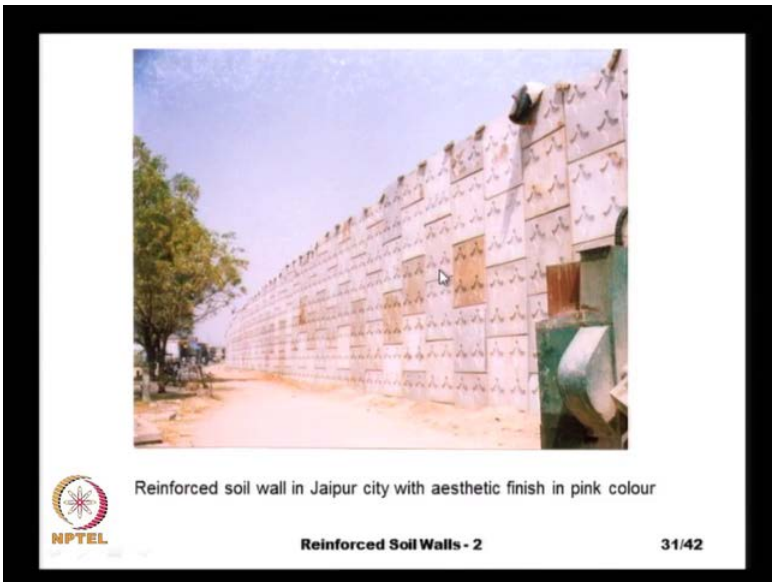


And different types of finishes can be given for this retaining walls, and this is the retaining wall that was built in Jaipur city, and as all of you know Jaipur is called as the pink city, and this retaining wall faces they were built using pink colored cement motor. So, they have the pink finish and then some architectural finish is given, so that this blends with the surroundings with beautiful design. So, this was built in Jaipur with good aesthetic finish, because the Jaipur itself is architecturally wonderful city with pink color buildings.

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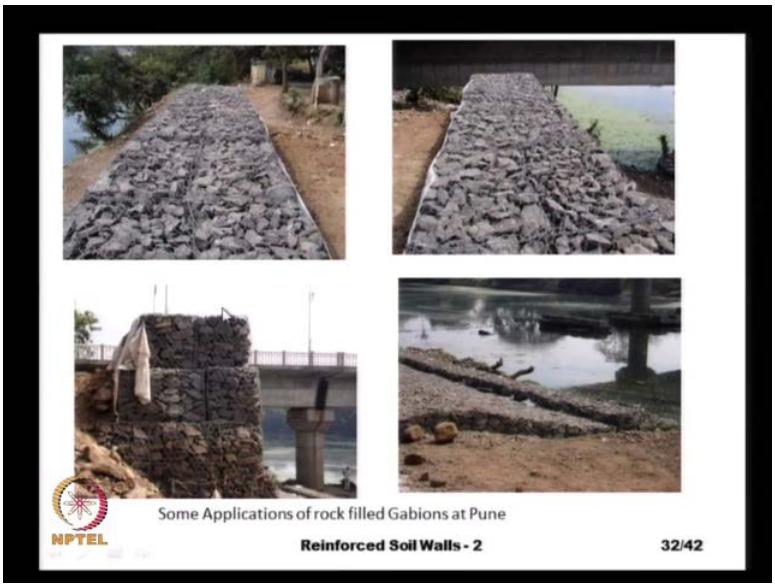


Here we see the application of the gabions, gabions are either steel wire baskets or polymeric rope net baskets, here we have this steel wire baskets, and this particular wall was built as a river training work. And the entire retaining wall was built using wire baskets filled with stone aggregate and this was built in the city of Pune, as a river training work and there was no reinforcement given.

It was purely design as a gravity wall, because the height is not much, it is only is actually these this is the soil height and the height of each of this gabion blocks is about 1 meter. So, the height is about 2 and half meters, and then an extra gabion was provided to provide the mask for the structure.

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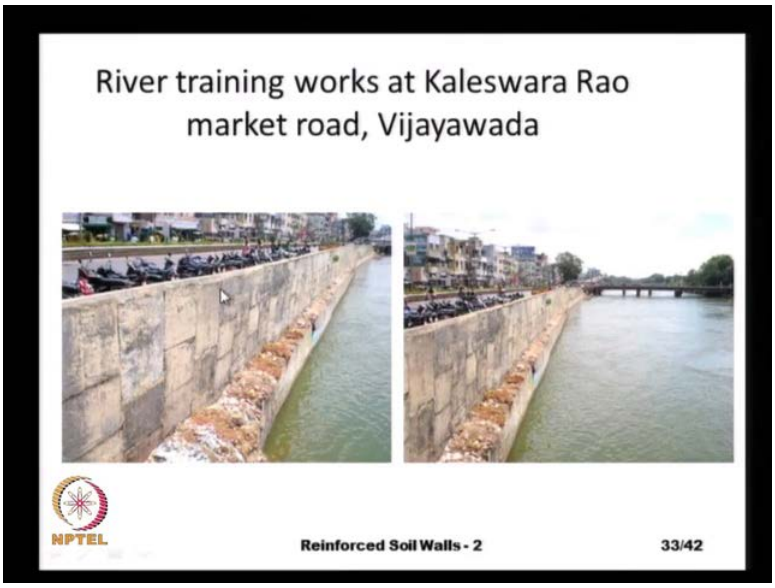


And here we see retaining wall as a river training work, this actually this is along a canal and this is a busy road in the city of Vijaywada, because the market is located here, and there is a very narrow passage way. And there is we cannot bring in any heavy construction equipment for building any retaining wall here, and so they used reinforce oil concept for construction of this river training work, they along this stretch. And here we see all these panels which are precast, they were brought to the site and assembled for this river training work.

(Refer Slide Time: 33:42)

And here is another example of a retaining wall, but this particular retaining wall was built using polymeric strips, this polymeric strips are 60 mm wide and the length that depends on the on the design based on the design. We decide the length and they are connected to the front facing by using a once again, the same concept as the previous wall that we had seen with the with the steel mesh.

Here, we have a hook that are cast into the concrete panel at the time of casting, and then there is a cross rod that is about 20 millimeters diameter. We take this polymeric strip, then bring it out and then in between that is locked in place by this steel rod, and this particular wall is under construction in Trivendrum there put approach road, and this particular walls they have used some other type of seating block.

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Here we can see this, the black color seating pads and here we see a picture of the reinforcement that is made of steel wires welded wire meshes, here these are the longitudinal elements and these are the cross bars. And these cross bars they can be at different distances and once again the distance that we that we give that depends on the amount of tensile force, that particular layer of reinforcement has to carry.

And if you have damat closer spacing, we will have more number of them and when we place them in the soil against these cross bars some passive force is generated, and so thereby we generate more amount of reinforcement force in the in the steel. And see normal distance is about 300 mm to about 500 mm and the number of these rods usually

either 3 or 4 more than that we do not use, and the connection of these welded wire meshes to the front facing is once again through the hook. And then this cross rod the cross rod is usually about 16 mm to 18 mm depending on the designs, that we have.

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And once again the polymeric strips that, we have that are used as reinforcement layers and the detailing at the backside is like this, so actual the front facing is somewhere here, we bring this polymeric strips. And these polymeric strips they are they comes in rows of 100 meters and continuously, they are used we do not cut them, and lets say that the front facing is here. It is start there and then it is brought back and then at the back side, we have a guide rod around, which we can stretch, and then we continuously wind this polymeric strip around.

And the joint between the different polymeric strip units after we exhaust 100 meters, we need to join some other strip and that joint should come in the stable zone of the soil. It should not come within the active zone, that is active zone is within the ranking wedge beyond that only we should have the joint, so that even if this slippage that is taking place at the at the joints the reinforcement is able to generate adequate resistance force either through the skin friction or through the tensile strength of the strip.

And these polymeric strips, they are actually they are made of polyester and they can consist of number of course, each of them containing a certain number of fibers and depending on the tensile strength of these polymeric strips, the amount of fibers that are

placed in the core they differ. And these cores they are all bundled together then they are given some PVC coating and then on top they bring all these cores together and give some polymeric sheeting. So, that these the core materials they are protected during the construction they stay together during the soil compaction and other things. And some companies they use these polymeric strips to make geo-grid type things by welding, this different polymeric strips we can make the grids out of this polymeric strips, I will show you some photographs in some other lecture, when we discuss the construction of that type of retaining walls.

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And here we another farm that we can have for the facing panels here, it is a bit of hexagon shaped facing panels, once again with vertical grooves and without much of an architectural finish. And this is part of a an approach road for a fly over, that is under construction here we can see this the bridge deck is going to come out this level, and this is all the length of the retaining wall.

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And this is the inside view of the of the construction and the type of reinforcement that is used is a knitted type geo-grid, and this geo-grid is connected at the facing panels by means of a cross rod of 16 mm diameter, and then the hooks they are 10 mm diameter. And this type of connection we call it as a positive connection, because directly the geo grid is connected to the to facing panels very rigidly by means of a steel rod whereas, the previous type of connections that we have seen earlier.

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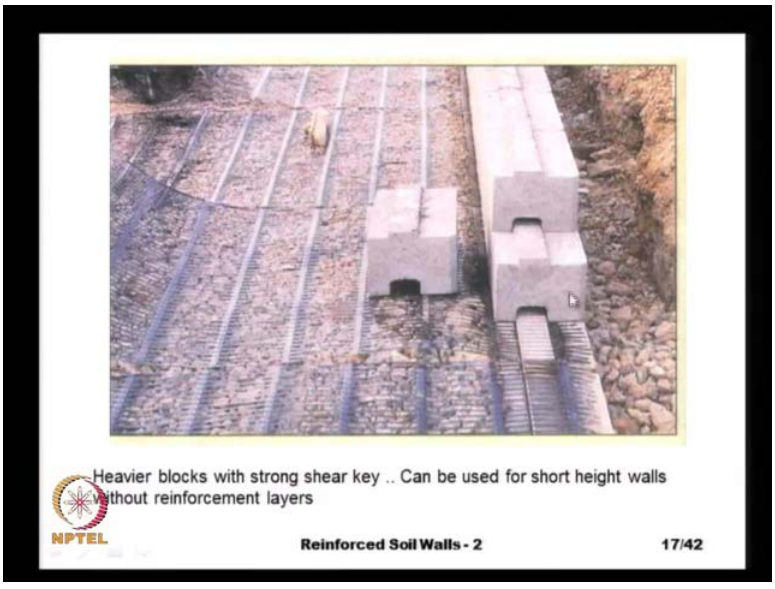

This type of connection that depends on the sheer key and the frictional force that is mobilized between the reinforcement layers, and the different type of blocks that we have and especially in the case of these modular blocks it becomes very critical.

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Because, the depth of these modular blocks is about 250 millimeters and then say if we have a very high strength reinforcement. So, that can generate force of 300 kilo Newton's per meter, we should make sure that the joint that we have between the facing modular blocks, and this reinforcement is also capable of generating that much of force.

Otherwise, the joint may be so weak that you cannot really consider the full strength of the reinforcement for the design purpose, and the connection is basically frictional connection, because we have lot of friction. And this gap is filled with stone aggregates and usually this is the weaker link in the in the retaining walls, and we need to consider the strength of this the connection as part of our design that we will see later on when we go to the design.

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And this polymeric strips they are similar to steel strips and their capacity is developed by friction, that is developed along this 50 mm wide strips. So, that also we assess by means of laboratory test that we will discuss in some other lecture

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Here, we see these blocks under manufacture is actually this before we do anything on the mould we apply some oil, and then we put in the nominal reinforcement that is required for withstanding the handling stresses. Then we have we pour the concrete then with after the concrete is set, we can de mould them, and then take to the site, and here

you can see these hooks in place that are used for connecting the reinforcement element to the facing panels through the cross rod.

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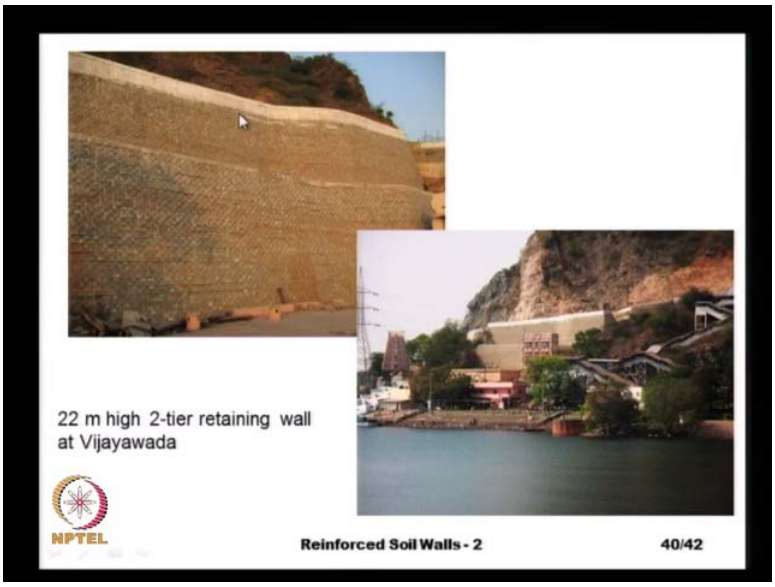


And so here we see the some walls that are built using modular blocks is actually this from the height of this wall is 22 meters it is built using modular blocks, and with flexible type reinforcement is actually geo composite. The entire height of the wall is 22 meters the bottom wall is 12 meters and the top wall is 10 meters, and here you see the long shot view and how it is nicely blending with the with the surroundings.

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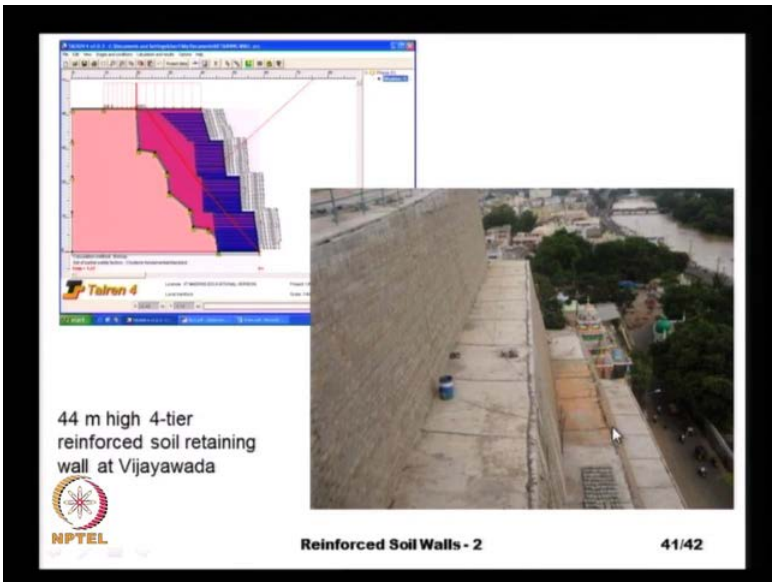

And just next to that there is another much higher wall that is 44 meters that is built in 4 tiers is actually that is the bottom most tier, the first tier second tier, third tier and the fourth tier. And the this much height of the wall could not have been built using normal reinforce concrete, because the dimensions of the members the stem thickness will be very, very high, and it could have been constructed.

Especially, if you consider the earthquake forces and such a high rigid wall the inertial forces will be so high that it becomes uneconomical to design this wall. And whenever we have that type of complicated structures in addition to normal retain wall designs, we also need to consider the possible internal rupture surfaces that could form. And the here we see a screen shot of a of a slope stable analysis of this particular retaining wall using some software called Talren.

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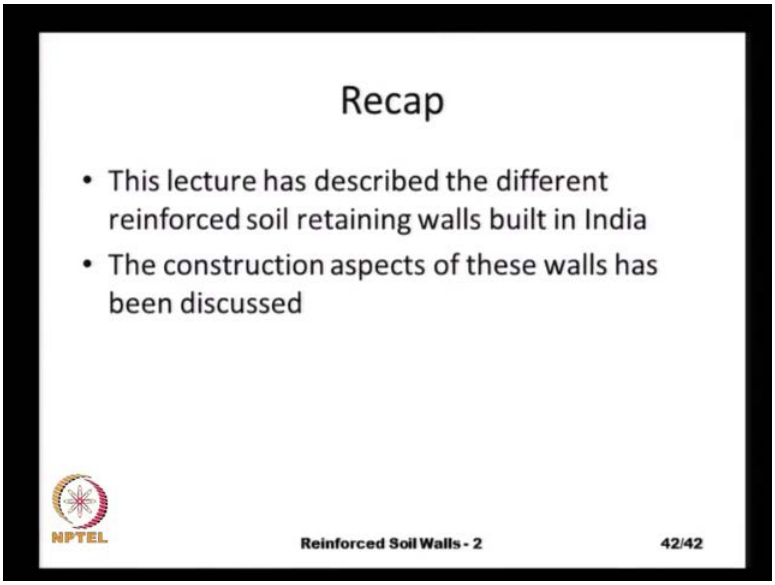


And just to recap in this lecture we have seen different constructions of the reinforce or retaining walls that happened all over India, and we have seen some construction aspects of the of the modular block walls, and then the full height facing panels, and then the concrete panels. And it is also we have seen the type of compaction equipment that we can use, and the very near to the facing panels is very important that the soil is compacted using light weight compactors usually half a ton, the compaction is done along the length of the wall and not perpendicular to the wall into the soil into the wall.

In order not to exert too much of pressure on the wall, because during the construction these facing panels may not have adequate lateral resistance, because we have not placed all the reinforcement layers in place.

So, it is and the these this type of retaining walls in India they have become very, very common and the height of the walls, as I have shown it has exceeded 50 meters. And in fact, one wall that is a steep slope that is coming up in Sikkim that has crossed 100 meters nearly 110 meters. So, the reinforce wall technology it has become very well accepted technology and even small time contractors are able to build retaining walls using this technology, thank you very much.

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So, if you have any questions you can send an email to me at this address.

Thank you.