Soil Dynamics
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Module - 6
Lecture - 34
Soil Improvement Techniques - Liquefaction Mitigation Method, Vibro Compaction Densification Techniques

Let us start our today's lecture on Soil Dynamics, we are continuing with our module 5 that is machine foundations.

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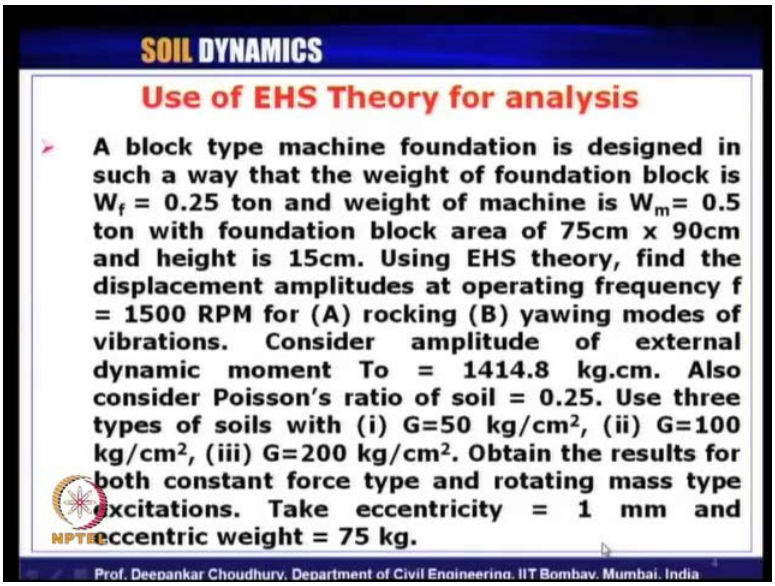

A quick recap of what we have studied in our previous lecture, also we have seen the example. We have worked out the examples for rocking and yawing modes of vibrations by applying elastic half space theory, for three different types of soil again for two types of excitation, constant force type and rotating mass type excitation.

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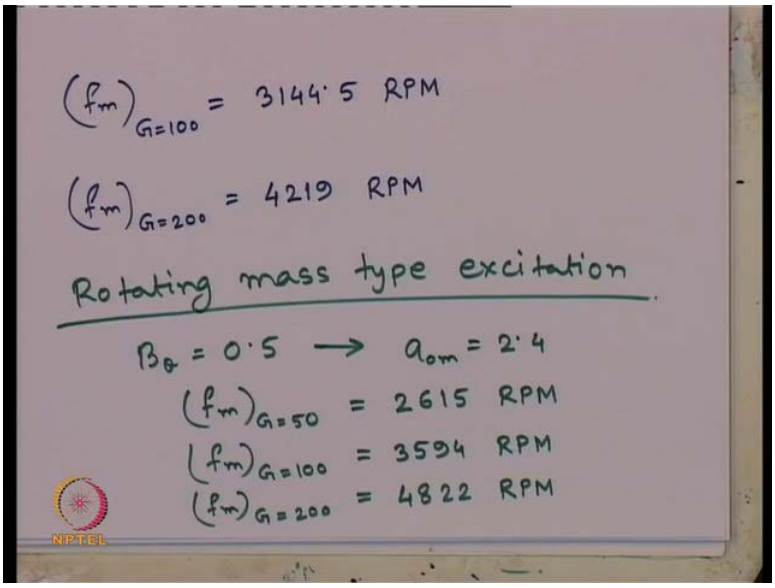

Now, coming to rotating mass type of excitation for B theta equals to 0.5 from the design chart again, once again; let me show it here, this is the value of 1, so 0.5 is somewhere here, so that is why I got 2 different values for rotating constant force type, I am reading a naught m as 2.4. You can extend the graph actually and get the values, because here no limit has been mentioned. Like, for vertical case we have seen liaise mars limit is there here no such limit is; so for design constriction we can extend it.

And if we put this expression back to the calculation of our f m for 3 different soil f m, I am getting as 2615 RPM fm with G equals to 100 is this 2615. Next 1 I am getting 3594 RPM and fm with g equals to 200 I am getting as 4822 RPM. So, again the comment for this design will be they are far away from the proposed operated frequency of 1500 RPM, hence safe. So, with this calculation we come to the end of this solution of the problem.

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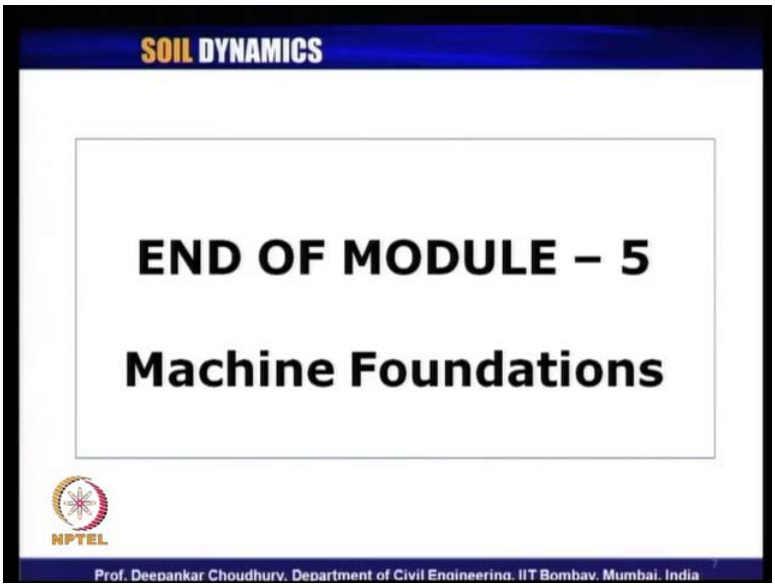

And also with this we have now come to the end of our module 5, that is machine foundation. So, we are completing the machine foundation module here.

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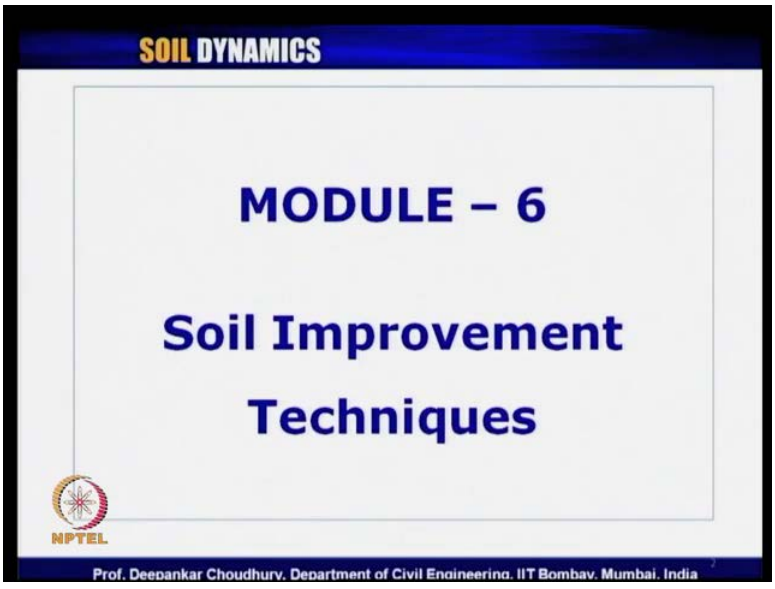

Let us start today's lecture of Soil Dynamics, today we will start with module 6 of this course soil dynamics. In this module 6 we will talk about soil improvement techniques, various soil improvement techniques, which are necessary for liquefaction hazard mitigation and many other similar things. So, we will discuss in this module what are the

different ground improvement techniques which we generally follow or should be followed.

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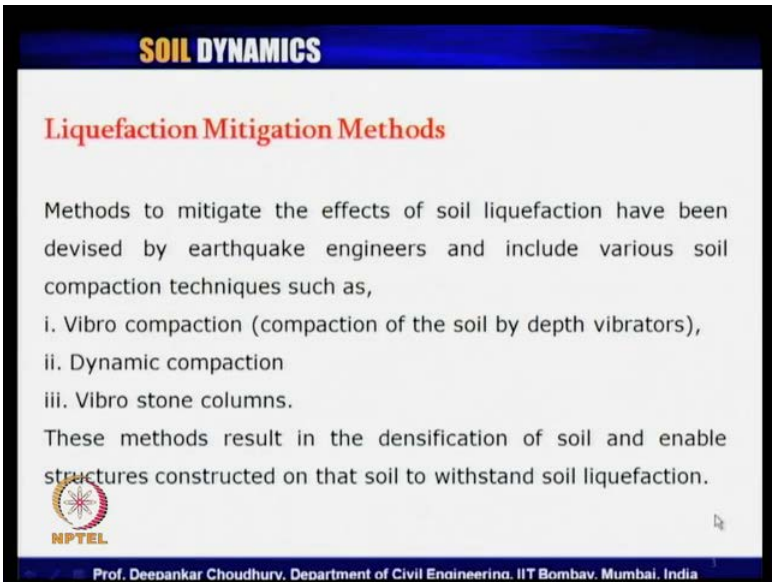

Let us see here, the liquefaction mitigation method, what are the various methods by which we can improve the soil condition. So, that the liquefaction susceptibility of a particular soil can be reduced or mitigated, so the methods of mitigate the effect of soil liquefaction due to the dynamic loading have been devised by earthquake engineers and include various soil compaction techniques.

What are those techniques? Like vibro compaction, which is the compaction the soil by at a particular depth using the vibratos, then dynamic compaction and vibro stone columns. So, these are three common compaction techniques by which we can reduce the soil liquefaction susceptibility of particular location of soil by improving it is condition. These methods what it does? It densifies the soil and that enables the structure constructed on that to withstand the soil liquefaction under any cyclic loading.

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Let us see what are the various types of soil improvement or ground improvement technique? The first one as we have mentioned the vibro compaction, in this case compaction of granular soil like cognition less materials by using depth vibrators which are commonly known as vibro compaction technique is used in this compaction method.

And the method is also commonly known as vibro flotation, natural deposit is as well as artificially reclaimed sands can be compacted using this vibro flotation or vibro compaction technique up to typical depth of up to 70 meter which is pretty large depth. As we already discussed during the liquefaction hazard assessment and studies liquefaction analysis while discussing the theory et cetera. We mentioned typically up to about 30 meter below the ground, we generally considered the liquefaction hazard assessment etcetera.

So, that is why in this case, if we are able to densify the soil up to the depth of 70 meter which automatically comes within the zone of our interest for the liquefaction mitigation, so that is why this is use full for this purpose. The intensity of the compaction can be varied to meet the particular bearing capacity criteria at each and every depth of the soil. Other improvements effects, like reduction of both total and differential settlement also can be achieved in addition to this liquefaction susceptibility reduction. So, this risk of liquefaction in an earthquake prone area is drastically reduced by this process of vibro flotation or vibro compaction.

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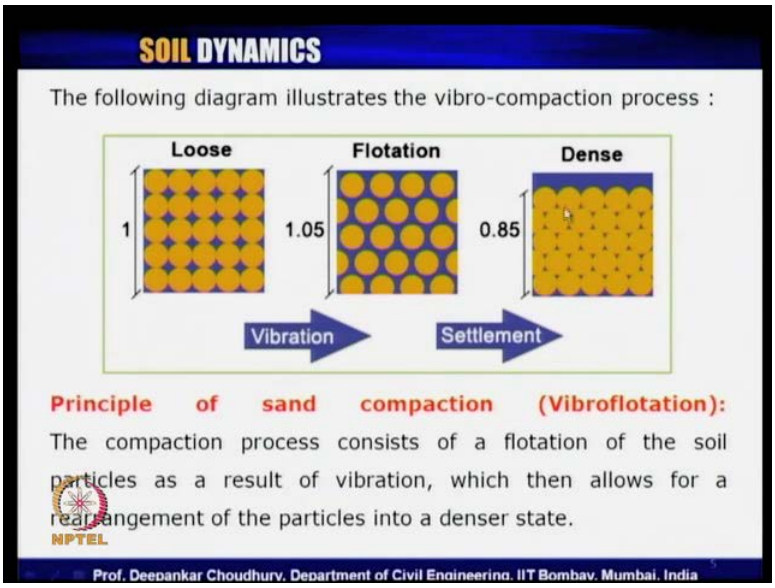

So, let us see what is the basic principle of this vibro compaction or vibro flotation process? Initially the soil grains in the cognition less soil material, granular material which we are discussing. As we know typically loose sand can be susceptible for liquefaction at a particular, magnitude of earthquake depending on various other input condition. If the lose state of that granular material something like this by using this vibro compaction technique.

They are a basically total to step process by which we can finally, get the denser compact of soil material of granular nature in this fashion. So, in between there is a process which his known as flotation where, so during the vibration the loose granular material will change from this state to flotation state. Where, there will be instead of compression, there will be a kind of a increase in the volume in that portion which is concerned for our study. But, final effect will be you can see the reduction finally, it will settle and densify and this will be the final state of the cognition less granular material after this vibro compaction.

So, the principle of the sand compaction vibro flotation is like this. The compaction process consists of a flotation of the soil particles as a result of vibration. So, this the reason for which it change the state, which then allows for a rearrangement of the particles into a denser state. Then it goes to the settlement process of the soil material and finally, reached the denser state of the soil.

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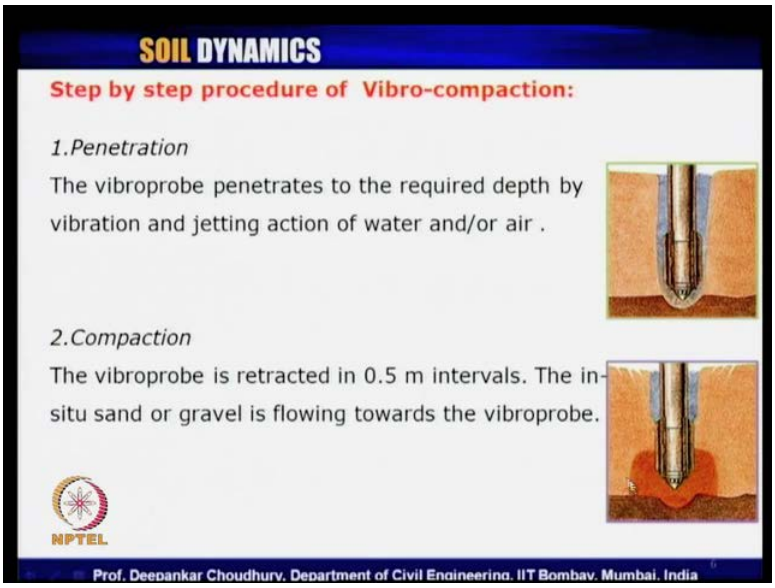

So, the step by step procedure of vibro compaction is shown here. The first step is penetration, you can see in this picture the first this vibro probe, this is called the vibro probe which is penetrated to the required depth that is the depth were we want to densify the loose soil present at the particular site at a particular depth. So, the vibro probe should be penetrated up to that depth were the densification is necessary by vibration and jetting action of water and or air is applied for this vibro compaction process.

The second step in the vibro compaction is the state of compaction, there is the vibroprobe this vibriprobe which was inserted at a particular depth is retracted in about 0.5 meter intervals at various depth. And in situ sand or gravel is flowing towards the vibro probe.

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You can see here, in the picture how it is flowing towards the vibroprobe. The third step and last step in this vibro compaction process is after this compaction this dark color zone, as you can see slowly this vibroprobe will be taken out. So, after compaction the working platform needs to be leveled.

So, wherever the work was going on finally, it has to be a level ground and this vibroprobe will be taken out and eventually a roller compacted top finish will be made in this vibro compaction process. So, let us see now what are various effects of this vibro compaction that is what are the things are getting effected or change in the soil properties is due to this vibro compaction technique.

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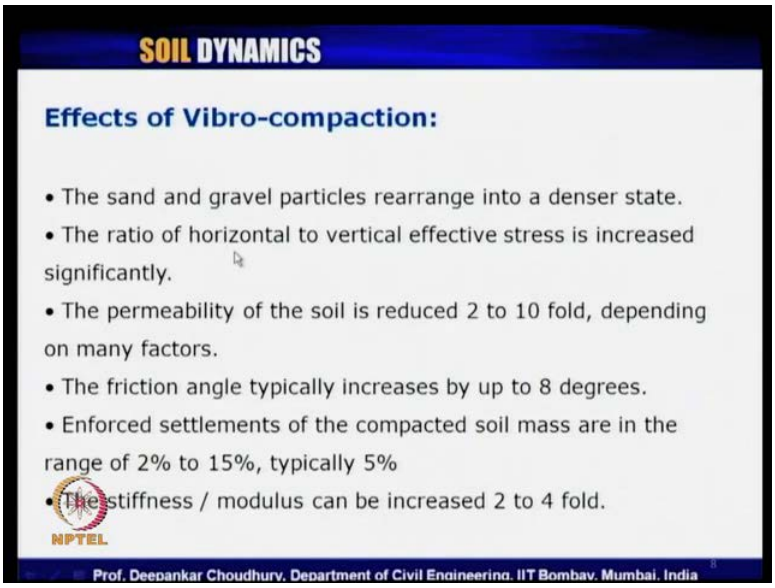

In this case this the sand and gravel particles they rearrange into a denser state. That is initially they will be in the loose condition, which will be transport through this vibro compaction technique into a denser material a denser state of this sand. So, a loose sand will become a den sand loose gravel material will become denser state of gravel material. The second effect is the ratio of horizontal to vertical effectives stress is increased significantly.

So, if the horizontal to vertical effective stress increases, what will be the advantage? In this case the effect of confinement in the soil at the particular depth increases, so which is; obviously, very helpful for mitigation of liquefaction hazard. The third effect is the permeability of the soil is reduced two to tenfold depending on various factor. The fourth factor is the friction angle of the material it typically increases by about 8 degrees. So, this is another advantage which is obtained through the sphere strength property of the soil through this vibro compaction technique.

Than enforced settlements of the compacted soil mass are in the range of 2 percent to 15 percent and typical value can be considers as 5 percent. That is due to this vibro compaction what we have seen, the various phases it goes to the vibration than settlement occurs. That amount of settlement is varying between 2 percent to 15 percent depending on various other conditions. So, un conditional extra initial state of the soil,

but typically about 5 percent. It can be considered that is the total settlement of that compacted soil mass can be expected.

And another major advantage we get from this vibro compaction is that the stiffness or the modulus of the soil it can be increased a by above 2 to 4 fold of each initial value. So, if each the stiffness of soil or the modulus of the soil increases by 2 to 4 times of it is initial value; obviously, it will provide better state for reduction of the liquefaction suscepsion. So, in that way the stiffness and modulus increases helps the soils not to get liquefied, as it is value is increased by about 2 4 rfold due to this vibro compaction method.

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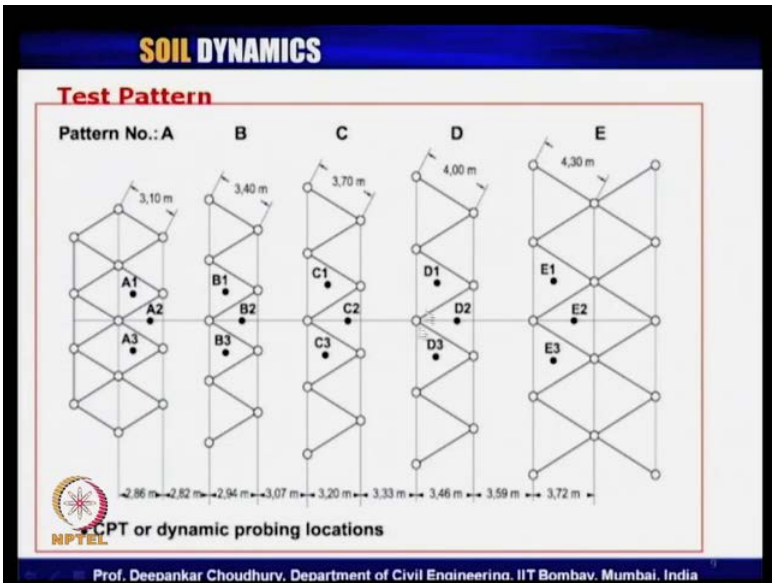

Let us see how this vibro compactions take place at a side, so this is a typical test pattern which is shown over here. Various pattern, pattern A, pattern B, pattern C, pattern D, pattern E are shown here. These are the locations the black spots or location for CPT or dynamic probing locations and these white open sharples. Those are the locations where this vibro compaction can be provided.

So, this is type of typical triangular grid pattern can be applied the side at typical distances of such 3.10 meter or 3.40 meter or 3.70 meter or 4 meter or 4.30 meter depending on the requirement of the side. And the amount of increases in the various parameter of the soil to be improvised or the densify. And this distance also typical distances are shown over here.

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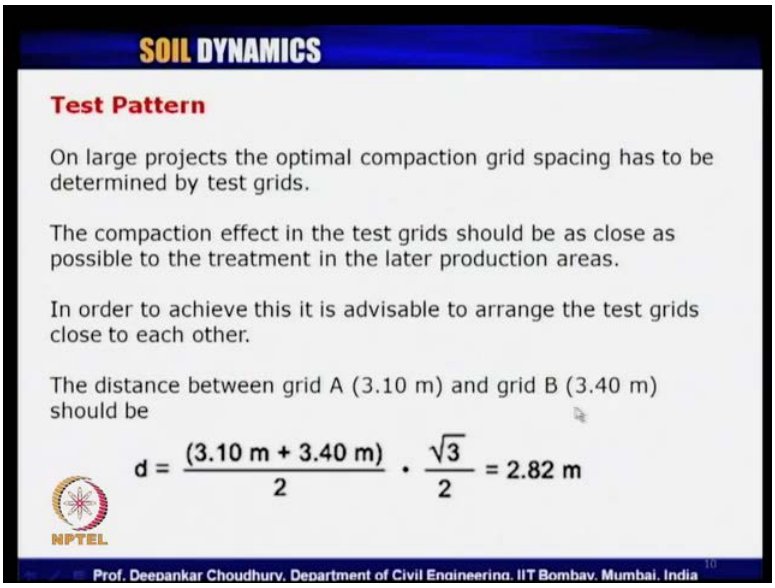

So, using this typical pattern what we can say about the test pattern that on large projects. The optimal compaction grid spacing has to be a determined by test grids that is initial fast few trailed test needs to be carried out. And after that trailed test than for the last project it is need to be decided the that how much is the improvement of the soils by choosing a very particular type of grid and spacing. So, that through again using CPT or dynamic proved technique.

We can find out how much improvement in soils state or soils property is achieved and that is what we can than further mention that this pattern can be adopted for the entire project. So, the compaction effect in the test grids should be as close as possible to the treatment in the later productions areas, because if the compaction tests grids are very close to the treatment area. Then; obviously, it can give a better idea how much improvement of the soil has taken place. Now in order to achieve this it is advisable to arrange the test grids close to each other. So, the distance between grid A that is 3.10 meter spacing grid which we have shown just now.

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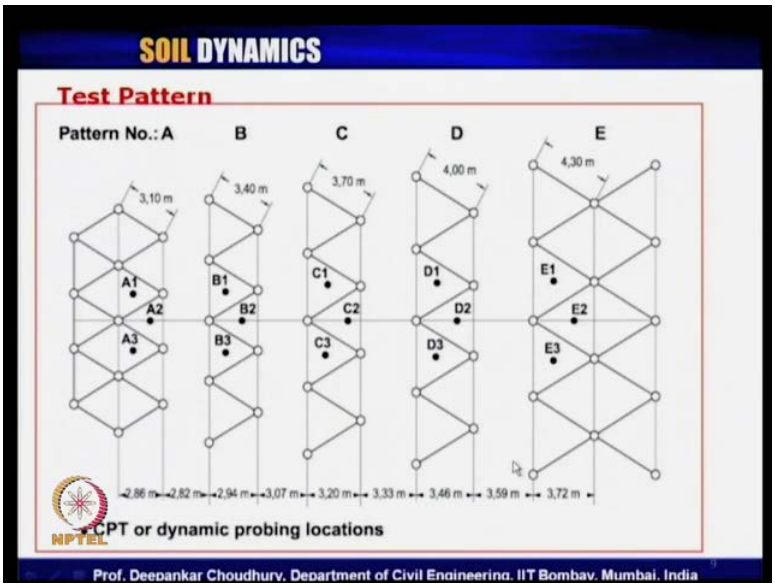

And grid B which is 3.40 meter spacing I will go back to that slide. So, here this A at spacing of 3.10 meter, where as grid B at 3.40 meter spacing. Now what should be the distance between this 2 that is need to be find out.

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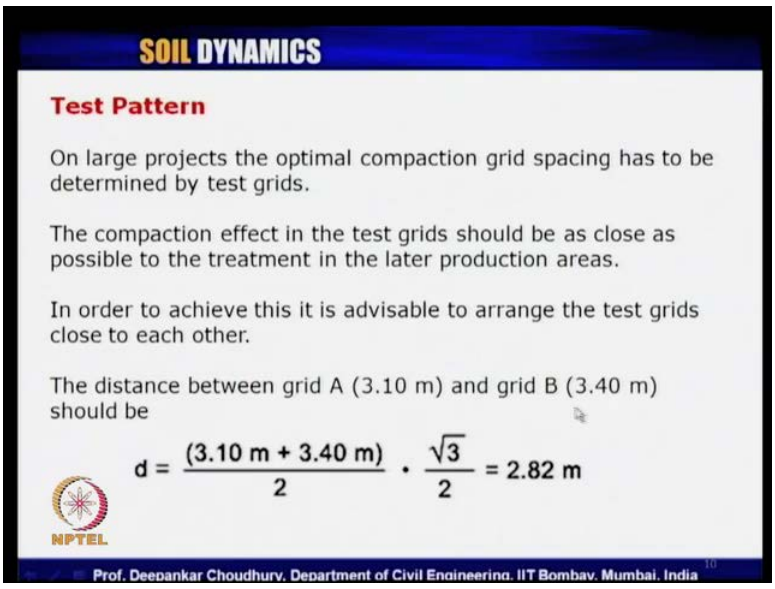

So, that is what it is computed over here, this d distance between this grid A and grid B pattern can be estimated like 3.10 for this 3.40 for this by 2 into root over 3 by 2. That gives us the value of 2.82 meter.

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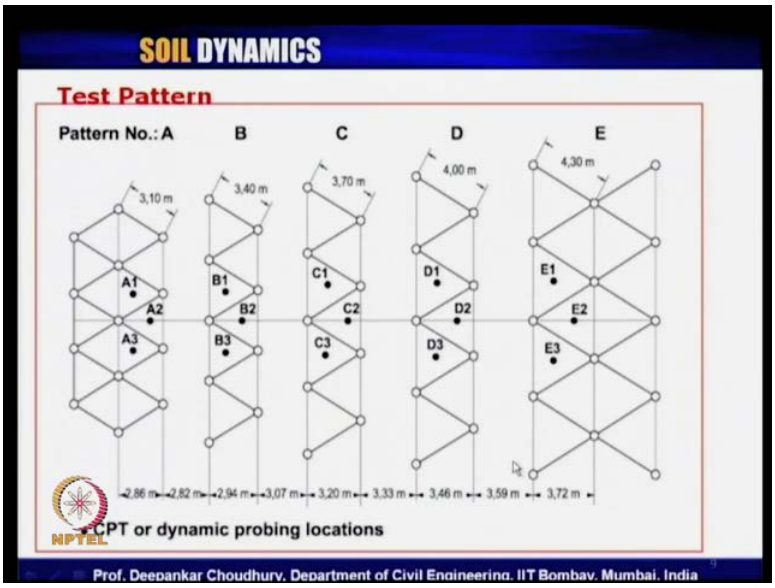

So, if we go back we can see this distance between pattern A and pattern B is specified out calculated and put as 2.82 meter.

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Now let us see what are the various option for vibro compaction technique, like it can be either offshore vibro compaction or the land based vibro compaction method. Now while the principal of this vibro compaction that is flotation of grains into a denser state by the process of vibration is a simple concept. We have already understood this the application of the technology in an optimal manner still and art. And that few have mastered this art

at field, so the difficulty of this application of this vibro compaction and different cases a like either offshore or land based lies in the many parameters.

That can be varied and the narrow band in which those parameter had to be adjusted to deliver the desired results. So, some of the parameters that can be varied are like type of the vibrator that we can have different types of vibrator. And we can achieved a different set of compactions effort or the vibration effort which can lead to a particular desired value of our densified soils material or we can have a control on the grid spacing.

And we can varied this grid spacing holding time per depth interval that is how long that vibroprobe needs to be kept at a particular depth. So, that it is ensured that entire vibrations followed by the settlement has occurred fully and the soil has reach from lose to a denser states by this process. Then another parameter which can be varied is the water pressure, how much jet pressure, water pressure is used for this vibro compaction also the location at which location it is applied.

What type of soil is present? And what type of water jets are used? So, based on all this parameters and by varying this anyone or combinations of this parameters, perfect vibro compaction at field can be achieved, but still it is really an art to achieved this at side.

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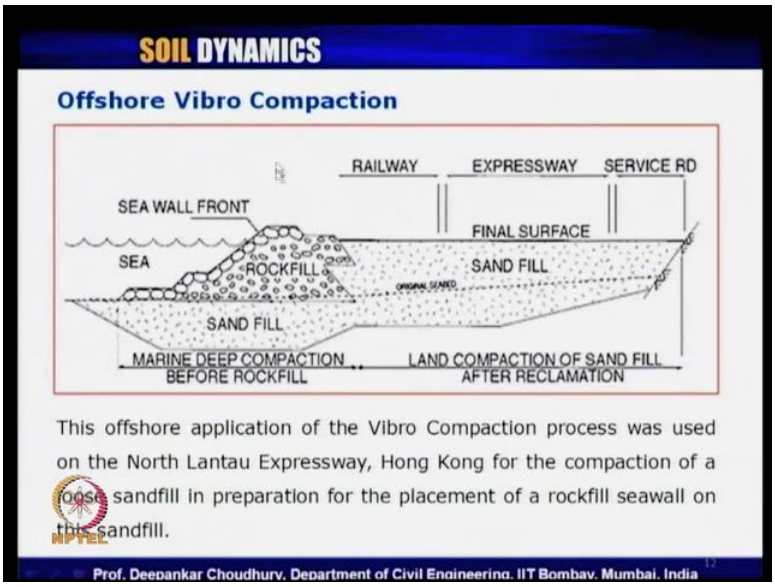

If we see at typical application of offshore vibro compaction, you can see here the land used et cetera where as, you have sea and here sea wall front. So, this portion if needs to

be compacted, so this part shows the land compaction of sand fill after reclamation. And this part is showing marine deep compaction before this rock fill. So, how this compaction is taken place this is this offshore application of the vibro compaction process.

It was practically used on the north Lantau expressway of Hong Kong for compaction of loose sand fill. In preparation for the placement of a rock fill seawall on this sand fill. So, this sand fill was vibro compacted act offshore by using the vibro compaction technique.

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Whereas land based vibro compaction for that also we have several example. So, here offshore land based like penny's bay Hong Kong one of the world's largest vibro compaction project, where this penny's bay reclamation has been made by the used of land based vibro compaction technique.

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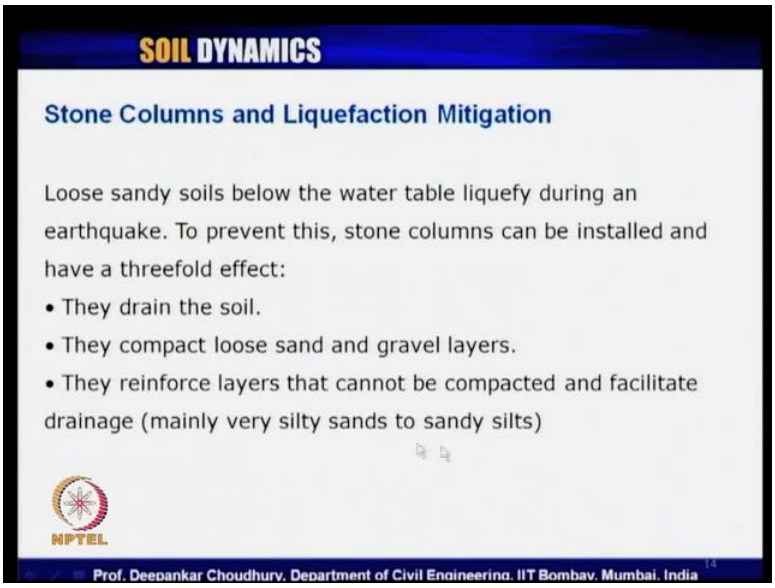

Let us come to the next one the concept of stone columns and the liquefaction mitigation by using this stone columns. Loose sandy soils below the water table, they have a tendons to gets liquefy when any earthquake come of a certain magnitude depend on various other parameters as, we have already discussed in our liquefaction theory. So, to prevent this stone columns can be installed and it has a 3 fold effect. What are those effects?

Like they drain the soil that is the permeability increase, that is in other word the core presser which gets generated, get a better chance to get dissipated by using this stone columns. Now they compact loose sand and gravels layers by providing the stone columns and also they reinforce layers that cannot be compacted and facilitate drainage mainly very silty to sandy silts.

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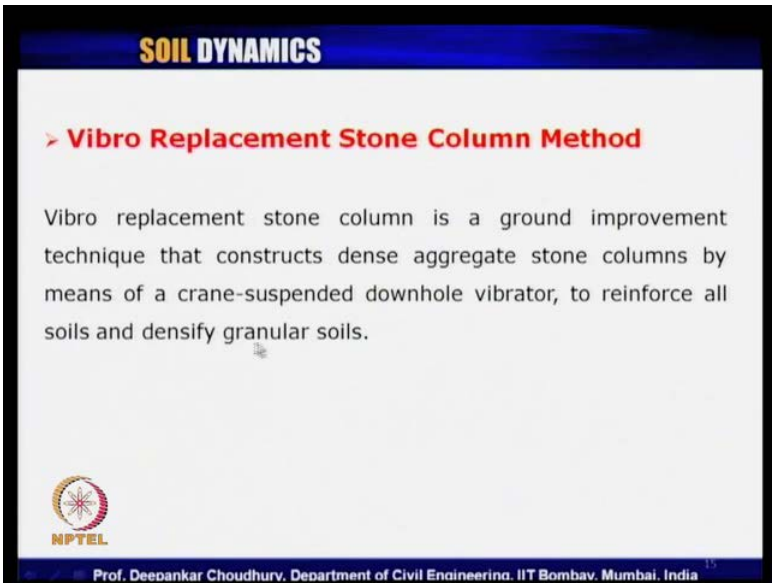

So, vibro replacement using the stone column method is such that the vibro replacement stone columns is a ground improvement technique that constructs dense aggregate stone columns by means crane which is suspended down hole vibrator to reinforce all soils and densify granular soils.

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And in this case it improves the load bearing capacity and reduce the settlement of the soil. So, obviously, the state of the soil it is get improve by this vibro replacement stone column method. On many occasions it is noted that the local soil is by nature unable to

bear the proposed structure loaded. Hence, the use of the ground improvement technique by the stone column may be necessitated.

So, use of the stones is one of the technique to improve the local weaker soil I will say to improvised further. So, the stone column consists of crushed, coarse aggregates of various sizes, the ratio in which the stones of different sizes will be mixed is decided by design criteria. So, how to decide on that mixing proportions etcetera, that comes under the preview of design of stone column.

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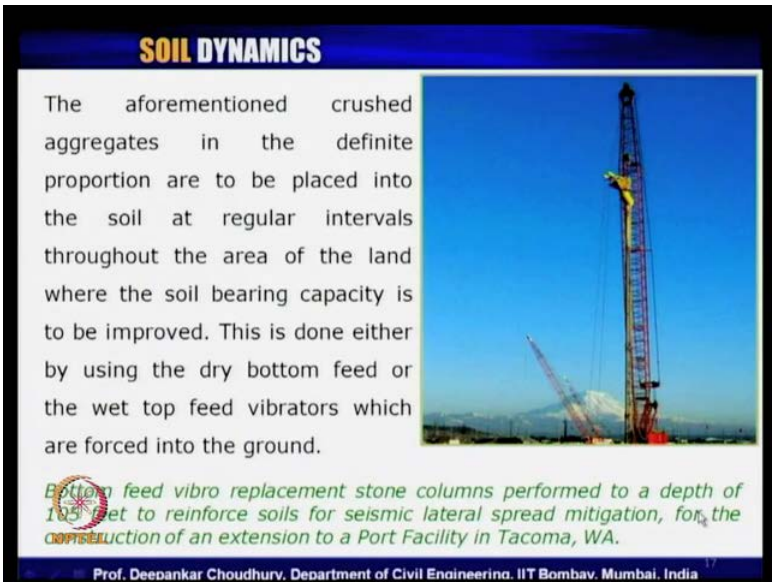

So, as we have just now mentioned the crushed aggregates in the definite proportion are to be placed into the soil at regular interval. So, at various intervals we keep on placing this crushed aggregated at a design mixed proportion at different location. And that throughout the area of land where the soil the bearing capacity of the soils need to be improved has to be applied. So, this is done either by using the dry bottom feed or the wet top feed vibrators which are forced into the ground.

So, this are 2 technique by which we can put this crushed stones columns or crushed stone into the entire area by using dry bottom feed or wet top feed vibrators. In this case the bottom feed vibro replacement stone columns performed to a depth of 105 feet, to reinforce the soils for seismic lateral spread mitigation and for the construction of an extension of a port facility in Tacoma. This has been used already using the bottom feed vibro replacement of the crushed stones to improve the soil condition at a facility.

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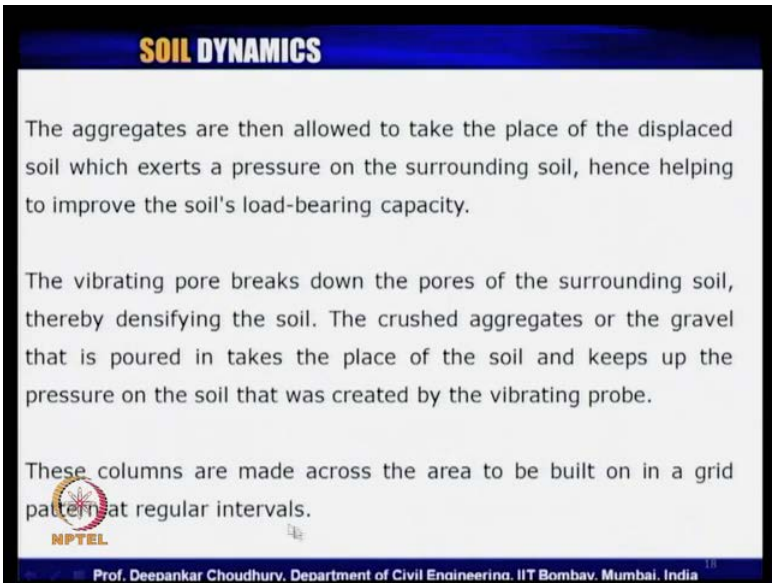

The aggregates are than allowed to take the place of that displaced soil which exerts a pressure on the surrounding soil. Hence, it helps to improve the soils load bearing capacity because; obviously, if we replace the softer soil with this improved crushed aggregates which are having a better strange and a denser stage. Obviously, it will have a more load bearing capacity than the original softer soil.

So, the vibrating pore break downs the pores of the surrounding soil thereby densifying the entire soil profile. The crushed aggregates or the gravel that is poured in takes the place of the soils and keeps up the pressure on the soil that was created by that vibrating probe. And these stones columns are made across the area to be built on a grid pattern at regular intervals.

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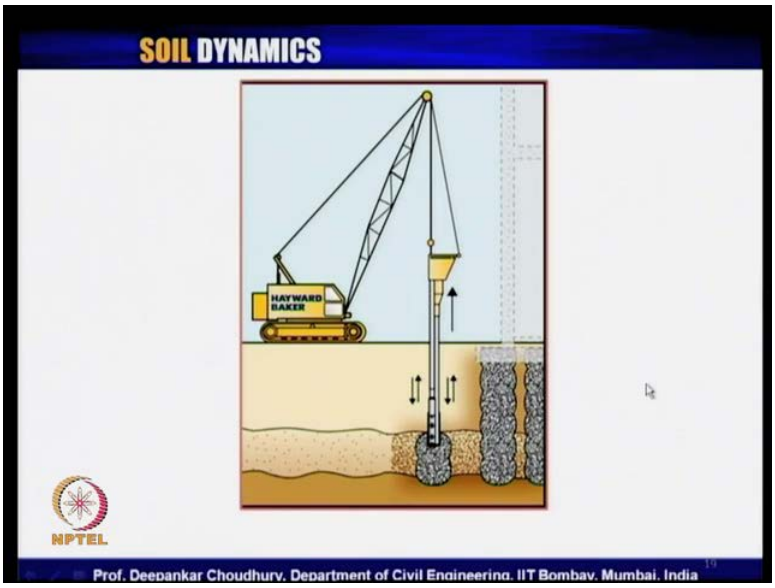

So, in this case also we applied the stones columns we construct stone columns in the grid pattern in regular intervals. So, this is the way how the stones columns getting the constructed, as we can see in this picture here. Stone columns are getting constructed which; obviously, replaces the soft loose local soil with the crushed stones material in form of columns. That provides a better load carrying capacity for the entire structures to be constructed on this soil.

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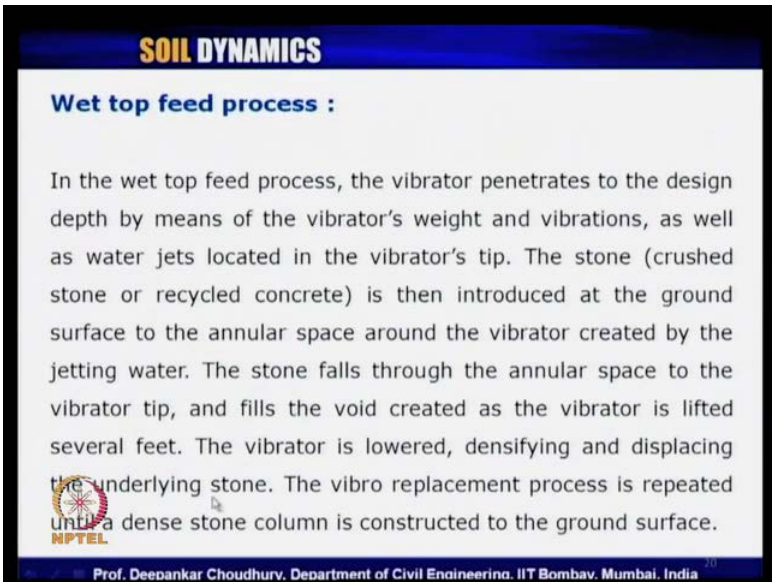

So, in the process the soil will gets densified and better, let us see what are those 2 technique. 1 is bottom feed technique and another 1 is wet top feed process, in the wet top feed process the vibrator penetrates to the design depth by means of the vibrators weight. It is own weight will take and penetrates at a particular depth bar is to be improvised the soil condition. And the vibration as well as water jets located in the vibrators strip.

So, obviously, the vibrators weight and water jet at the top or tip portion of the vibrated tip will allow the vibrated to reach to a particular depth, so that it can than further construct the stone column. The stone or crushed stone or recycled concrete is then introduced at the ground surface to the annular space. Around that vibrator creating by jetting of the water and the stone falls through the annular space to the vibrator tip and fills the void created as the vibrator is lifted several feet. The vibrator is than lowered than densifying and displacing the underlying stones. The vibro replacement is repeated until a dense stone column is constructed to the ground surface.

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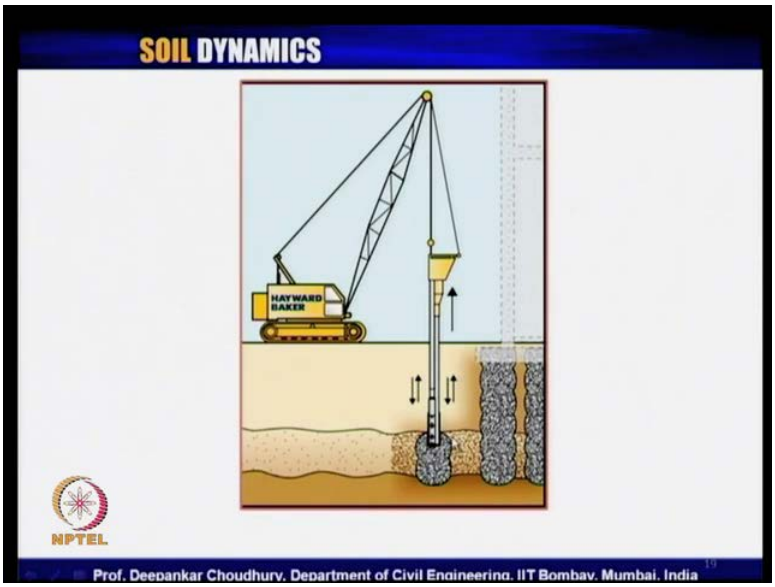

So, that is word we were showing in the previous picture as you can see here, this crushed stone or used concretes remains can be put through a vibrator at this location and slowly this is lifted up. And make to sure that the entire portion is made out that stone column which is getting finally, constructed up to the ground level and till the level of your desired depth where the improvement is necessary.

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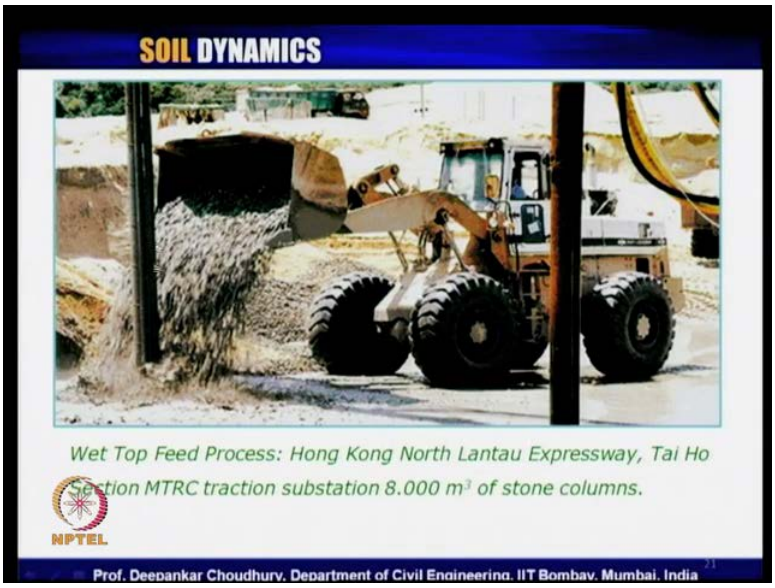

So, this is the technique which is used that site, this picture shows how the wet top feed process is carried out. This picture is taken from Hong Kong North Lantau Expressway, when the used of stone columns where going on Tai Ho section MTRC traction substation 8000 meter cube of stone columns. You can see over there the crushed stones are getting feed into this and finally, the stone column is getting constructed.

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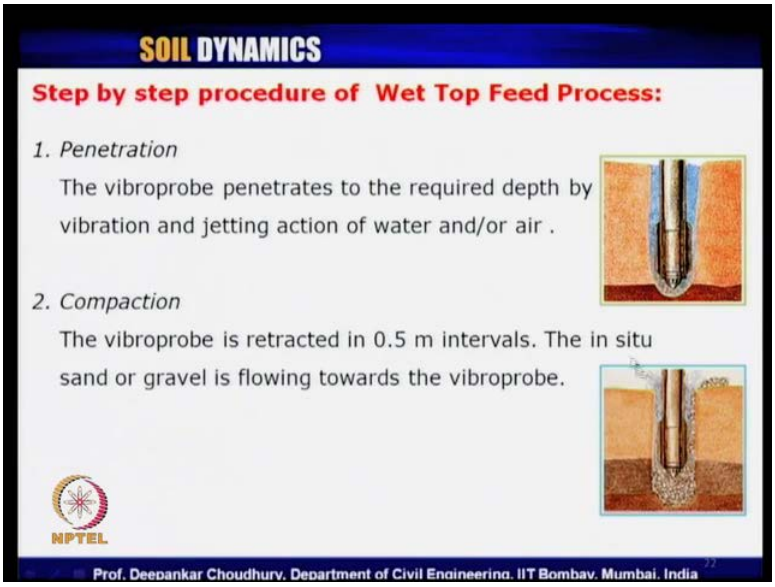

So, what are the step by step procedure for this wet top feed process, similar to the vibro compaction technique. Here also first the penetrations, that is the vibroprobe penetrates

to the required depth by vibration and jetting of the water and air and the self wet. Of course, in the second phase the compaction is done and all this stone and crushed stones material is getting injected over here and at field up.

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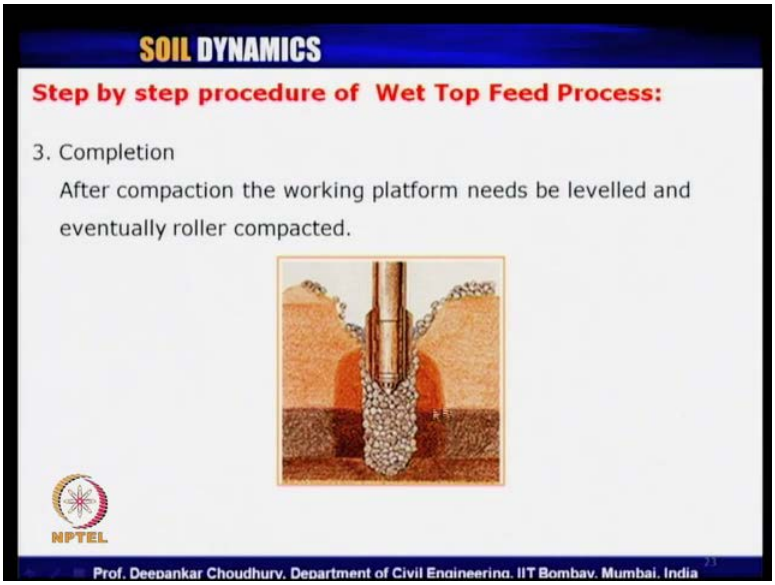

Completion is after compaction the working platform finally, needs to be leveled, once the stones column get constructed like this as we can see in this picture

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Now where to use this wet top feed method? Where the compaction of sandy and gravelly layers is required? And those layer are located above the water table, than than

the compaction is generally better accomplished with the wet method than with the dry method. Because, as the flushing water assists in compaction of the sandy soil around the column. And where particularly clean stones columns are required there this wet top feed method used.

The flushing water automatically cleans the columns during it is installation, because water jet is using and flushing water technique is adopted for this wet top method. So, wet top method basically applies to dry soils as well as it it helps to get a clean stone column to get constructed to at a side site. Also wherever there are no contaminants in the soil and the soil is not a highly plastic lay, leading to the problem of handling the mud in the process water.

There this wet top feed method can be used, where space is available for 500 meter square settling pond. And where the installation crew has sufficient experience in more demanding installation methodology they are also wet top of feed method it proposed to be (( )).

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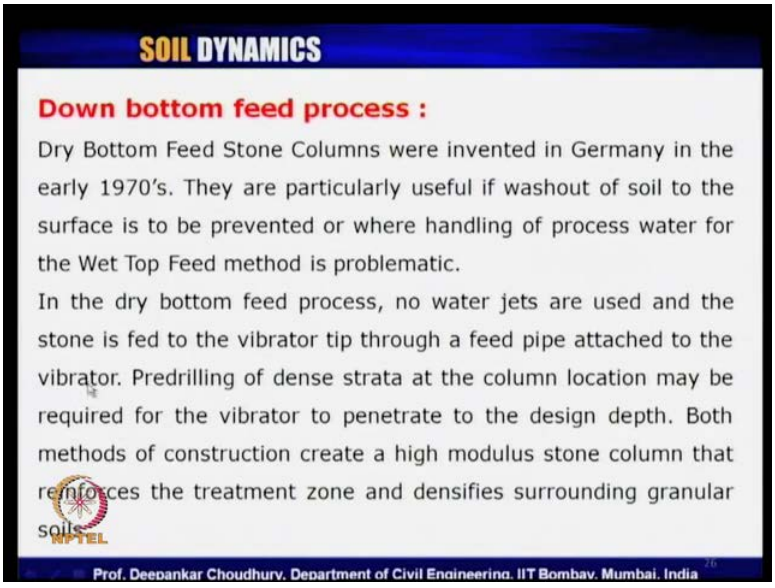

Now, let us come to the next method which is known as down bottom feed process. So, in down bottom feed process, down bottom feed stone columns were invented in Germany way back in 1970's. They are particularly useful if wash out of soil process to the surface is to be prevented. That is in earlier case we are washing out the soil as well as the stone column, but if we want it to be prevented.

In that case dry bottoms feed stone column method needs to be adopted or where handling of process water for the wet top feed method is problematic, there we should go for the other method of this down bottom feed process. So, in the down bottom feed process as the name or the requirement suggest, no water jets are used in this case. And the stone is fed to the vibrator tip through a feed pipe attached to the vibrator.

So, pre drilling of dense strata at the column location may be required for the vibrator to penetrate to the design depth. Both method of construction create a high modulus stone column, that reinforces the treatment zone and dandifies surrounding granular soils. So, in this case no use of water directly the stones are pipe or feed through to a pipe with the vibrator.

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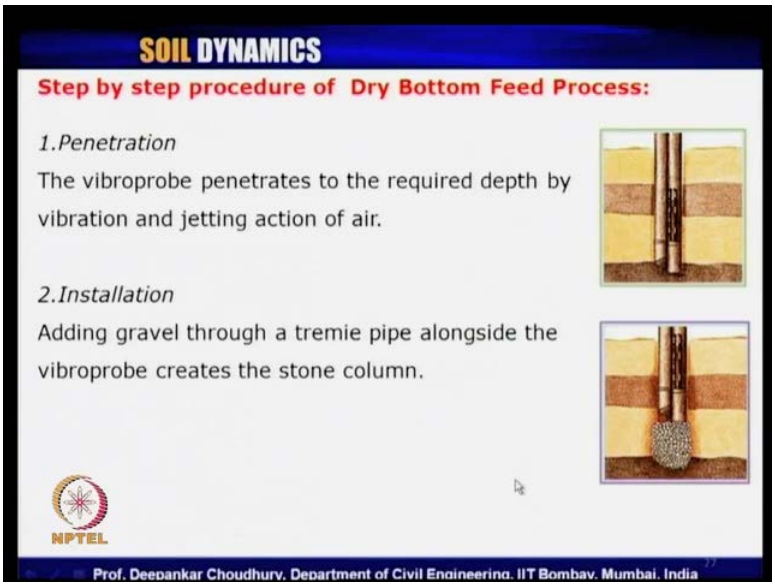

See if we look at the step by step procedure for this dry bottom feed method, in this case the fast step is penetration. There is the vibroprobe penetrates to the require depth where it needs to be improvised by vibration and jetting action of air. So, let us notice here we are not using water, but we are using air because it is a dry method. And installation is the second step in this, what we do? We add the gravel or the crushed stones through a tremie pipe through a tremie pipe we are adding this gravels or crushed stones here. Alongside the vibroprobe creates this stone columns and slowly this stone columns get constructed once the lifted up slowly.

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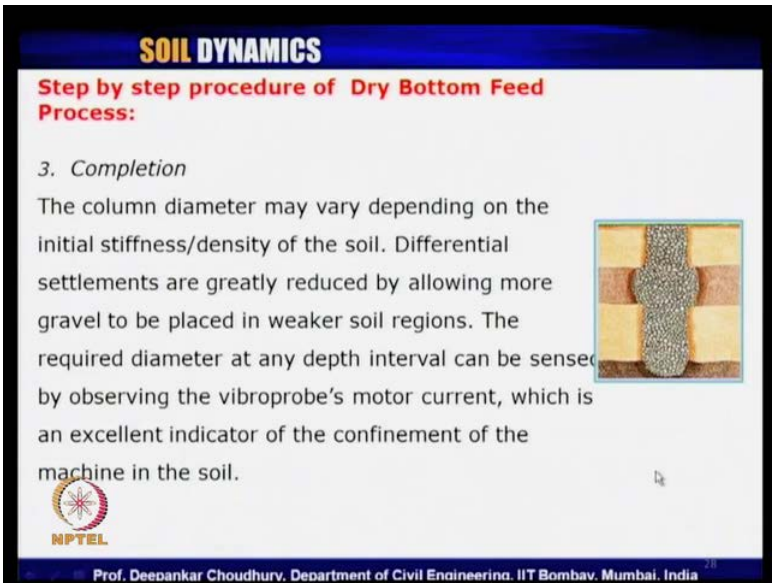

And third and the last step in this dry bottom feed is completion, the column diameter this column diameter it can vary depending on the initial stiffness or the density of the soil. Like, differential settlements are greatly reduced by allowing more gravel to be placed in weaker soil regions. If you can see over here more gravels are allowed or more crushed stones are allowed with a higher diameter of the stone columns at weaker locations.

So, that the differential settlement all together can be reduce at site, the required diameter at any depth interval can be sense by observing the vibroprobes motor current which an excellent indicator of the confinement of the machine into the soil.

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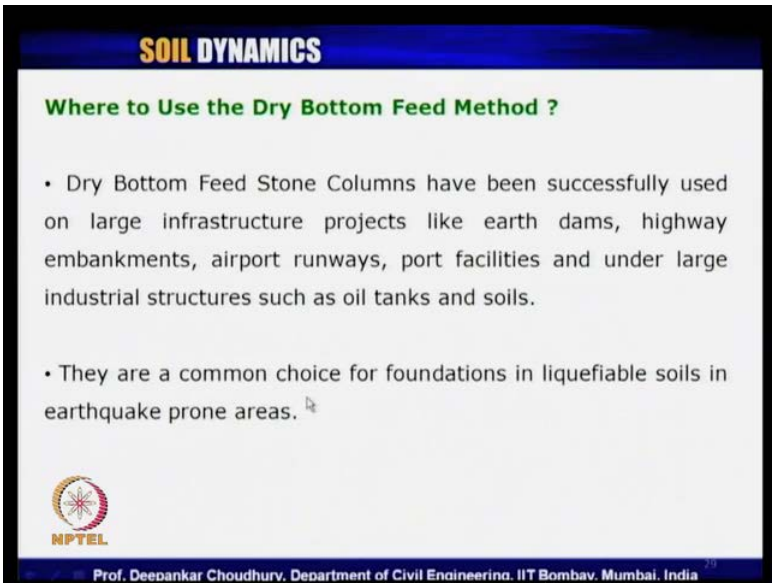

Now, where do we use this dry bottom feed method? This dry bottom feed stone columns, these are successfully used on large infrastructure projects like earth dam, highway embankments, airport runways port facilities and under large industrial structures like oil tanks and soils. There are a common choice for foundation in liquefiable soils in earthquake prone areas, because in earthquake prone area we already have soil below water table typically which needs to be densyfied. So, in that case weight process will not serve our purpose.

Actually, it will cause more problem or it will create more susceptibility for the liquefaction at that soil location instead of using weight process or water jet. If we go for this dry bottom feed method that will be the best option of soil densification using this technique. So, that is why it says it is good for foundation in liquefiable soils in the earthquake prone areas.

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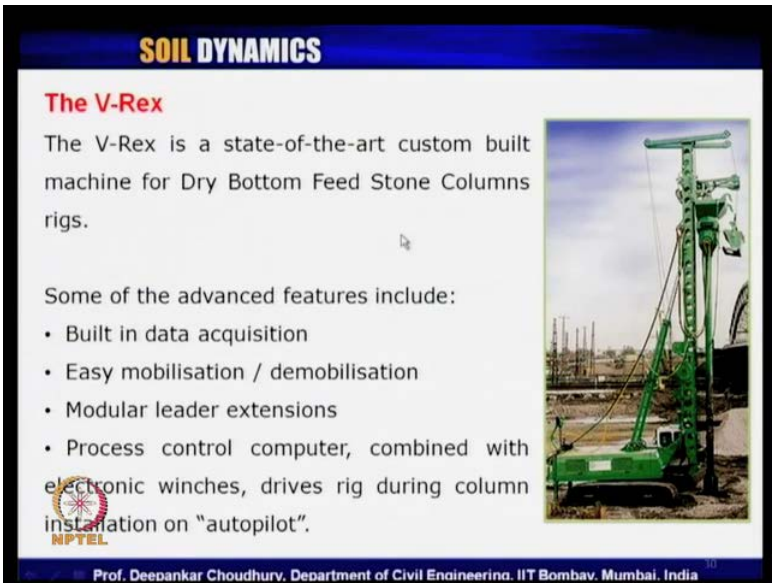

Coming to the V-Rex, the V-Rex is a state of the art custom built machine for this dry bottom feed stone columns rigs. So, this V-Rex is used for this dry bottom feed method. Some of the advanced features include, built in data acquisition easy mobilization demobilization, modular leader extensions and process control computer combined with electronic winches, drives rig during column installation on autopilot. So, this V-Rex which is commonly used in dry bottom fed stone columns construction is having these additional advantages.

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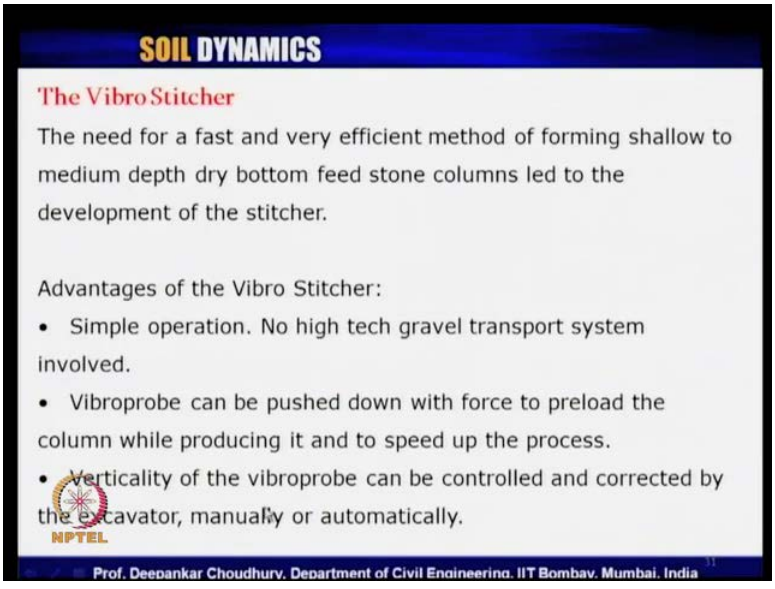

The vibro Stitcher what is it the need for fast very fast and very efficient method. For forming or shallow to medium depth, this dry bottom feed stone column led to the development of the method or technique which is called stitcher. What are the advantages of vibro stitcher? Like simple in operation, no high tech gravel transport support system is required, vibroprobe can be pushed down with force to preload the column while producing it and to speed up the process, vertically of the vibroprobe can be controlled and corrected by the excavator either manually or automatically.

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So, this is the typical picture of a vibro stitcher, which can be operated manually or automatically using this type of technique bottom dry bottom feed method, the feeding of the stone are taking place by this there is no water involved that we can note over here.

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Vibro replacement stone columns have been used to increase bearing capacity, and decease settlement and mitigate liquefaction potential for all the types of planned structure like buildings, embankments dams, tanks towers etcetera. Vibro replacement rigs can be fully instrumented with an on-board computer to monitor specific parameters.

Monitoring these parameters allows the operator to correct any deviation in real time during the construction process to keep the stone column within project specification. And data collected from the data acquisition system such as amperage and lift rate are recorded and displayed in real time alongside specification target values on an in cab monitor.

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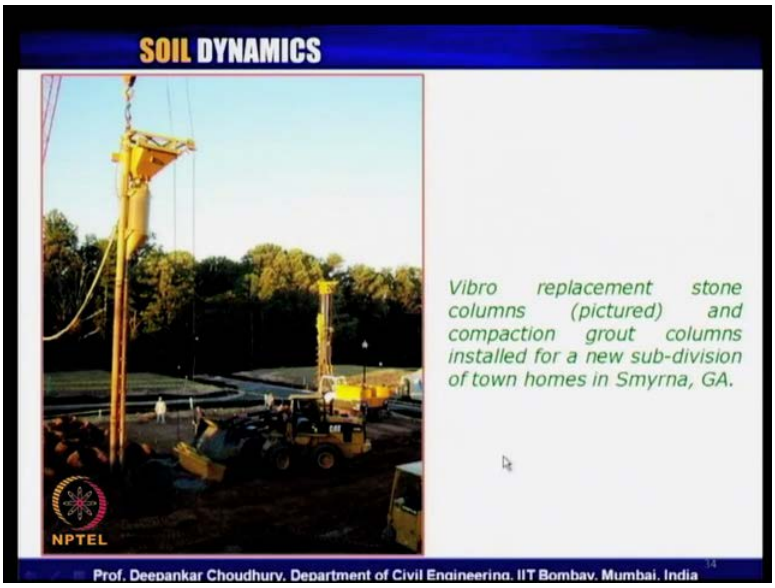

So, this is the typical picture, which shows the vibro replacement stone column and compaction grout columns installed for the new sub division of town homes in smyrna. So, this the common way you can see how the vibro replacement stone column are getting constructed at a site for densifying the soil condition.

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There is another picture shows vibro replacement of stone column performed by 4 rigs to densify, this 4 rigs are used to densifing and reinforce the underlying soil to meet

earthquake code requirements and control settlement for the new Voorhees hospital in Camden, New Jersey.

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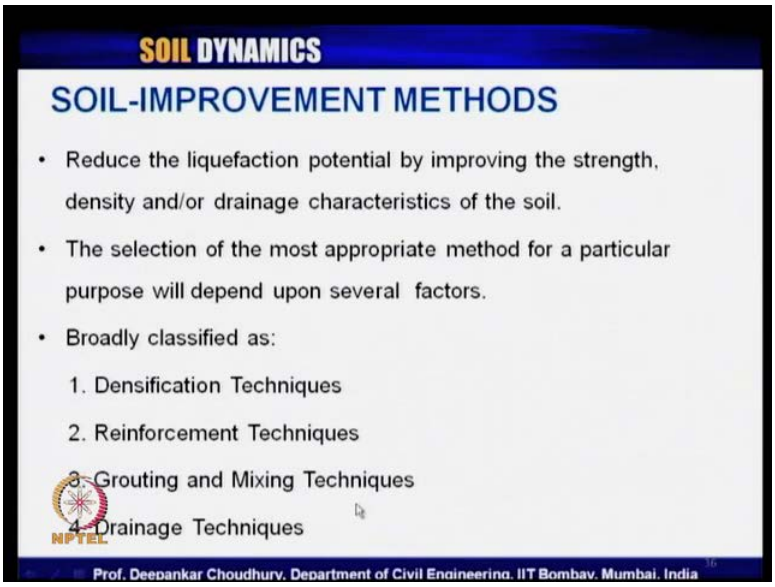

Now, coming to soil improvement method, for the soil improvement we want to reduce the liquefaction potential by improving the strength, density and or drainage characteristics of the soil. So, the selection of the most appropriate method for a particular purpose will depend on various factors. And what are the broadly classified soil improvement techniques? Like densification techniques, reinforcement technique, grouting and mixing technique and drainage technique.

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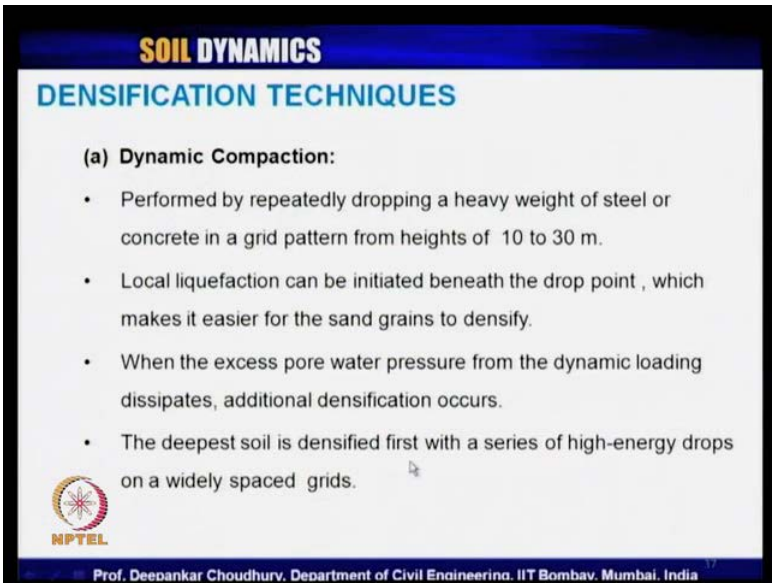

Now, in this densification techniques, where we use this dynamic compaction which we have discussed. Performed this dynamic compaction is performed by repeatedly dropping a heavy weight of steel or concrete in a grid pattern from the height of 10 to 30 meter to compact the soil at particular site. So, the local liquefaction can be initiated beneath the drop point which makes it easier for the sand grain to densify.

So, at a point by applying the dynamic load the local liquefaction can be initiated and through the process the soil finally, gets densified. When the excess pore water pressure from the dynamic loading dissipates then additional densification also occurs, because once; obviously, the excess pore pressure moves out, then definitely soil gets densified better. The deepest soil is densified first with a series of high energy drops of a widely spaced grids.

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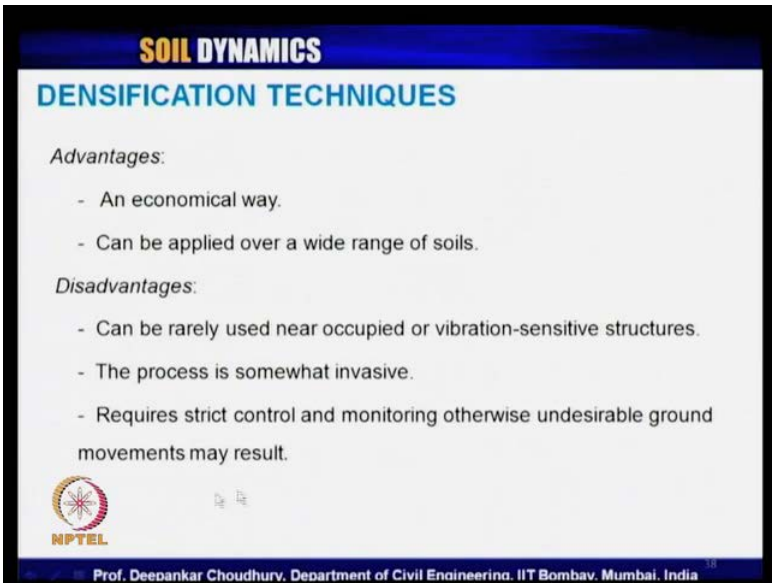

So, what are the advantages? Like, it is very economical way, it can be applied to at a site over a wide range of various types of soil, but what are the disadvantages? It can be rarely used near occupied or vibrated sensitive structures, that is if we want to use the dynamic compaction in a urban environment. Then it is not applicable or not desired, because it creates lot of noise and also probable damage to the near by existing structures through this dynamic compaction process.

The process is somewhat invasive, requires strict control and monitoring otherwise undesirable ground movements may result. That is some part may get more densified and another location adjacent to it may not get that much densified. So, automatically the what is the objective for which this process is started will not be fulfill, because the entire area is not getting uniformly densified.

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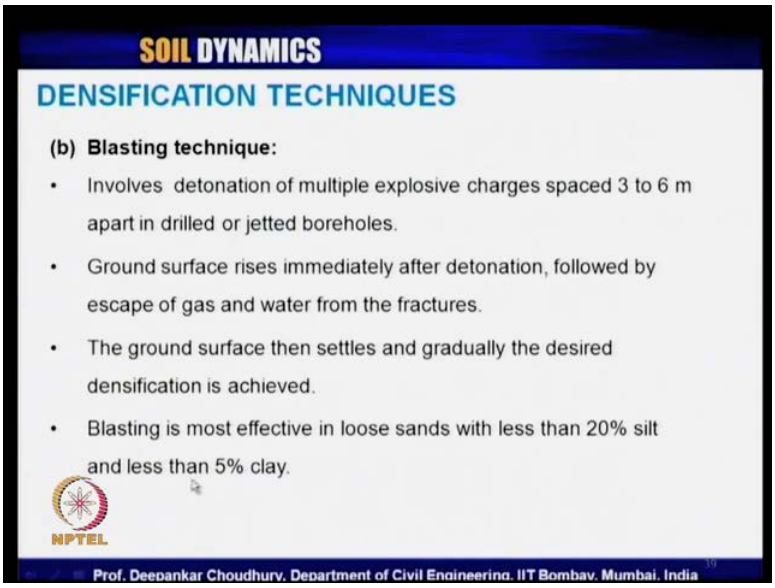

So, what are the various densification techniques? Like, blasting involves detonation, the first 1 we have seen a has dynamic compaction, the second one of densification technique is blasting. Involves detonation of multiple explosive, which charged at a space of 3 to 6 meter apart in drilled or jetted boreholes.

Ground surface rises immediately after detonation followed by escape of gas and water from the factures of the material. The ground surface then settles and gradually the desired densification is achieved. Now blasting is most effective in case of lose sand with less than 20 percent silt and less than 5 percent clay.

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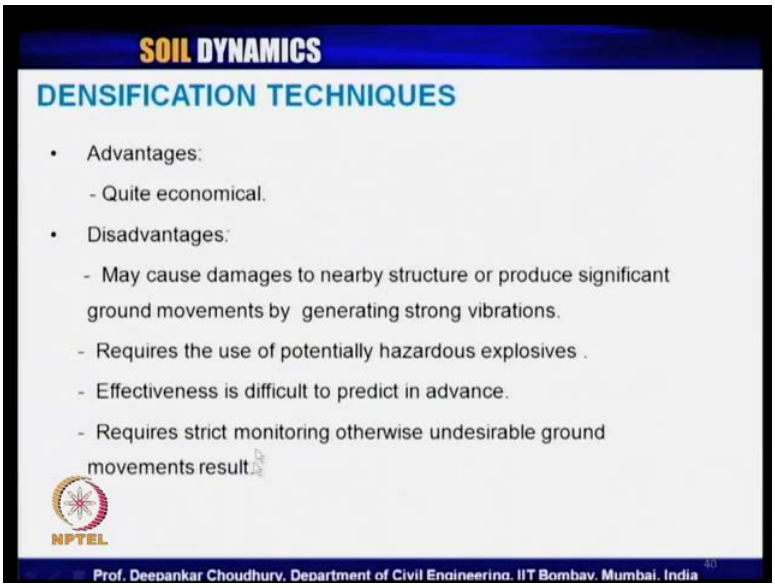

The advantages of this blasting technique is, it is very economical, but disadvantages are like it may cause damages for near by structure in this case also. Like, if the blasting is not a control blasting, it can produce sever damage to the existing buildings or near by locality. And it create problem to the existing structure or produce significant ground movement at a particular location by generating strong vibrations.

So, it requires the use of potentially hazardous explosive; obviously, a very big disadvantage for using the blasting technique of densification. Effectiveness is difficult to predict in advance and it requires strict monitoring otherwise, undesirable ground movement will result from this blasting method. So, with this we will stop our lecture today with the blast technique for densification and we will continue our lecture further for this module 6.