Ground Improvement

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Lecture 16

Rapid Impact Compaction

Good morning to everyone, I welcome you to this course Ground Improvement module 4. And we are discussing the ground improvement and initially we have taken the shallow densification that is by roller and other thing. And which is very conventional everyday activity we see particularly for making road, parking areas, etcetera. And but those are actually when you are making some site for some facility then we can do in leap thickness 30, 40 centimeter and compact like that you can do.

But when a particular site that is a problematic soil or a great depth for example up to 8meter, 10meter, 6meter then that technique, that shallow densification technique will not work, for that type of problematic soil to make it useful you have to go for some other technique one such method is deep dynamiting compaction that also we have covered in the module 3.

And we are now I want to choose that another topic on ground improvement or densification of soil by applying energy that is rapid impact compaction. From the name itself it is quite clear the rapid impact means very quickly in a short time we make a number of blows in at a particular place.

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Whereas in your deep dynamic compaction there will be a weight is quite heavy. And that has to be lifted by crane up to 30, 40 meter and then it has to be dropped once dropped it will be in short, the crater will be there then with some efforts you have to pull it up and again it will go and then you have to pore. So, it takes a long time to make it one first blow to second blow, second blow to third blow, sometime gap used to be there.

Whereas this rapid impact compaction already there will be a plate will be set on a predetermined location. And then by hydraulic lifter the weight will be lifted and allowed to fall lifted and allowed to fall by that way it will be several impact times will be, can be given at one time and a short time. By that name itself it is quite clear that rapid impact compaction. And this rapid impact compaction what way it is different from deep dynamic compaction.

It is also compatibility but it is not so deep as it is in deep dynamic compaction or the dynamic compaction. It is in between shallow compaction and this deep dynamic compaction. Some areas it is useful. So, before going to much detail we will discuss about its application, merits, demerits, etc. let me take to the first slide.

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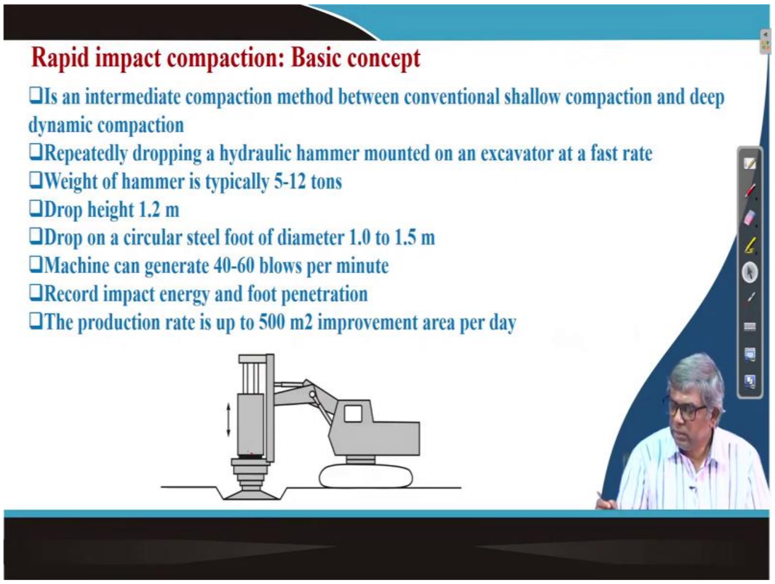

And you can see this that whatever I have said already that rapid impact compaction. This is the weight actually, it is and this is the plate it will be fixed in the, and this is by hydraulic arrangement. This one lifted up to this much height and again is allowed to fall here. That way it can be given within a short time a good number of blows can be applied here. So, this is the machine basically and this is some excavator actually can be attached to this one and by that this can be done.

Here actually can whatever already I have mentioned you can see. It is an intermediate compaction method between conventional shallow compaction and deep dynamic compaction. So, already I have mentioned because it can be some medium in between like 3, 4 meter or 5 meter and not like deep dynamic compaction 10 meter. And whereas shallow compaction means not beyond 0.5meter, 0.6 meter.

It is because of that we can say it is intermediate method of compaction and it is repeatedly dropping a hydraulic hammer mounted on an excavator this is the one at a fast rate. So, as I have told you that it is through the hydraulic machine it can be done very quickly. And weight of hammer is typically 5 to 12 tons, whereas deep dynamic compaction it was 5 to 40 ton. So, you can see it is a weight also comparatively less.

And drop height it was there 10 to 40 meter and here it is only 1.2 meter. Because this is the distance only can be lifted and drop on a circular steel foot of diameter 1 to 1.5 meter. And generally, this is the one plate, the foot plate on that actually will be an impact will be given. And the machine can generate 40 to 60 blows per minute, so that so the rate actually in one minute it can give you that means second one up to one give the second it can give you an impact.

And record impact energy and foot penetration that means when it will be this operation will be done during that how much it is settling that can be monitored and also recorded and it involves energy how much energy is applied to the soil that also can be recorded. And the production rate the how quickly we can do we have mentioned that deep dynamic compaction itself is a faster method.

But this is again similar a much faster and the approximate quantity is mentioned is a 500meter square improvement can be done for the 500meter square. This is the by enlarge what is rapid impact compaction let me take to the next slide.

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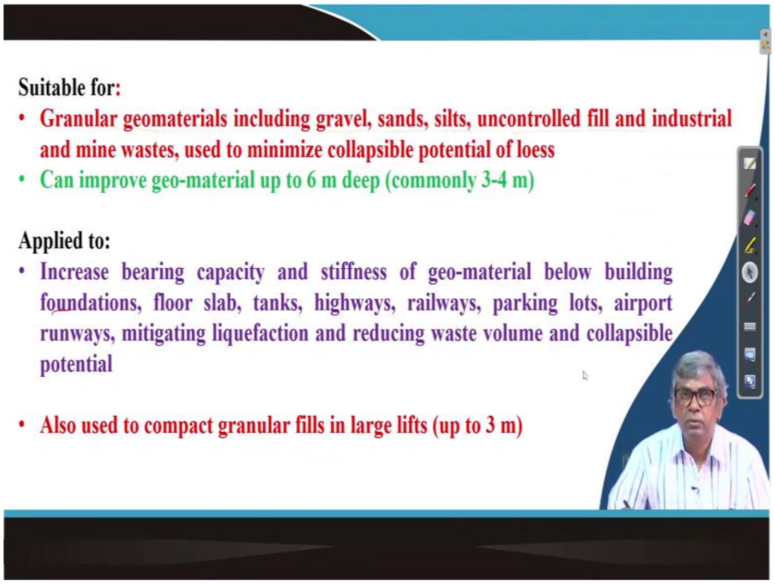

You can see where it is suitable it is suitable for granular material including gravels. So, granular gravel also granular, sand sealed, uncontrolled field and industrial and mine waste and use to minimize collapsible potential loess. Loess also is a granular soil around it basically and this type of soil actually very effectively can be densified of course not up to 10 meter it can be up to 4, 5meter, meter. What is the level degree of depth of improvement for different type of soil that will come later on?

That will be different actually for all soil the depth of improvement will not be equal. And also, can improve geo-material up to 6, so that is what it is the limit is 6meter. And typically, 3 to 4 meter is very commonly used for 3, 4meter fill, making a 3, 4meter fill and then densification if it is needed give and soil is granular. Then the deep, that rapid impact compaction will be perhaps more suitable.

Then where to apply, why, when why we, what is the use of this type of compaction, this increase we are in capacity and stiffness of geo material below building foundation. So, that means if there is a soil here this is the ground and here actually, we want to build something. So, that means the below the building the soil should be stiff enough. And it will be strong enough to make the stiff and strong. What do you have to do? This compaction can be done, so that is the one the bid increases the bearing capacity, stiffness of geometrical below the building.

And then many other things floor slab that means then tanks, highways, railways, parking lots, airport runways, then mitigating liquefaction and reducing waste volume and collapsible potential. So, all those the purpose of ground improvement is these only increasing bearing capacity, stiffness all those things here also similar thing. The basic purpose is to make the soil strong. So, it would have less stiffness, it will have more resistance to failure.

Although such a similar type of any ground improvement technique you talk about it will have similar purpose. And also used to compact granular fill in large lifts. So that means as I have told you that these are the different areas where we can do these are rapid impact compaction. And sometime in a large lift as you have told shallow compaction, a shallow densification actually 30, 40centimeter but if you can use large lift if you use and granular soil and if you want to compact quickly then perhaps this rapid impact compaction is also another solution.

Otherwise for granular soil shallow densification method also you can compact by roller the vibratory roller. But there also the lift thickness is similar same at 30, 40centimeter but here actually in a large lift a granular soil if you want to improve or densify up to 3, 4meter then this perhaps is another solution. Let me take to next slide.

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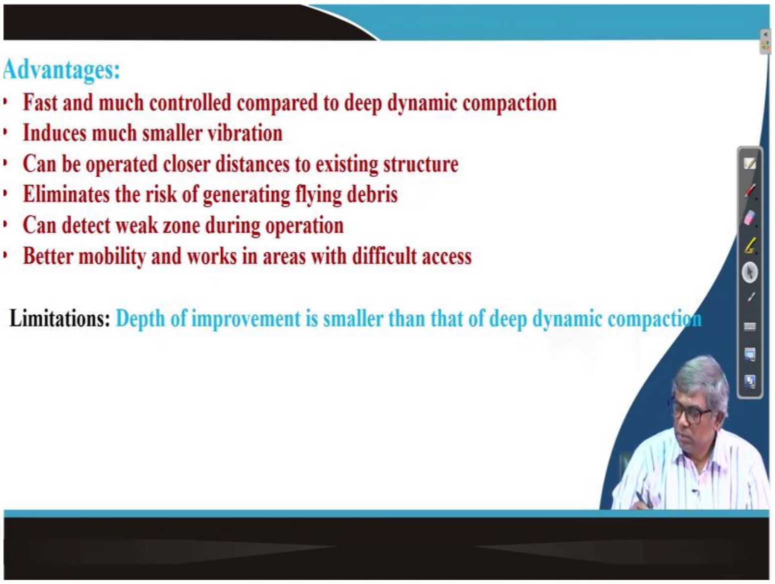

And some advantages that means so far whatever we have used, discussed that is shallow densification then deep dynamic densification with respect to that what is the advantage here? First and much controlled compaction to deep dynamic compared to deep dynamic compaction.

So, why it is because deep dynamic compaction it makes a heavyweight heavy along huge height because of that surface get disturbed also the placing the impact there may be some changes here and there control will be little difficult sometime.

But here since we are fixing the plate and, on that plate, only, we are impacting the same plates and further then the plate is small size again you can go to the next and then even if do the same by this way entire copped area can be covered. And so, this is actually that is why it is fast and at the same time is much controlled compared to the deep dynamic compaction. Control is better that means quality control and other things, induces much smaller vibration actually for because energy level is that lift height is smaller because of that energy will be less.

And that will also cause lesser vibration or environmental effect. And this can be operated at closer distance to existing structures. As we have mentioned or discussed or for deep dynamic compaction that how far or what is the clear distance where we can do that type of activities there is a regulation that and we have that regulation is fix based on peak particle velocity and those peak particle velocity is a function of weight up top, height and distance.

And so those things and based on that if you see that peak particle velocity is greater than some value so the unlimited value then that technique cannot be applied there. Because people will get disturbed and they may come and oppose the activities. Here actually that vibration will be there but it is comparatively less. Because of that it will be less harmful. And because of that it can, you can go much closer to the structure compared to the one you do by deep dynamic compaction.

And eliminates the risk of generating flying debris, another thing is that when it is deep dynamic compaction heavyweights and I mean from heavy height, long height. And then because of that a lot of debris flows will happen. It will fly certain things and it will be again or if there is wind it will be carrying to the nearby areas that sometimes that is a big hazard sometime should that type of things here is not there.

Because actually on the ground itself plate is fixed and then you are impacting. So, nothing is flying and can detect weak zone during operation that means we know that by one come one impact how much generally is known by trial a test we can find out by one impact how much deformation it can have or shuttle one can have if you find that by 1 or 2 blow or impact you will find too much of subsidence then you can clearly visualize that particular zone may have much weaker soil than we have visualized.

If you find that type of problem then immediately what you have to do you have to either over excavate and replace by some material and then compact or you have to take some precautions. Then better mobility and works in areas with difficult access. Sometimes, the deep dynamic compaction that is heavy cranes are required and that mobility or access to the site sometimes difficult.

But here actually one only excavator is required and then that mechanism. So, for that actually mobility and the works areas in difficulty access area is better. But it has some limitations, what is that limitation? So, compared to deep dynamic compaction where we can go up to 10 meter and here, we can go up to some 4, 5meter just maximum is 5, 6meter. And which is almost few half of the deep dynamic compaction.

So, that is the only limitation but it is better than of course shallow densification. Sometime in some application this deep dynamic compaction may prove useful or not deep rapid impact compaction. Let me go to the next slide.

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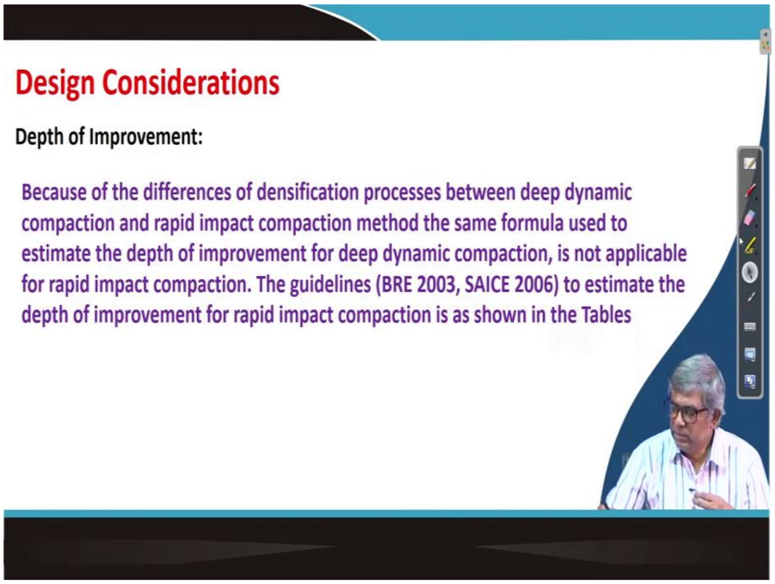

Then design consideration why you like deep dynamic compaction we have designed different parameters to be first they would select and then you have to calculate certain things. Then a you have to select the temper or wait you have to select height of all then you have to select a pattern, you have to select number of drops, number of passes, a number of passes and then number of, number of drops its need passes.

Those are the design things here actually comparatively not much to design few comparatively less design involvement will be here. But still there is some design aspect also here and you can see depth of improvement first of all that first parameter to be identified the depth of improvement. And depth of improvement of course we know that rapid impact compaction method we can go maximum up to 5, 6meter.

And again, it will be different soil different but you have to see the site condition and based on that you have to identify what is the depth of improvement if that depth of improvement is within the range of rapid impact compaction, then we can select this method. What we have mentioned in this paragraph? Because of the differences of densification processes between deep dynamic compaction and rapid impact compaction method the same formula used to estimate the depth of improvement for deep dynamic compound is not applicable.

So, there was an equation to find out SD equal to WT SD to the power 1.54 or something that equation will not be working here. And the guide guidelines to estimate the depth of improvement for different impact compaction, rapid back compaction is I have shown the next table that I will show you that there actually in the deep dynamic compaction there was some empirical relationship by which you can just make a preliminary estimate.

What could be the depth of improvement? If you select weight and weight of temporal height. But here since there is a process is different that equation will not work here. Instead, people based on their experience they have suggested what is the depth of improvement can be there for different types of soil that is actually given in a tabular form. And you have to see that and if you find that when a particular site the problematic soil within that depth then only you can make it that method is suitable and select. And we can see go to the next slide.

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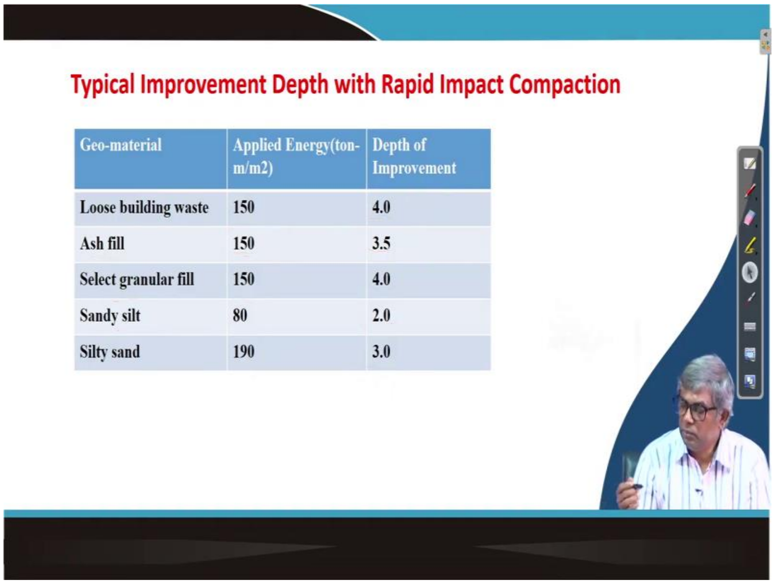

And we can see the table we can see this table that geo-material which is to be considered as problematic material sometime loose building waste. And applied energy ton meter per meter square is 15meter ton meter per meter square and depth of improvement will be 4meter. And if it is ash fill and by applying energy of 15ton meter per meter square we can only improve up to 3.5 meter.

And select granular field again same amount of energy you can go up to 4 meter of improvement then sandy silt comparatively less amount of energy you can put and then you can get two-meter depth of improvement if it is a silty sand then you have to apply 190ton meter per meter square energy to get the improvement up to 3meter depth. So, this if it is a little more or less than sometime what is the corresponding energy requirement that I will show while solving the problem.

So, this is the guideline actually if there is a problematic material this is the energy level, this is a depth of improvement. And but if depth of improvement little 4.5 then what would be the energy level is required you can estimate. And if it is an instead of 3.5 it is 4 what is the energy level here that can be also converted and then accordingly you can use that much energy. And otherwise, this type of soil can be improved whatever range is given 3, 4, 5, 6 like that maximum. Let me go to next slide.

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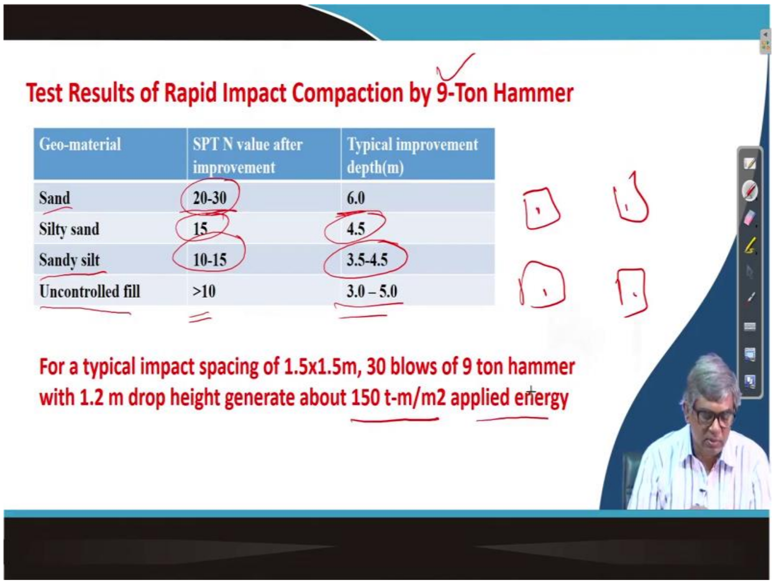

And see the results of rapid impact compaction by 9 ton, hammer a 9ton hammer is used and in that for different geo-material suppose if the sand is taken and SPTN value 9ton hammer then after compaction their typical improvement depth is 6meter. And in that case the SPT value can be after compaction can be up to in between 20 to 30. And if it is silty sand the SPT value can be achieved by deep dynamic compaction 15 and it can be improved up to depth of 4.5 meter by using 9ton hammer.

Then if it is a silty sand that SPTN value can be achieved between 10 and 15. And in that time by 9 ton hammer we can improve up to 3.5 to 4.5 meter. And in uncontrolled fill you can have SPTN value greater than 10 is the requirement then only you can use useful. And then to have that by 9ton hammer then we can improve up to 3 to 5meter.

And for a typical impact spacing of 1.5 meter 30 blows of ton 9tton hammer that 1.5 height meter means 1.5meter 1.5 meter like that you have a 1 here 1 here 1 here and then 9 ton hammer you can use and 1.2meter drop if you do. Then generate about this much applied energy in a single drop that is the calculation.

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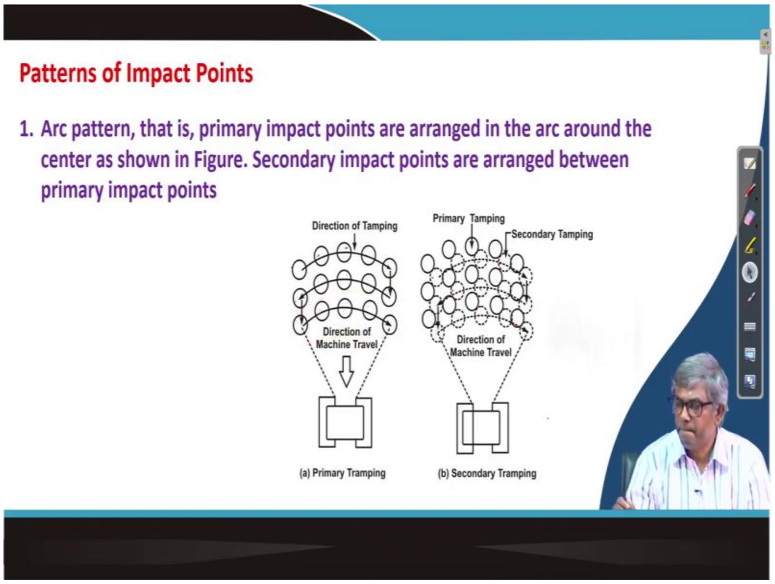

Then there is a pattern or the impact that is very important as it was in a deep dynamic compaction here also similar since it is an excavator is used which can be moved different direction and fixed in a particular location. So, there is an arc pattern there is a method is an arc pattern you can see this is the excavator and you can move either this direction or that direction and you can see if this is the so with this standing here it can give impact here, it can give impact here, it can give impact here, it can give impact here, here like this.

And similarly, it can be given like this, it can be given like this and with this spacing can be decided. And this is the you are actually supposing a primary tamping and if you want to make secondary tamping, then what you have to do so in between suppose you have here or you have here. So, same this one so before this one, this one, this one arc. So, accordingly you can have this, you can have this, this, this you can have this, this, this like that it can be compacted.

So, this is called arc pattern the primary impact points are arranged in the arc around the center as shown in the figure. This is the center and this is the arc. That means this the handle of the excavator will move in an arc along an arc. When it is here it will be put like this, it will put like this, it will put like this, it will put like this, and like this it then completes the operation.

Similarly, when it is a secondary pass is required. Wherever it is applied according to the spacing you have to before and after you have to again place and compact like a long arc like this. This is called arc pattern.

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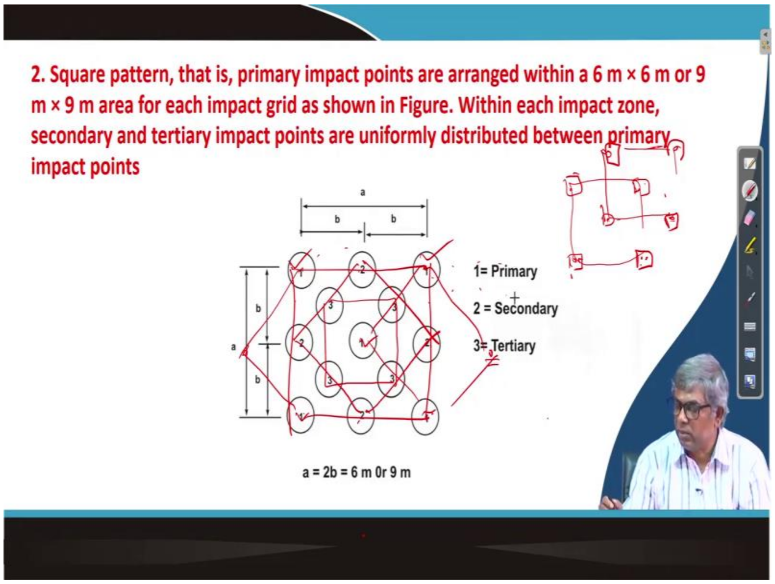

Next one is the square pattern. And you can see the square pattern now from the name itself is quite obvious that it will be in the square form that means you can see by the corner, 4 corner this is a square. So, it will be impact will be created here, impact will be created here, impact will be created here, impact will be created here and next level maybe it will be done here it will be level, it will be level like this. So, there will be another will be like this. So, like this.

So, square pattern means whatever primary secondary whatever a tertiary always we follow the square pattern that means and you have to have maintained a particular spacing. When you are doing this one this is supposed primary then you are maintaining some distance that is spacing this distance we are maintaining, this distance we have maintained this like that you are progressing all direction.

And when you are getting next stage then again, we can in between this and in between this you can fix one point. And then if you do here perpendicular to this direction you can have another an equal distance this direction equal distance, this direction also equal distance, this direction So, like that you can complete it you can see here same thing is explained here primary 1 1 then 1 1 1. This is a primary and then secondary 1 1 1 1. This is the 1 and again you can see this 1 actually corresponding to again you can have another square formation along this like this this like this and secondary is you can see 2 2 2 2 here and all those things. And you can see that tertiary that means in between again you can see 3 3 3 again it is also forming triangle 2 2 2 also forming triangle 1 1 1 also forming triangle so like that.

Similarly, this 1 corresponding to this also we can have square part because if you do here then you will get another square. If you do here you will get another square like this. This is a square pattern and so you can have a primary, secondary, tertiary according to the requirement.

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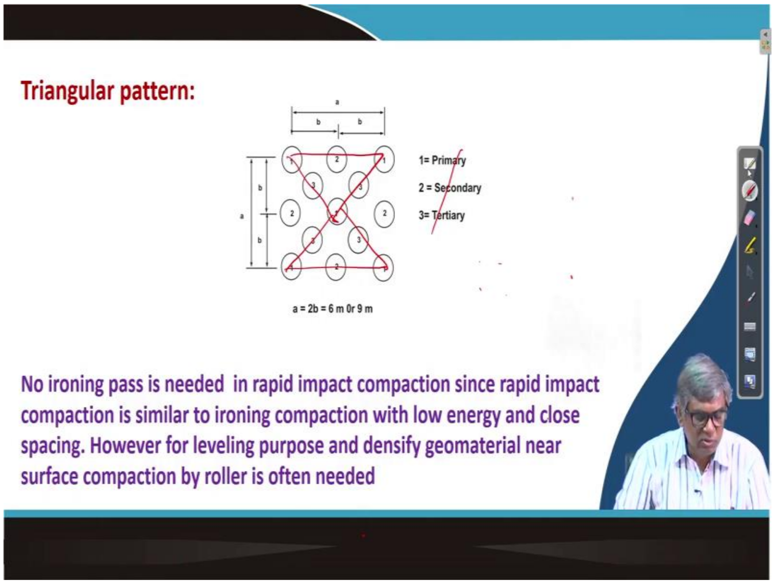

Then you can have a triangle I am not done separately triangular pattern. So, if you have if you plan yourself primary secondary for. I forget the primary secondary I just ignored that and if I do this one this, this is the pattern, this is a pattern then it is triangular. And similarly, if we do then they are triangular pattern. In this actually in particular rapid impact compaction the advantage already we have mentioned that no ironing pass is required.

In rapid impact compaction since rapid impact compaction is similar to ironing compaction with low energy and loose and close spacing. The spacing between this are quite close so disturb soil in between will be less. Because of that the ironing pass is generally not required but for leveling purpose final leveling purpose some time we can use roller is often needed. That ruler sometimes vibratory roller also can be used. By this way the rapid impact compaction can be completed.

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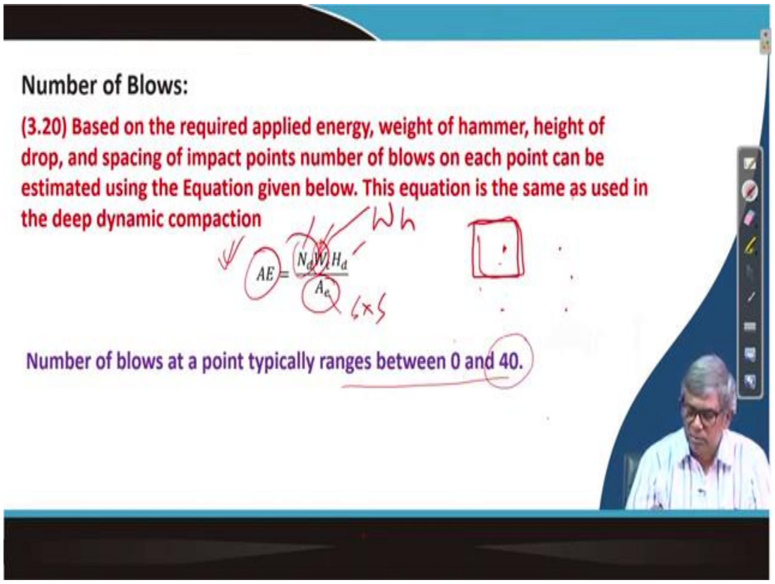

Now, number of blows here actually since ironing pass is not required. Whatever amount of energy required whatever I have shown in the table different type of soil and how what is the energy requirement. This energy is totally applied by the rapid impact compaction in no calculation though we may use at the end a roller that calculation is a small amount we cannot be separated. So, total required energy.

$$AE = \frac{N_d W_t H_d}{A_e}$$

This is the total required energy and if you know that is actually this equation is same deep dynamic compaction also, we have use same equation this is the influence area of the impact suppose this, this, this, this. So, a particular one the influence area will be the spacing the square. So, that is the AE will be spacing square S into S and Nd is the number of drops, W weight of top, here weight of top instead weight of hammer we can say, better I will write W_h weight of hammer and W_{hd} means height of drop.

So, by this way actually total required energy and while doing this operation we generally take from the table what are from the guideline how much energy is required. So, this will be known and this and this to be selected and the spacing also to be selected. And then if you select that then what is the number of drops required you can find out. Number of blows at a point typically range between 0 to 40. So, it can be little more a little of course the beyond 0 nothing can happen. It will be some 0 to 40 is no meaning you can see up to 40. So, by this actually number of drops can be estimated.

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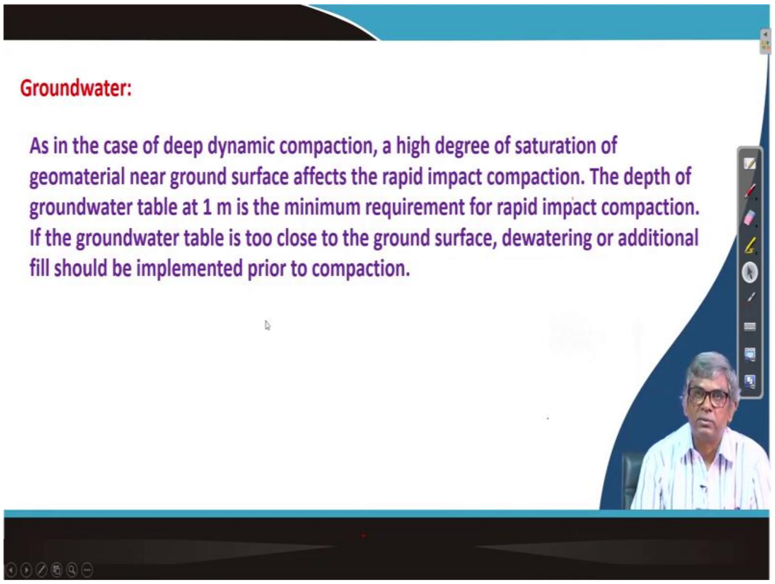

And next will be the groundwater and when there is a groundwater obviously like deep dynamic compaction will not be so easy. Here also it is so and actually the minimum requirement is groundwater should be below 1 meter depth. And if the water table comes above water 1 meter or within 1 meter in that case actually sometime you dewatering will be required or sometime additional filling can be used.

So, you can see that the depth of groundwater table at 1 meter is the minimum required rapid impact compaction. If the groundwater table is too close to the ground surface dewatering or additional fields should be implemented prior to compaction. This is the things already I have mentioned. And with this I will close this one lecture. Next one other aspect of design of rapid impact compaction I will take in the next lecture. Thank you.