Ground Improvement
Professor Dilip Kumar Baidya
Department of Civil Engineering
Indian Institute of Technology, Kharagpur
Lecture 17
Rapid Impact Compaction (Contd.)

We are in rapid impact compaction and we have discussed shallow, we have discussed deep and the rapid impact compaction is the intermediate type of compaction. And less energy required and it is faster and many other benefits and many are limitations I have already discussed in the previous lecture. And then I was discussing about that design step and compared to deep dynamic compaction here steps are quite less actually.

First of all, you have to select the depth of improvement and for finding out the depth of improvement though in the dynamic deep dynamic compaction there is an empirical equation. But here that equation will not be applicable. And because of that you have to get this depth of improvement from experience. And from experience people have recommended depending about type of soil what should be the depth of improvement that also I have discussed.

At a particle site if you go and if you see there is soil is problematic. And by geophysical investigation you have to find out what is the depth up to which the problematic soil exists. And that depth if you find that lesser than the recommended depth for a particle type of soil then that method can be adopted. And once you adopt that method then you have to do number of things you have to select weight and we have to height up drop.

And then you have to find out number of drops required. And of course, before finding out the number of drops energy requirement you have to also take from the recommended value. The people already conducted some tests on 9ton hammers on a and then based on that they have given a chart for different types of soil in ton meter per meters, ton meters, ton meter per meter square that actually unit they have given for different types of soil.

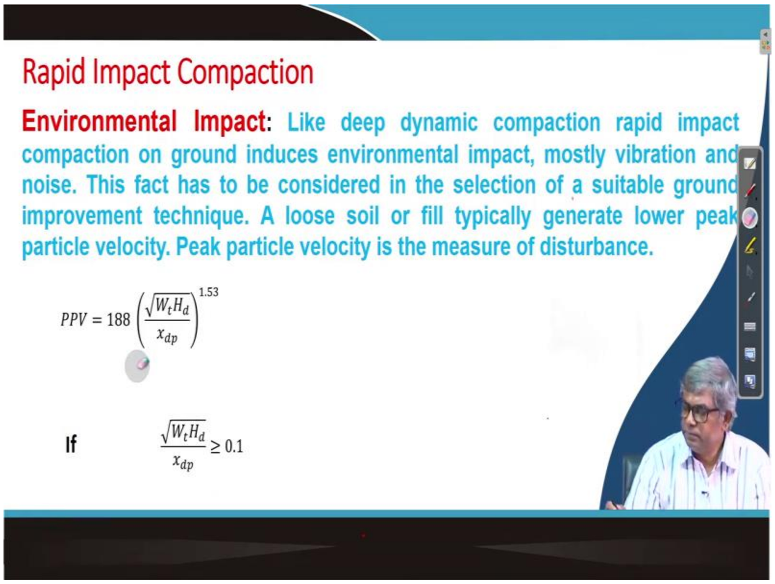
And corresponding depth of improvement in depth of improvement little change then that can be modified that also you have mentioned. So, once you select that energy requirement and then in a deep dynamic compaction or rapid impact compaction the total energy, energy by impact that actually can be obtained by equation actually by number of drops multiplied by weight of hammer multiplied by height of drop of hammer divided by area of influence.

Area of influence is actually the if I use a spacing between the two impact then the influence area for a particle impact point can be estimated depending upon your pattern. So, if the square pattern some value can it is a spacing square. And if it is a triangular pattern then it will be different that can be discussed later on. Then 0.8678 square or something it is and that can be used. So, that instead of Ae we can use that.

So, those things already we have mentioned and once you know that if you select the energy if you know the spacing or select the spacing and based on that if you find out the influence area and then if you know the hammer weight if you know the drop hammer drop height and then from this you can find out number of drops required.

And number of drops that also we have discussed previous lecture and then the subsequently we have seen the requirement of groundwater and all if there is a groundwater up to very close then what to do that recommendation already mention.

(Refer Slide Time: 4:42)



So, let me see in this one hour like in your deep dynamic compaction the rapid impact compaction also produces a vibration or health or environmental impact or environmental hazard. And these environmental hazards sometimes because of that we cannot select every any site these type of activities. So, you have to do some calculation and you have to see that you are not making any value which is exceeding some regulated values.

$$PPV = 188\left(\frac{\sqrt{W_t H_d}}{x_{dp}}\right)^{1.53}$$

$$if\left(\frac{\sqrt{W_t H_d}}{x_{dp}}\right) \geq 0.1$$

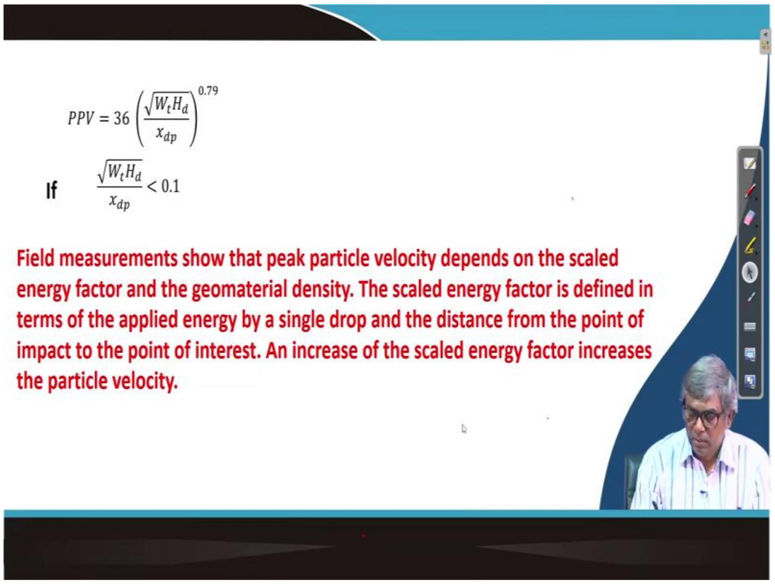
So, what happens actually because of this impact like deep dynamic compaction rapid impact compaction on ground induces environmental impact mostly vibration and noise. This is already I have mentioned this fact has to be considered in the selection of a suitable ground improvement technique. So, how to exercise that, so for exercising that there is a term called peak particle velocity.

Loose soil or fill typically generate lower peak particle velocity and peak particle velocity is the measure of disturbance. The loose soil will have lesser peak particle velocity and the peak particle velocity is the measure of disturbance. So, that peak particle velocity how to find out people have already started over the time and finally and measured and based on that they have given an empirical equation that is peak particle velocity equal to 188.

Then this expression to the power 1.53. Under root Wt Hd. So, here actually instead of Wt I can use W h and this is Hd. So, it is instead of t it was tamper when it was deep dynamic compaction but here it is not tampered it is hammer. So, you can change that and X_{dp} is the distance from the structure. So, it is the point of impact and this is a structure so this distance is called X_{dp}.

Because of this so you have to calculate this. This is the equation and this equation only applicable if this quantity is less than or equal to 0.1. These quantities called some energy ratio or something I will see next. So, this term you have to calculate this quantity or this expressions from this expression you have to calculate the value if the value falls below 0.1 then only this equation can be used. If not so if this value comes greater than 0.01 then you have to use some other equation let me come to the next slide.

(Refer Slide Time: 7:46)

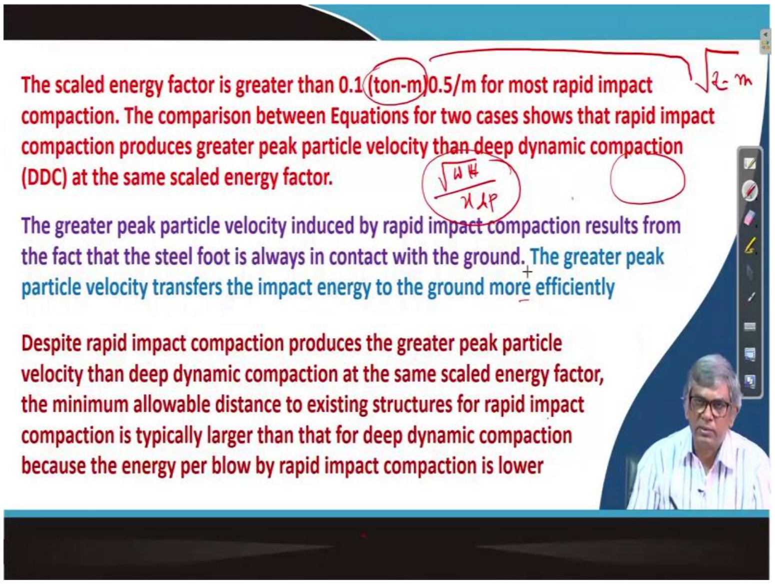


You can see here that this is the PPV equal to 36 and under root W2 Wt instead of Wt it can use W_h H_d divided by X_{dp} to the power 0.79. So, this equation can be used and if this value is this value is less than 0.1. So, now some as I was telling that some term the field measurement show that peak particle velocity depends on the scaled the energy factor. So, this is the one is called scaled energy factor, scaled energy factor means what is it, how it is defined?

It is the under root the energy that it W into h divided by the distance from which were actually impact upon the impact point to the structure. So, that measurement show that the peak particle velocity depends on the scaled the energy factor and the geometrical density. So, as I have mentioned that lose material will have may lesser value, denser material will have bigger value. So, these two things are known fact and the scale energy factor is defined already I have mentioned.

And increase of the scale energy factor increases the particle velocity that is what because of that we have used one equation 1 when it is less than 0.1 and is greater than 1. So, this is a fitting actually. So, because the variation is such that by single equation, we are not able to feed. These are all empirical fit. So, because of that we have given two equations, one for less than 0.1 other one given for greater than 0.1 or less than or greater than. So, this is the by enlarge the peak particle velocity how it is important. Let me go to the next slide.

(Refer Slide Time: 9:47)



And some discussion here actually the scale energy factor is greater than 0.1. That is actually this is under root actually this is nothing but sorry this is nothing but this portion is nothing but under root ton meter say this 0.5. So, properly expression is not there, scale energy factor is greater than 0.1 this for most rapid impact compaction. And the comparison between the equation for two cases that means two equations are given shows that rapid impact compaction produces greater peak particle velocity than deep dynamic compaction at the same scale energy factor.

Same scale energy factor means under root Wt W_h divided by X_{dp}. So, if deep dynamic compaction and the skilled iron rapid impact compaction if these are same in that then pick particle velocity will be more for rapid impact compaction that is the one important observation to be noted. The greater particle velocity induced by rapid impact compaction results from the fact that the steel foot is always is contact with the ground.

The greater peak particle velocity transfers the impact energy to the ground more efficiently. That is the reason is clear why it is more the because it is already contact in the ground. And that greater particle velocity transfers the impact energy to the ground surface efficiently that is what another point to remember.

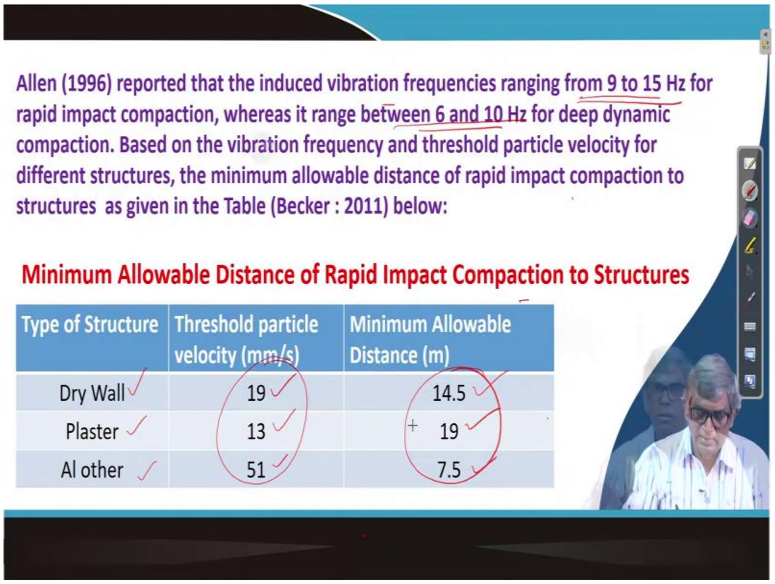
And third point is the despite rapid impact compaction produces the greater peak particle velocity than deep dynamic compaction at the same scale energy factors the minimum allowable distance to existing structure for rapid impact compaction is typically large. Then that for deep dynamic compaction because the energy per blow by rapid impact compaction is low. So, that is the reason actually.

So, if I see the distance, clearing, clearance distance required for deep dynamic compaction whatever value is generally large but in your rapid impact compaction is small r. But we have seen that peak particle velocity is larger for rapid impact compaction for same level of scale energy factor. But still because of these each blow the energy is low that ultimately we can do rapid impact compaction closer to the structure than by deep dynamic compaction.

So, these are the two contradictory things that if you feel but it is not really contradictory because the same scale energy factor if it is there then your rapid impact compaction producing bigger peak particle velocity. Because it is in contact with ground and in you are impacting but the scale energy factor will not be same actually. Because in each and every impact in rapid impact compaction your energy is much lower.

And because of that we can do this rapid impact compaction quite close to the structure than by deep dynamic compaction why it is so because of that energy is less. So, it is ultimately still it is it will produce lesser peak particle velocity. So, that we will see in the subsequent table and other things.

(Refer Slide Time: 14:03)

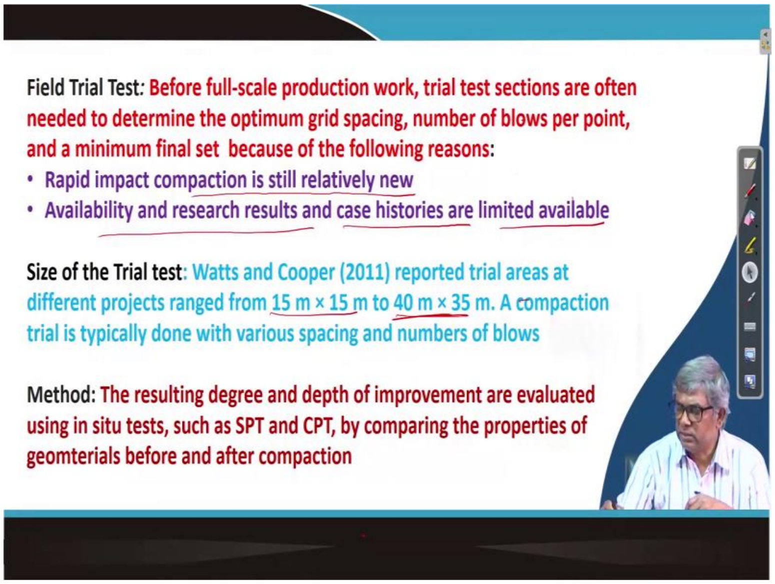


And you can see here this person this Allen reported that the induced vibration frequencies ranging from 9 to 15 hertz for a rapid impact compaction. Whereas deep dynamic compaction it is 6 to 10. And based on the vibration frequency and threshold particle velocity for the different structure the minimum allowable distance of rapid impact compaction to structure can be estimated and that is actually done and it is given in the table this is there.

So, you can see that minimum allowable distance of rapid impact compaction two structure is one is the drywall that threshold particle velocity is 19 and a minimum level of distance is 14.5 if it is plaster work then it is threshold particle velocity is 13 and minimum distance is 19. And all others structure it is 51, distance is 7.5 meter. And you can see here if you look back to deep dynamic compaction these values are different.

Now that means the frequency is difference and you know the either of these either if you know the distance you can find out threshold velocity or if you know the threshold velocity and then you can find out what is the distance we can go. This way actually design can be you know that I have to do compaction up to the structure already existing and I have to do the compaction then up to what distance I can compact that can be calculated here. And if you find that the distance up to which you want to do is unable to that is not satisfying this by this equation. Then under that situation if this method cannot be selected.

(Refer Slide Time: 16:14)



And next is actually you have to so these are the design that means design means what I have decided the depth of improvement and then I have decided hammer weight, I decided drop of hammer height, height of hammer drop, then I have the decided the size of the plate footplate, I have decided the spacing, and then all after deciding all those things, I have decided how many primary secondary passes or spacing all we decide decided.

And then how many drops required for each drop point that is calculated. Now, this is actually these are the design is done by sitting in the office and based on geotechnical data received and we assume based on data that this is the site condition, this is the, these are the parameters and based on that you design sitting in the office. But sometime that designed 100 per satisfactory may not work satisfactorily in the field. Because of that to make sure that whatever design we have done it will be workable in the field. So, before doing an actual activity final production what we can do we can do an on trial. And this trial actually field trial why you need to do field trial before full scale production work trial test section are often needed to determine the optimum grid spacing number of blows per point and minimum final set because of the following reason.

Why you need because as I have mentioned that we are designing sitting in the office based on certain information that is one issue. At the same time that the rapid impact compaction was not so popular, not so bold, information is not available. Because of that though we have designed still we have to make sure that it is working in a trial area if it is not then you have to redesign. So, that is why, why it is required mainly to because of two reasons.

So, rapid impact compaction, compaction is still relatively new they are not frequently used here and there and availability and research result case histories are limited. So, people are experience is less not much publication, not much case histories and all those things are not there. If it is available people get confidence that this work is done already in the similar condition so it has to work. Like that people can take decision to choose certain method.

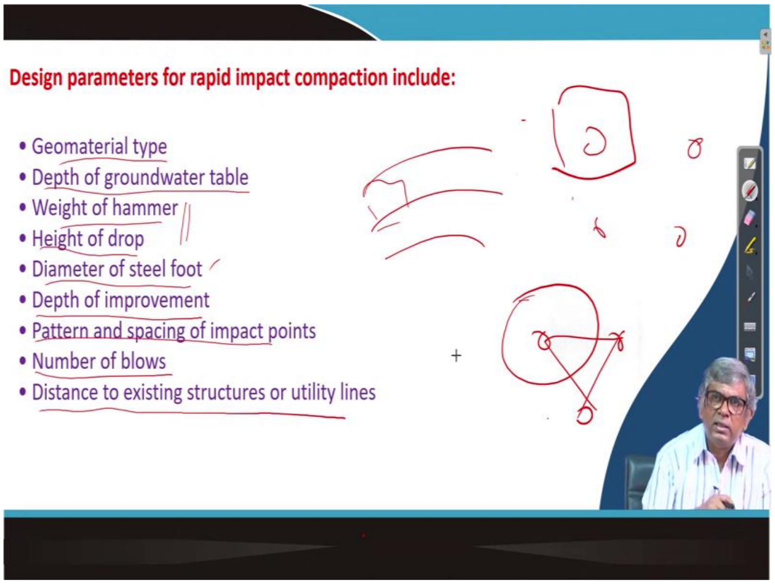
But method I think are less those things are available. People have to when will people will be doing these will have some sort of doubt and to create the doubt once you complete the design you do a trial test. Once you get a satisfactory result in trial test then you can go for the final production That is the thing I want to mention here and then size of that trial one, so here actually trial can be how big area.

So, you have to do a large area of compaction. But what will be the size of the trial area? Trial area generally 15 meter15 meter by 40meter by 35 these are the maximum minimum or maximum range 40 meter by 35meter 15 meter by 15meter in between any size can be chosen and test trial, trial test can be done to confirm the design acceptability. A compaction trial is typically done with various spacing and number of blows.

Of course spacing will be designed obviously but you can choose different and then we will see effectiveness. And next one is a method how you do the resulting degree and depth of improvement are evaluated using in situ test such as a SPT, CPT and by comparing the properties of geomaterials before and after compaction actually basically so these are the you generally take the help of few fields test mostly commonly used field test is SPT, CPT.

And before compaction you conduct CPT, SPT and after compaction you again conduct CPT SPT compare the values. And based on that comparison you have to decide how is the degree of improvement and that resulting improvement will guide you whether the design is acceptable or not.

(Refer Slide Time: 21:07)



Next one is the design parameter for rapid impact compaction that you have to find a finalized already you have discussed certain point I have listed here. And we can see here the most important part is geometrical type the all material cannot be compacted by rapid impact compaction it is generally granular type of soil, silty sand, and all can we add some fill. So, that is what you have to see that is most important parameter for rapid impact compaction.

The depth of groundwater table that is actually we have mentioned that if it is a water table is at least it has to be below 1 meter. If it is very close to the ground surface then you need to do dewatering to make this rapid impact compaction effective. Otherwise, or some fill can be done and prepare for compaction. That is depth of groundwater table is second important parameter by which you can which will help you to select the particular type of ground improvement technique.

Then weight of hammer it does not vary much actually mostly 9 to 12 ton actually used maximum 15 ton and height of drop mostly 1.2 meter most of the cases. So, those parameters not much so that is also can be changed according to the requirement. But most company will have these fixed values actually be ranging between that. And diameter of steel put generally 1 meter, 1 meter to 1.5 meter that also can be chosen as a parameter.

Then depth of improvement and depth of improvement obviously we know that by rapid impact compaction maximum can be up to 5 to 6meter. And different energy up to what depth and depending upon soil type there is a guideline. So, that also you have to fix you have to see that your site condition and based on that you have to decide how what is the depth of improvement you require.

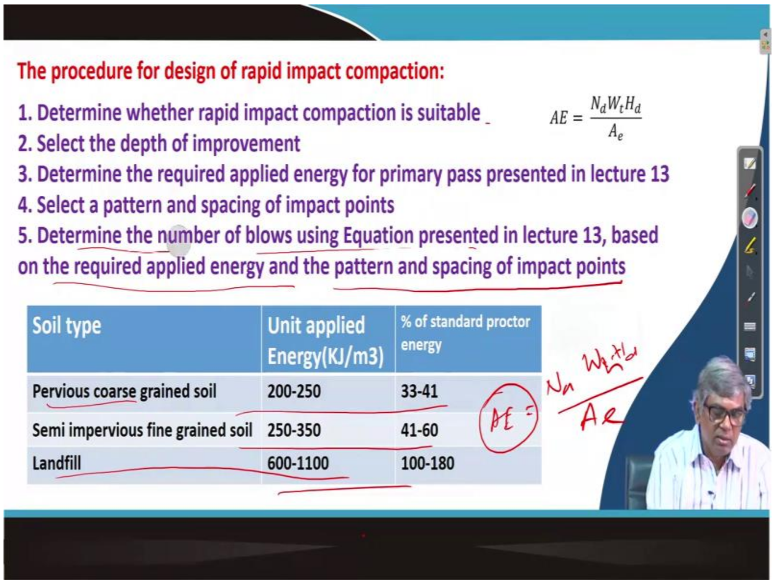
That means you have to see by geotechnical investigation that what is the depth of problematic soil actually in the field and that become the depth of improvement required. And pattern and spacing again as we have mentioned arcs pattern, then we mentioned square pattern, then we have mentioned triangular pattern. Those things and if it is triangular pattern, these are the spacing. And equivalent area for this spacing, equivalent area for this spacing, equivalent area for the spacing actually to be estimated.

And then accordingly it can be used in the calculation number of blows as we have used in the equation by using particular equation. You have to find out that in the design parameter that means you have to find out finally either doing all those things you have to find out what is the how many numbers of drops required in a drop point. And distance to existing structure that is utility line, etcetera that is actually based on some peak particle velocity calculation.

And that is already we have mentioned that depends on skill energy factors and if the skill energy factor is greater than 0.1 then we have to use some equation if it less than 0.1 in some other equation. And so that is the one need to be calculated. So, that means if there is an existing structure close to the site ground improvement site you have an existing structure you have to limit up to which you can go by this method.

And beyond that we may have to use some other technique other than this rapid impact compaction. This is the way you have to first select the parameters for and then you to design and all those things and then you have to go to trial one.

(Refer Slide Time: 25:09)



And then you can see procedure for design of rapid impact competition. How will you proceed? And you can see that determine first whether the impact rapid impact compaction is suitable as I have mentioned that all type of material cannot be done. Then all depth if the depth of problematic soil is 10 meter you cannot do that.

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

Like that whether at all suitable or not that to be decided then select depth of improvement again by geotechnical investigation seeing the or the geotechnical stratification up to what depth problematic soil existing that to be determine. And based on that you have to decide what is the depth of improvement required and then accordingly. Then determine the required applied energy from the table depth of energy type of soil.

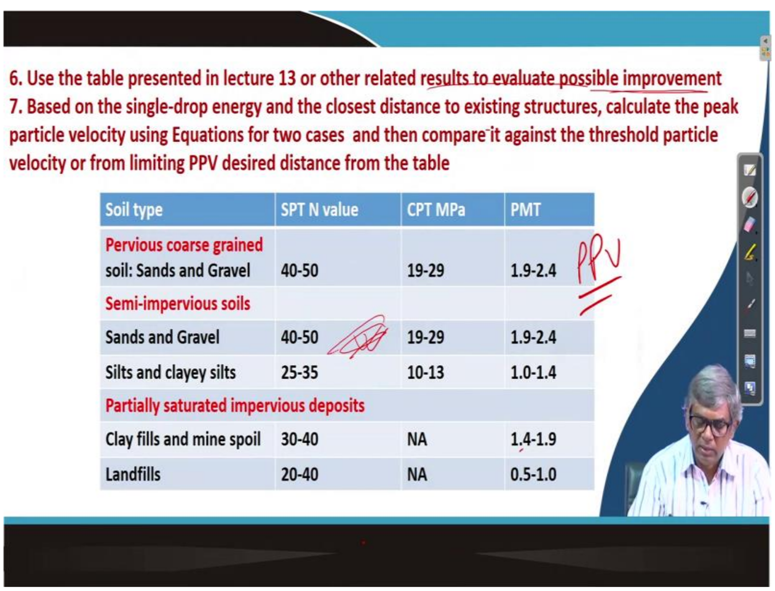
And then energy requirement that can be determined and that is also given some table in the lecture 3. So, here also you can see these are the way actually can be used or here also we have mentioned some other way this is not the actual table for rapid impact compaction I have shown the few minutes back the same one that is ton meter per meter square the energy that we actually have to see for 3meter, 4 meter like that.

That determine that required applied energy for primary pass, determine the required applied energy for primary pass presented in lecture 13 actually again same thing primary pass secondary pass, how much energy is required? That can be again can be estimated that is AE equal to N_d W_t W_h H_d divided by Ae. So, spacing and everything is known then we can find out what is the energy required. And then once you know the index then you select the pattern and spacing and then determine the number of blows required by this equation.

The number of blows will be again from this equation only number of blows actually you can take the other side this thing then you will get number of blows from this equation based on the required applied energy and the pattern and spacing of the of impact energy.

Pattern and spacing will give you AE and hammer and hammer drop point these are all give you and this energy all will be known and all the unknown quantity will be number of drops. This is the way actually you have to proceed for the design. These are the few steps and from some more steps will be there.

(Refer Slide Time: 27:49)



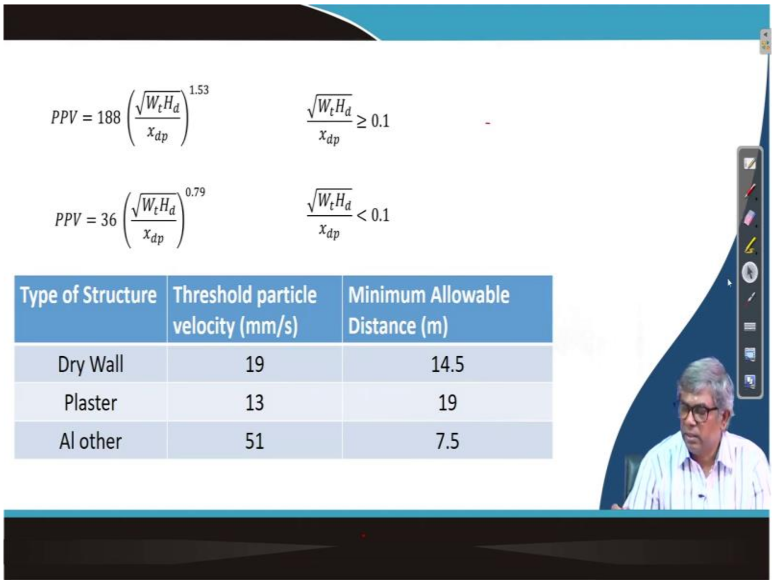
Soil type	SPT N value	CPT MPa	PMT
Pervious coarse grained soil: Sands and Gravel	40-50	19-29	1.9-2.4
Semi-impervious soils			
Sands and Gravel	40-50	19-29	1.9-2.4
Silts and clayey silts	25-35	10-13	1.0-1.4
Partially saturated impervious deposits			
Clay fills and mine spoil	30-40	NA	1.4-1.9
Landfills	20-40	NA	0.5-1.0

And then actually you can see that 6, 7 so use the table presented in the lecture 13 or other related result to evaluate possible improvement. So, these are the actually SPT values, what is the range? CPT value, what is the range after compaction? So, this is awkward this is not the right table because for this rapid impact compaction I have shown another table. That table to be used this is for deep dynamic compaction. Then 7 finally based on the single drop energy and the closest distance to existing structure calculate the peak particle velocity that is last one.

That PPV to be calculated and if you know the distance or you have the limiting PPV. Then how much distance you can go that can be obtained, so either way, either you find out distance is known and then based on that distance you find out the PPV and that limiting PPV can be compared. And then you can decide whether this is suitable or not. Alternatively, if the distance if you, you take the limiting PPV and then from that other parameter if you put then you can get the distance X_{dp} that means beyond that actually you can compact.

And you cannot go beyond or close to closer than that distance. So, that is what you can find out either way that by using PPV equal to and again for rapid impact compaction two equations are there. What is that scale energy factor that can be as estimated first if it is greater than 1 that one equation to be used and if it is less than 0.1 then another equation to be used. That way finally you had to complete the design. This is actually by a large rapid impact compaction briefly I have almost completed and only thing is I will take one more lecture.

(Refer Slide Time: 29:51)



$$PPV = 188\left(\frac{\sqrt{W_t H_d}}{x_{dp}}\right)^{1.53}$$

$$if\left(\frac{\sqrt{W_t H_d}}{x_{dp}}\right) \geq 0.1$$

$$PPV = 36\left(\frac{\sqrt{W_t H_d}}{x_{dp}}\right)^{0.79} \quad if\left(\frac{\sqrt{W_t H_d}}{x_{dp}}\right) \leq 0.1$$

And there here actually already whatever I have told actually that two equations one equation this and PPV skill energy factor should be this. Another equation is this and there are limiting velocity or limiting distance that can be calculated and based on that whether design is acceptable or not can be decided. This is the one towards almost end of this one.

And I will only discussed at the end finally I will take one problem to illustrate the whatever we have discussed so far. Of course, illustration of merits, demerits cannot be shown numerically that whatever I have mentioned you have to remember certain things. What is the useful thing? What? Why we can do? Where we can do? How we can do? What is the advantage? What is the limitation?

Those are actually you have to remember and once you get experience that will be there in your brain. But illustration what we can do design actually different steps I have mentioned different tables, different equation, how to use them to illustrate that I can do some and solve some problem and discuss some problem. And by that is illustration will be there. I will take the next lecture. That part. Thank you.