Construction Methods and Equipment Management
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Lecture-17
Piles and Pile Driving Equipment (Part 2)

Hello everyone, I welcome you all to the lecture 17 of this course construction methods and equipment management. In this lecture we are going to discuss about the pile driving equipment. So, let us have a recap of what we discussed in the last lecture, the last lecture we discussed about the different types of piles merits and demerits of different types of piles.

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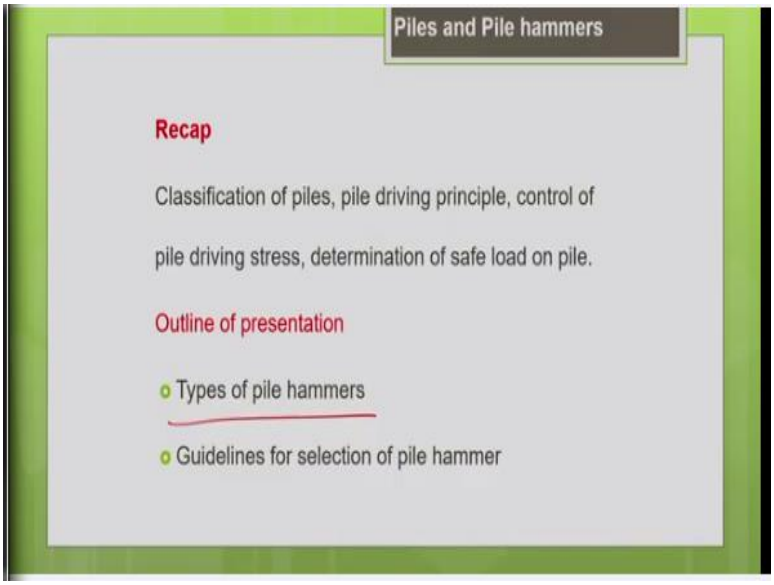

And about the basic pile driving principle and the methods of how to control the pile driving stress and how to determine the safe load on the pile. So, these are the important things which we have discussed in the last lecture. Now, let us look into the outline of today's presentation. In today's presentation, we will be discussing about the different types of pile hammers, and we will be also discussing about the guidelines for selection of the pile hammer.

So, how to select the pile hammer for a particular type of soil and for a particular the length of pile and weight of pile for a particular material type, how to make the selection of pile hammer we are going to discuss in this lecture.

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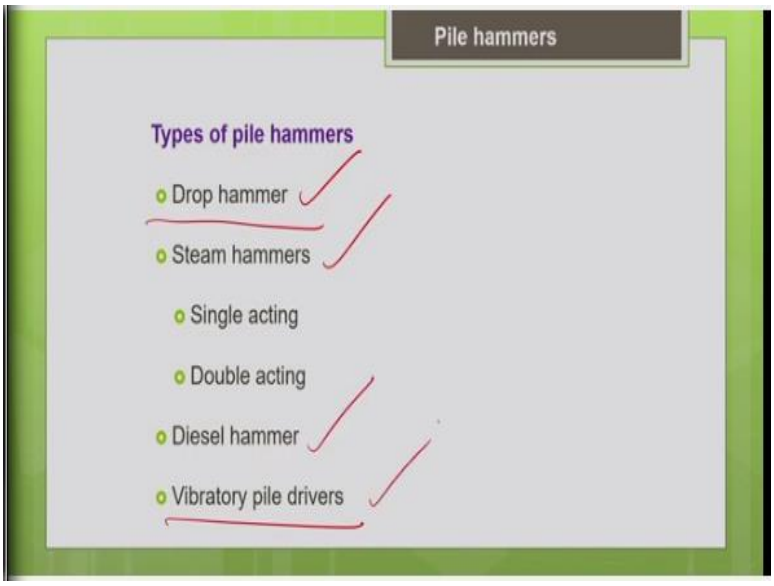

So, there are different types of pile hammer ranging from the oldest drop hammer method to the modern vibratory the pile drivers. So, we are going to discuss all these types of pile hammers one by one in this lecture. So firstly, we will be discussing about the drop hammer followed by the steam hammers, then we will be discussing about diesel hammer and the vibratory pile drivers.

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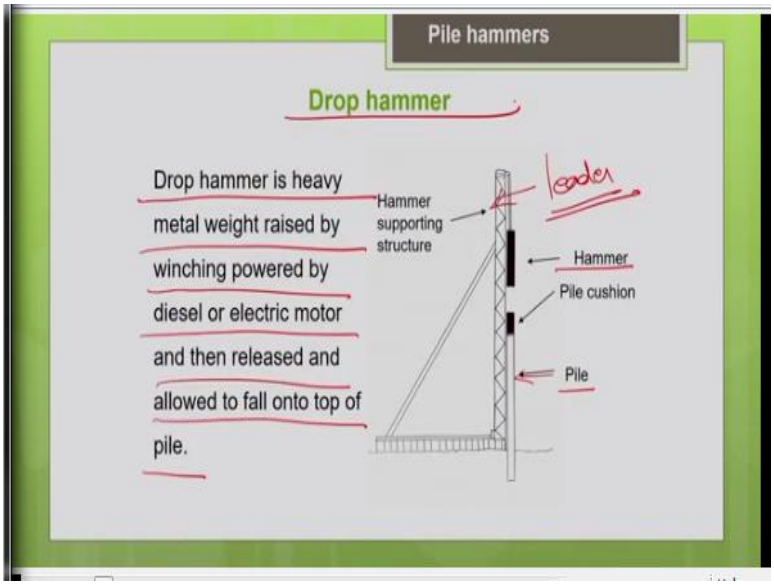

So, first is about the drop hammer. So, basically and this is nothing but a heavy metal weight, so this has to be lifted with some lifting mechanism. You can go for any lifting mechanism depending upon your project size, depending upon your project budget or the availability of equipment. So, you can go for any lifting mechanism, you can go for a simple pulley and rope mechanism or you can go for a crane.

So, depending upon the availability of an equipment and a project budget, so you can go for the lifting mechanism. So basically, you are going to lift the hammer, that hammer is nothing but a heavy metal object. So, we are going to lift it with some lifting mechanism to a particular height, then allow it to fall on the pile height by gravity, allow it to freely fall on the height of the pile. So, you can look into this setup, so basically this is your hammer.

And this is your pile, in between the hammer and pile, you have the pile cushion to control the pile driving stress to protect the pile head from the damage, you put the pile cushion. So, you are going to lift this hammer with some lifting mechanism and then allow it to fall on the pile. So, and you can see some more supporting arrangement this is called as the leader or lead.

So, this frame structure, it is going to help you to place everything in right position, it helps you to hold the pile, pile hammer, everything in the right position helps you to maintain the alignment. So, for that you need the supporting arrangement called as leader so this is your leader, lead or leader**.** So, these are the supporting equipments you need. So, as I told you for the pile driving, we cannot just do the pile driving only with the pile hammer.

We need the supporting equipment like we may need some lifting equipment like crane, and you need a structural frame like leader to hold everything in position. So, what is this drop hammer, let me summarize what we discussed just now. Drop hammer is heavy metal weight, raised by winching, powered by diesel or electric motor and then released and allowed to fall on to the top of the pile.

So, winching mechanism, winching mechanism is a lifting mechanism as everyone knows. Basically, it is nothing but a rotating drum, this drum will be rotated by any motor diesel motor or electric motor, on this rotating drum, you can see the rope winding over. So, with the help of this rotating drum, I can either pulling the rope or pull out rope. So, this is a common mechanism which we use in the crane also. So, basically with any pulley, rope and winch mechanism, so you can just lift the hammer to a particular height and allow it to freely fall by gravity on the pile height, so that is what is a drop hammer.

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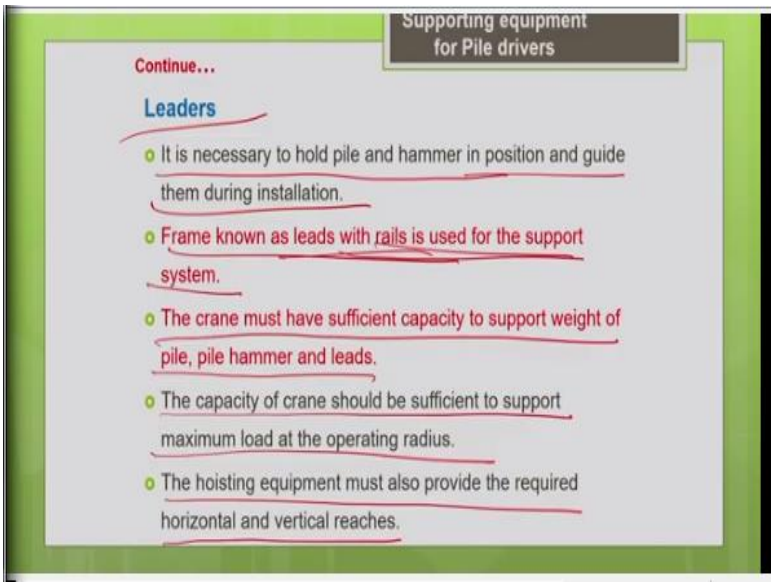

So, as I told you it needs some supporting frame structure to hold everything in position, so that you can maintain the proper alignment of the pile, so for that you need help of the needles. So, it is necessary to hold the pile and the hammer in position and guide them during installation. So, for that we need the frame known as lead, it has a rail, you can see it has the rail kind of arrangement, it is used as a support system for the pile driving operation.

And one more important thing you need to know that whatever lifting mechanism, you are going to use maybe a crane. If you are going to use a crane, you have to check for this lifting capacity of the crane whether the crane has a sufficient lifting capacity to lift your pile, to lift your pile hammer and to hold your lead everything in position. So, for that the crane should have the sufficient capacity, crane must have the sufficient capacity to support the weight of pile, pile hammer and the leads.

So, the capacity of the crane should be sufficient to support a maximum load at the operating radius. So, operating radius is nothing but the distance from the center of axis of rotation of the crane to the load line, that is a operating radius. This operating radius keeps varying depending upon your boom, crane boom inclination, just by changing the angle of inclination of the boom I can vary the operating radius.

I can either reduce the radius or I can increase operating radius by changing the angle of inclination of the boom. So, you know that when you reduce the operating radius, that means you are going to bring the load line towards the center of the crane. In that case the crane will be in a more stable position, so it is lifting capacity will be high. But when you are moving your load line away from the center of the crane, that means your operating radius is more.

In that case your crane will be relatively unstable, it is stability is relatively poor, so the lifting capacity will also be less. So, that is why we need to check whether the crane has a sufficient lifting capacity to lift your pile, pile hammer and the lead, so at various operating radius that we need to check before making the selection of your crane for the pile driving operation.

So, the hoisting equipment must also provide you the required horizontal and the vertical reaches. So, you need what is the working range needed, what is the horizontal and the vertical reach needed? And the crane what you are going to use must be able to satisfy that requirement. Accordingly, you have to make the selection of the supporting equipment for pile driving operation.

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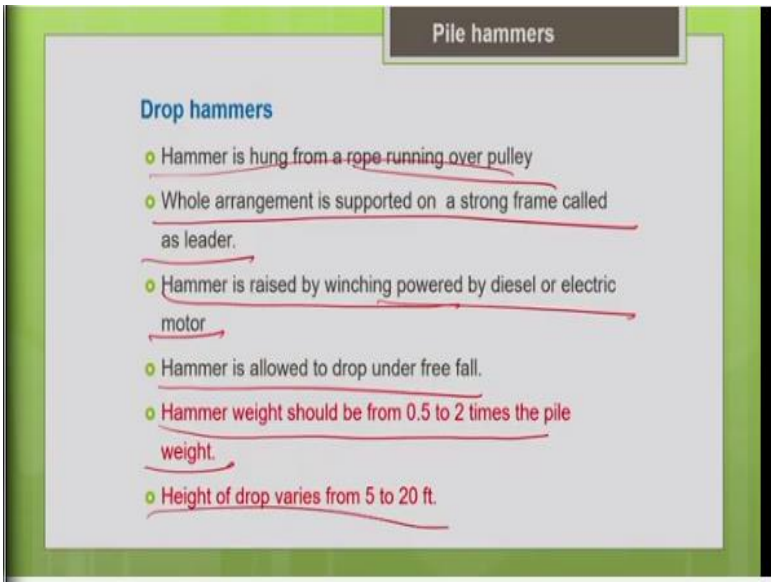

So, hammer is hung from a rope running over a pulley. So, the whole arrangement is supported on a strong frame called leader. Hammer is raised by winching and that is powered by either diesel motor or electric motor and hammer is allowed to drop under free fall on the pile. So, basically

when you select a weight of the hammer, it is advisable to select the weight of the hammer at least equal to the weight of your pile.

So, that you can get your desired blow energy. So, if your hammer weight is going to be lesser, then in that case you have to increase the height of fall to get the desired blow energy. So, you know the impact already when you increase the height of fall the impact velocity will be more. So, that is likely to create more driving stresses on your pile height particularly for the concrete pile we should be very careful with respect to the driving stresses and we have to restrict the stroke or the height of fall.

So, we have to select a heavy hammer at least equal to the weight of pile. So, for this drop hammer as per the literature you can see the hammer weight should be from 0.5 to two times the pile weight depending upon the availability of your hammer and you can make the selection. And the height of drop varies from 5 to 20 feet. So, like depending upon the material type there will be restriction on the height of fall. As I told you concrete is weak in tension it is more easily susceptible to shattering while ramming it the driving the pile.

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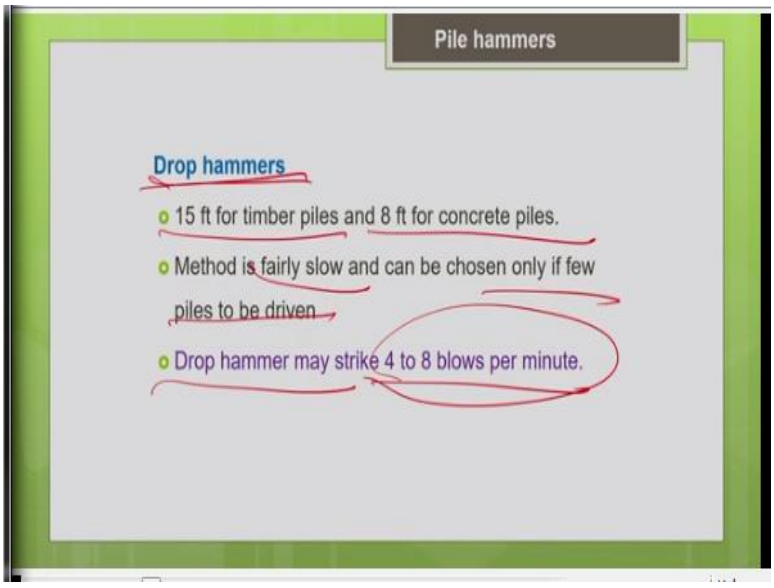

So, that is why for concrete piles the limitation of height of fall is given for the drop hammer as 8 feet, for timber pile it is 15 feet. And one more important thing to be noted is, this drop hammer method is very slow, it is fairly slow. So, if you have to drive only few piles, if you do not have a

very tight deadline, so if you are not very much concerned about the productivity, if you do not have a tight deadline.

In that case, you can go for the drop hammer method, because this is basically a slow method. So, you can see the blow rate number of blows you can make is only 4 to 8 blows per minute, the blow rate is relatively very less. So, that is why you can go for the drop hammer, if you have only very few piles to be driven, and if you do not have a very tight deadline, in that case you can go for the drop hammer method. It is an oldest method, nowadays we have lot of advanced techniques.

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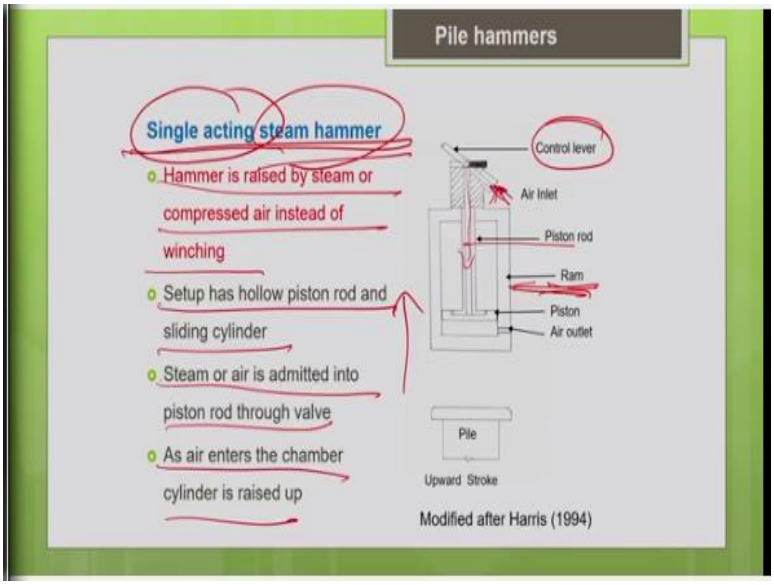

Next is your single acting steam hammer, so this is an improvement over the drop hammer. As a name indicates steam hammer, so it means you are going to use a steam energy, you can either go for steam energy or you can go for compressed air also. So accordingly, you may need a steam boiler or air compressor for this method. So, the name says single acting, that means you are going to use the steam energy only in the upward stroke.

That means when you are lifting the hammer that is called as a upward stroke, only during the upward stroke I make use of the steam energy. So, the downward stroke that means when you allow the hammer to fall, it will fall freely by gravity, so that is why it is called a single acting steam hammer. So, the hammer is raised by steam or compressed air instead of winching, and you can see the setup.

So, this setup you can see you have a sliding cylinder which can move over the frame, this is a hollow piston rod, you can see the hollow piston rod and the piston. So, this is the control level which can control the air inlet and the air exhaust. So, first what you are supposed to do is, for the upward stroke, so you need to allow the entry of air into the piston rod. So, allow the air entry through the piston rod as the air fills the chamber, what happens?

Due to the pressure the ram is raised up, your cylinder is raised up, so due to the air pressure. So, to complete an upward stroke what you supposed to do is you allow the air entry into the chamber. Once the air enters into the chamber, you can say as the air starts filling the chamber, your hammer will be raised up due to the air pressure. So, now your upward stroke is complete. So, let me summarize.

So, the setup as a hollow piston rod and a sliding cylinder**,** this is a sliding cylinder it can move up and down. But the piston rod is fixed, only the cylinder can move up and down. Steam or the air is admitted into the piston rod through the valve, you can see the inlet valve. So, you can adjust the control lever, so that the air can enter through this inlet and into the piston rod. So, now as a air enters the chamber, the cylinder is raised up, so that is your upward stroke **y**our cylinder is raised due to the entry of air into the chamber due to the air pressure.

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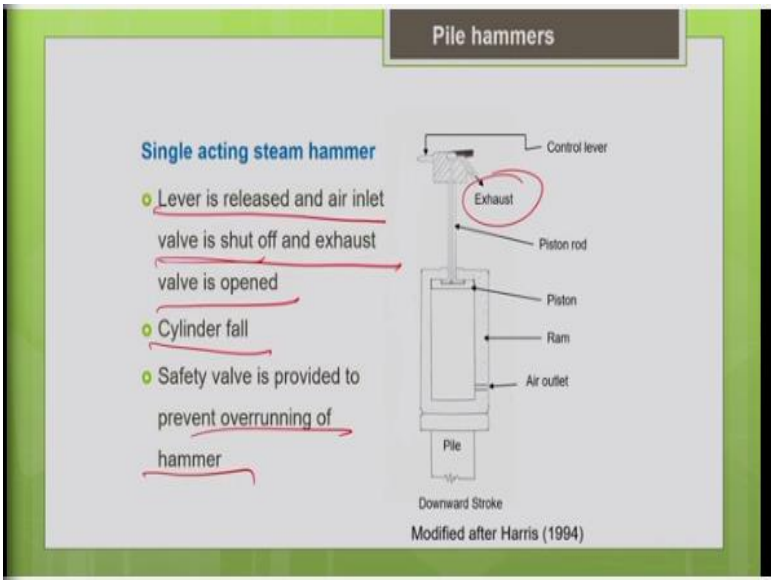

Now let us see how the downward stroke is done. Now what you do is you control the lever in such a way that the air inlet is shut off, you close the air inlet and all the air from the cylinder will be expelled out of the exhaust valve, so all the air now comes out of the exhaust. As the air is released out of the chamber, the hammer will fall down, so hammer falls down, so that is a downward stroke.

So, your lever is released and the air inlet valve is shut off, and the exhaust valve is opened. So, now you stop the entry of air into the inlet valve and you open exhaust valve, so all the air from the cylinder will go out. Now this will result in the fall of your cylinder, cylinder will fall down, that is a downward stroke. So, you are providing a safety valve also, mainly to prevent the overrunning of the hammer to prevent the excessive buildup of the air pressure. So, we have a safety valve to prevent overrunning of the hammer.

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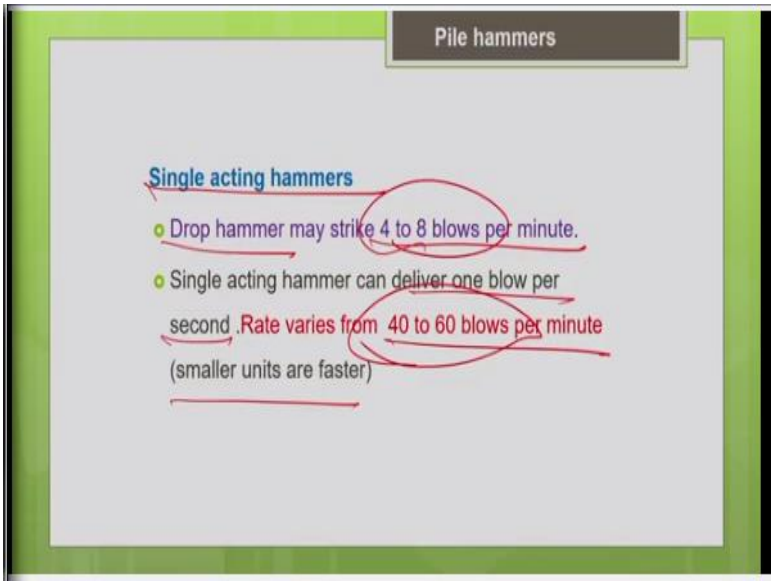

So, when you compare the productivity of your single acting hammer with the drop hammer, say earlier we discuss the blow rate of the drop hammer is 4 to 8 blows per minute. But your single acting hammer has a better productivity, it can go of a 1 blow per second. That means the blow rate is almost 40 to 60 blows per minute, even the smaller will more faster, when compared to the larger units.

So, when compared to the drop hammer you can see that the blow rate is significantly high. That is why when you are concerned about your productivity of your job, if you have a tight deadline, it is preferable to go for single acting hammer.

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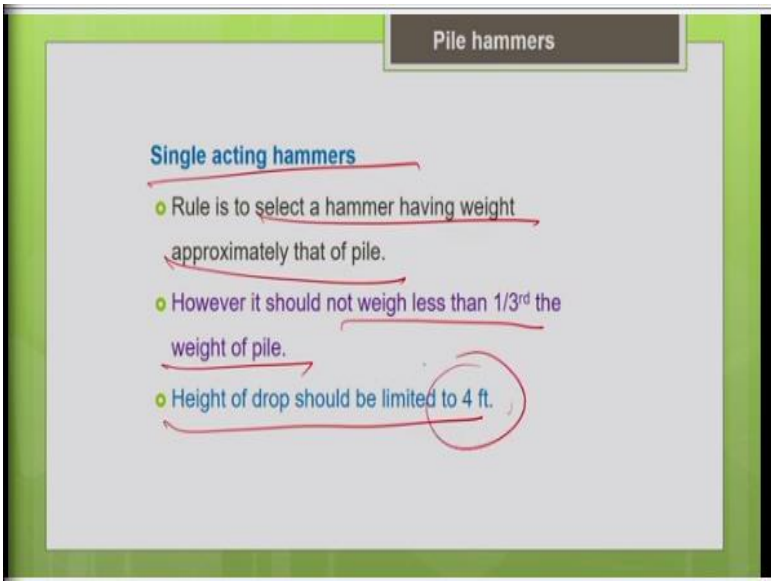

And again, the guidelines are given for single acting hammer. So, as I told you the basic rule is, select a hammer having a weight approximately equal to that of the pile. So, at least a hammer weight which should be equal to that of the pile. But sometimes certain concrete piles are too heavier, we do not have equivalent size hammer in the market. In the worst case, we should make sure that the hammer weight should not be less than one third of the weight of the pile.

So, that is a minimum requirement and the height of the drop should be limited to 4 feet. So, particularly for the concrete piles, we have to restrict the height for the single acting hammer it has mentioned there you should restrict it to 4 feet.

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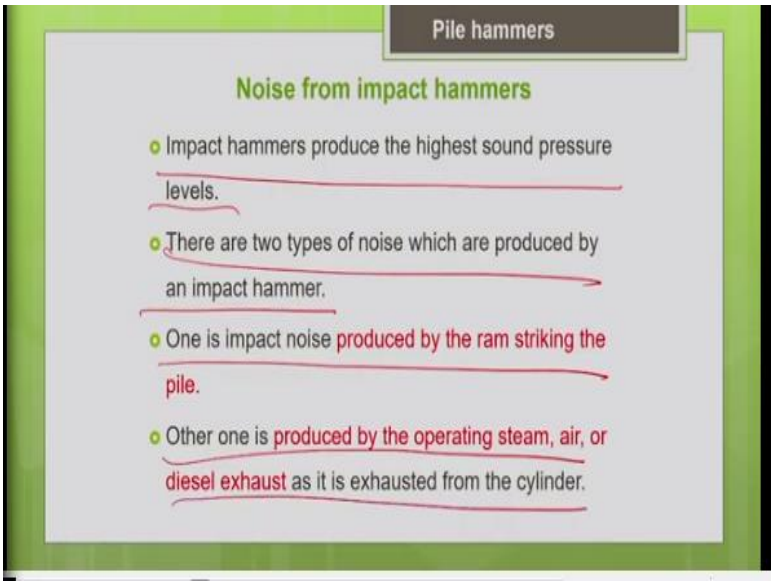

So, whatever hammers we discussed so far, a drop hammer, single acting hammer, all these impact hammers are noisy hammers, that means it results in lot of noise prediction during the driving operation. So, the impact hammers produce the highest sound pressure levels. So, there are different types of noises. One is because of the hammer the ramming against a pile head, that results in one type of noise.

The other type of noise is due to running of your air compressor or steam boiler, all these things also results in production of noise. So, there are basically 2 types of noise which are produced by impact hammer, one is your impact noise produced by the ram striking the pile, and other one is produced by the operating steam air, or the diesel exhaust as it is exhausted from the cylinder.

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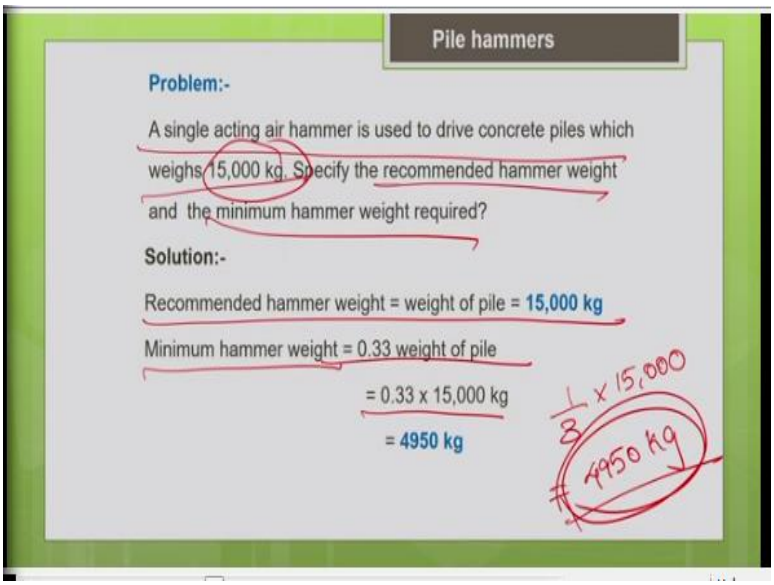

So, let us work out a simple problem on the hammer selection. A single acting hammer is used to drive concrete pile which weighs 15,000 kg, so the weight of the concrete pile is given as 15,000 kg, you are going to recommend the hammer weight needed, recommended hammer weight and the minimum hammer weight required. As I told you the basic rule for the single acting hammer is hammer weight should be equal to the weight of the pile.

So, the concrete weight pile is 15,000 kg, so recommended hammer weight is nothing but 15,000 kg. In the worst case, if 15,000 kgs of heavy hammer is not available in the market. In that case, the minimum requirement is you should never go below one third of the weight of your pile. That means minimum weight needed is

Minimum hammer weight = 0.33 × 15000kg = 4950kg

At least we should never go below this. So, this is the minimum requirement needed, you cannot go below this. So, this is a basic guideline that we should keep in mind.

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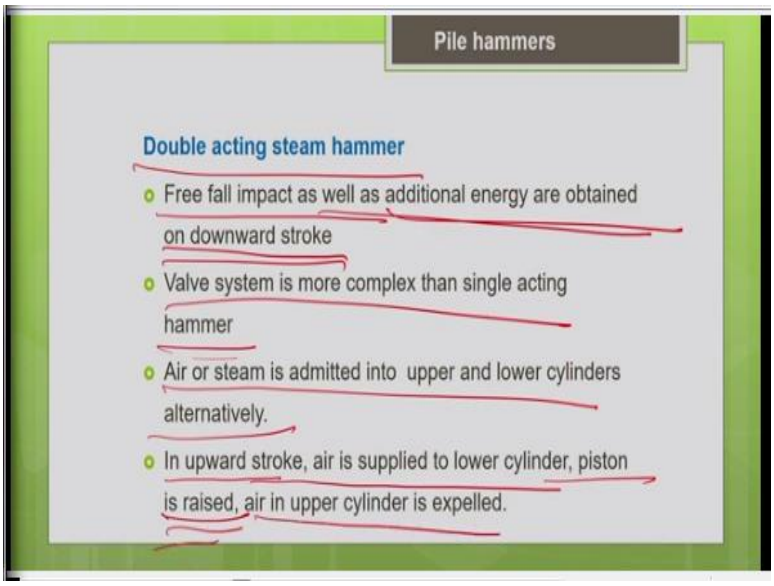

So, we have discussed about the single acting hammer, now let us move onto double acting steam hammer. As the name indicates double acting, so you are going to use the steam energy for both the upward stroke as well as for the downward stroke. So, that means you are going to use the steam energy for rising of the hammer as well as for the falling of the hammer. So, the freefall impact as well as additional energy or obtained on the downward stroke.

That means you are using the steam energy for the downward stroke also. Here the valve system is little bit more complex than the single acting hammer. If you look into the setup I will show you in the next slide. Basically, there are 2 cylinders here, upper cylinder and the lower cylinder. Alternatively, you will be supplying to the upper cylinder and the lower cylinder to carry out the upward stroke and the downward stroke. So, air or steam is admitted into upper and lower cylinders alternatively.

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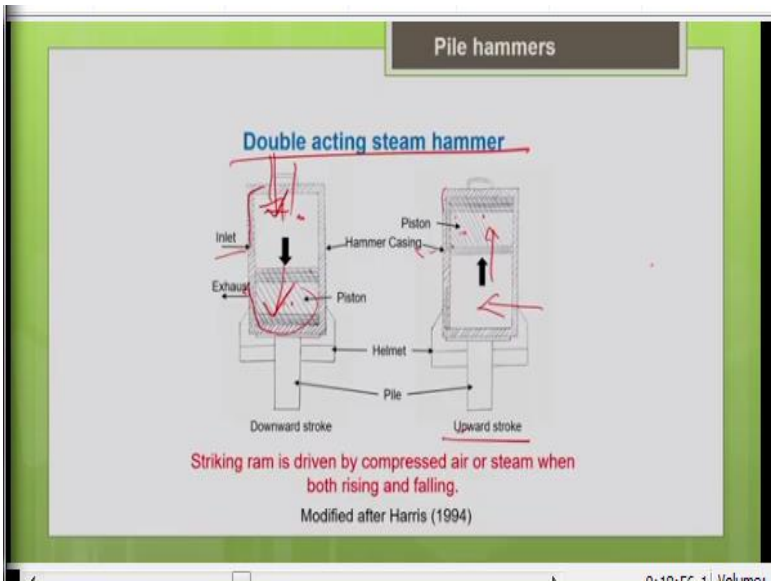

So, basically what to do here is, so this is a setup of the double acting steam hammer, you can see two cylinders one is the upper cylinder, other one is a lowest cylinder. Now in the upward stroke what you do is, you supply air into the lower cylinder. So, when you supply into this, this is a lowest cylinder, when you supply air into the lower cylinder, the hammer which was earlier in the lower cylinder will be pushed up into the upper cylinder.

So, the hammer is pushed up into the upper cylinder, the air which was already there in the upper cylinder will expel out to the exhaust. So, the air which was already there in the upper cylinder will be expelled out through the exhaust. So, basically what you are doing here is you supply air into the lower cylinder. So, that will push your hammer upward into the upper cylinder and the air which is already in the upper cylinder will be released through the exhaust, now your upward stroke is complete.

So, what are you doing the downward cylinder? You supply air through the inlet into the upper cylinder. So, when you are supply air into the upper cylinder, the hammer which was already there will be pushed into the lower cylinder. And air which was already in the lower cylinder will be expelled out through the exhaust. So, now that completes a downward stroke, so alternatively you are supplying air into a upper cylinder and the lower cylinder, so that you can have the rising and falling.

So, that was explained here in upward stroke air is supplied to the lower cylinder, your piston is raised, when the piston raises and occupies upper cylinder all the air which was in the upper cylinder will be expelled out. Similarly, in the downward stroke what you do, air is supplied to the upper cylinder and the hammer will be pushed into the lower cylinder**.** And the air which was already in the lower cylinder will be expelled out, so this is how you do it.

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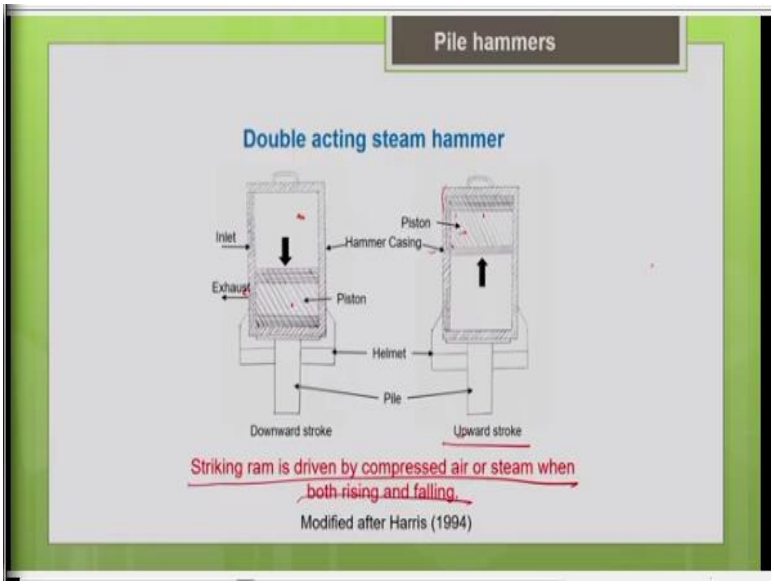

So, the striking ram is driven by compressed air or steam, when both rising and falling.

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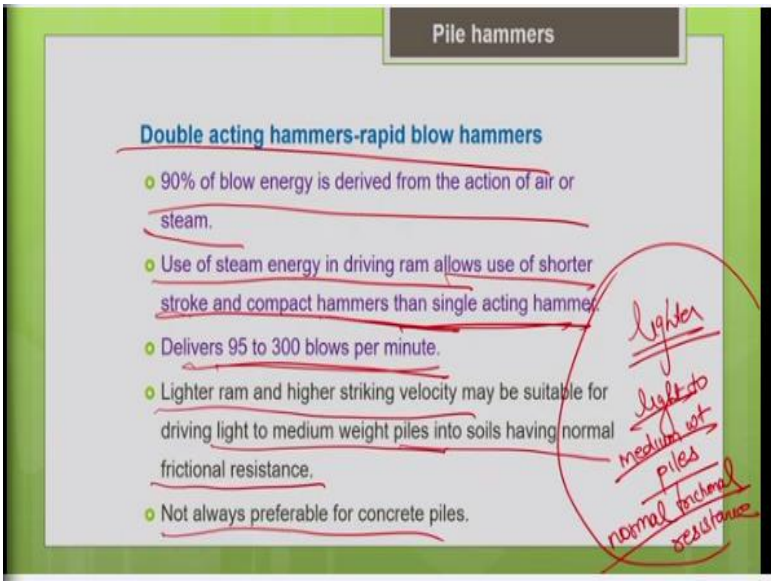

So, another important thing we need to know with respect to double acting hammer is in this most of the blow energy is the derived from the steam energy. Both for the upward stroke as well as for

the downward stroke, the blow energy is derived mainly from the steam energy**.** So, 90% of the blow energy is derived from the action of air or the steam. So, that is why, for the double acting hammer we need not for a heavier hammer.

We can go for lighter hammers, smaller in size and you can go for the shorter stroke or shorter height of fall. So, these hammers are basically designed to be lighter in weight. So, because most of the energy is derived for the upward stroke as well as for the downward stroke is derived from the steam energy. We are not mainly dependent upon the weight of the hammer, so we can go for lighter hammers in this case.

And this hammer is basically designed for I can say lighter conditions, lighter conditions in the sense. So, it is basically designed for light to medium weight piles and for soil with normal frictional resistance**.** So, very tight clay, hardened clay with very high frictional resistance, so we are not supposed to use these double acting hammers. Because these double acting hammers are designed for lighter conditions, that means for light to medium weight piles and for the normal soil with normal frictional resistance.

So, it is basically designed for this kind of conditions only, and you should never use this double acting hammer for concrete pile. Because these double acting hammers, they basically have a very high blow rate, if you look into the blow rate, you can see that the blow rate will be 95 to 300 blows per minute. So, it is very high when compared to the single acting hammer. So, such a high blow rate may can easily damage the concrete pile.

So, that is why it is not recommended for the concrete pile. So, let me summarize what we discussed, so your use of steam energy in driving the ram allows use of shorter stroke and compact hammer than single acting hammer. So, when compared to single acting hammer these hammers are more compact smaller in size, lighter in weight and they have a shorter stroke.

And they are designed for lighter conditions, they can deliver a blow rate of 95 to 300 blows. This lighter ram and highest striking velocity maybe suitable for driving light to medium weight piles into soil having normal frictional resistance. So, we cannot recommend this hammer for a tough

soil condition with very high frictional resistance**.** And not always preferable for concrete piles, as I told you high blow rate can result in damage of your concrete pile, which is basically weaken tension. So, it is not recommended for concrete pile but you can use it for steel piles.

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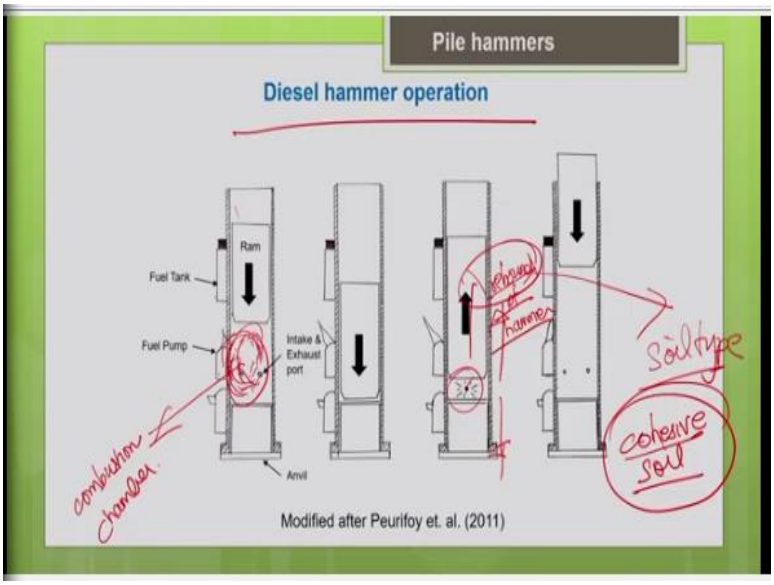

So, we have completed the double acting stream hammer, now let us move on to diesel hammer. So, basically this diesel hammer is a self-contained unit, that means everything is contained within a single assembly, I do not need a separate accessory a steam boiler or air compressor as we need it for the steam hammers. Everything is contained within a single unit you can see, so what will be the advantage?

So, it will be more compact and easier to move it in the site from one place to another, it is mobilization is very easier when compared to steam hammers which need a separate steam boiler or air compressor. So, now let us look into the operation of the diesel hammer. So, basically here what we do is, the ramp is lifted with some lifting mechanism to initiate the operation, any lifting mechanism you can use.

So, if you are going for a crane, so first with the help of a crane, you lift the hammer or the ramp to the required height and allow it to fall by gravity. So, you can see there is a fuel tank and a fuel pump and this is called as the combustion chamber. So, basically what happens is as the hammer

moves down, it activates the fuel pump and the fuel pump will spray the fuel into the combustion chamber.

This is a combustion chamber, the fuel is sprayed into this combustion chamber. Now as the ramp compresses the mixture of air and the fuel in the combustion chamber, so as it moves down it will compress the mixture of the air and the fuel mixture. So, what happens, it will result in ignition or explosion. So, this explosive energy what will happen? It will help you in driving your pile downward and also it helps you the rebound of you hammer.

So, it helps you in the rebound of your hammer. So, this explosive energy helps for both driving a pile downward as well as for the rebound of your hammer. So, the next cycle will continue on it is own, you need not lift it again with any lifting mechanism or crane. So, based upon the rebound, it will continue on it is own, the cycle will continue on it is own till the fuel is available. So, another important thing to be noted here is, this rebound will depend upon the soil type, this hammer is more suitable for the cohesive soil.

So, basically if the soil is more cohesive, the frictional resistance will be very high. So, the driving resistance will be very high, so that will result in a greater rebound of the hammer, that will deliver more energy from pile training. So, that is why in cohesive soil the cycle can continue easily when compared to lose sand.

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Let us see the picture of this diesel hammer you can see, this is a picture of the diesel hammer lifted by a crane. So, it is driving a steel pile, you can see this is a diesel hammer, this is a pile, it is lifted with the help of your crane.

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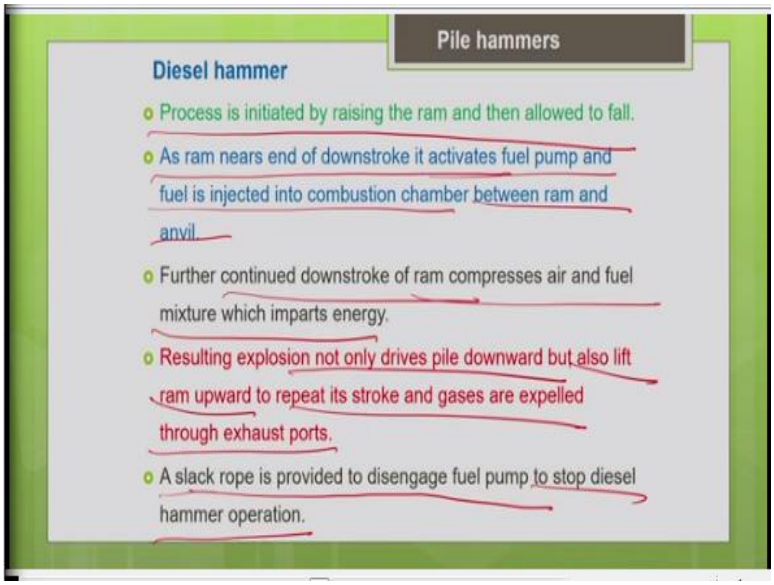

So, let me summarize the operation of the diesel hammer, this process is initiated by raising the ram and then it is allowed to fall. You have to raise the ram with help of any lifting mechanism the crane. As the ram nears the end of the downward stroke it activates a fuel pump, and the fuel is injected into the combustion chamber between the ram and the anvil. So, further continued downward stroke of the ram compresses the air and the fuel mixture, so that will impact the energy.

The resulting exposure, so not only drives the pile downward, but also lift your hammer of the ram upward to repeat it stroke, and the gases are expelled through the exhaust ports. So, if you want to stop the operation, there is a slack rope provided to disengage the fuel pump to stop the diesel hammer operation. So, there is a provision to stop the functioning of the hammer, so this is how the diesel hammer work.

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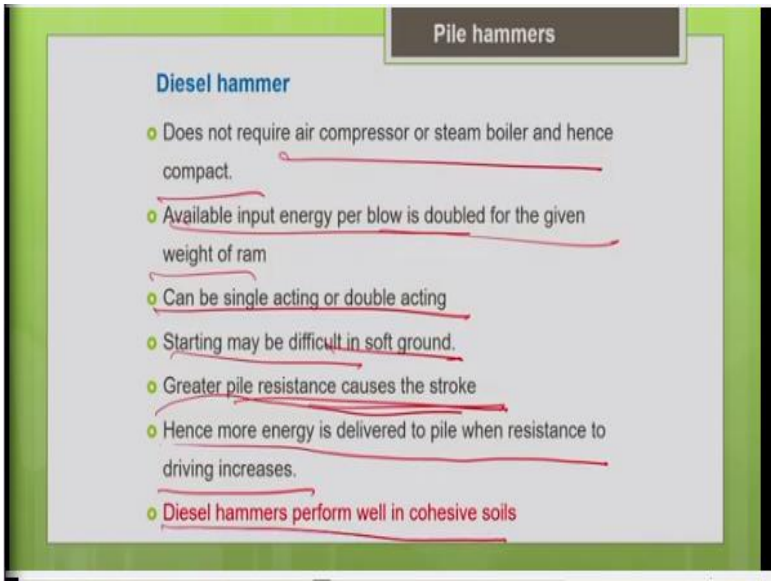

The main advantage is it does not require a separate air compressor or steam boiler and hence very compact. And the available input energy per blow is doubled for the given weight of ram, how it is double? Because of the explosive energy we get additional energy for driving, so it can be also either single acting or double acting. So, as I told you in a soft ground, the initiation of the process is difficult.

If the pile resistance is going to be greater, if the soil is more cohesive, if the driving resistance is more that will result in a better stroke, that will result in better rebound, that will result in more energy delivery. Hence more energy is delivered to the pile when the resistance to the driving increases, so this will happen in cohesive soil. So, diesel has performed well in cohesive soil than in soft ground.

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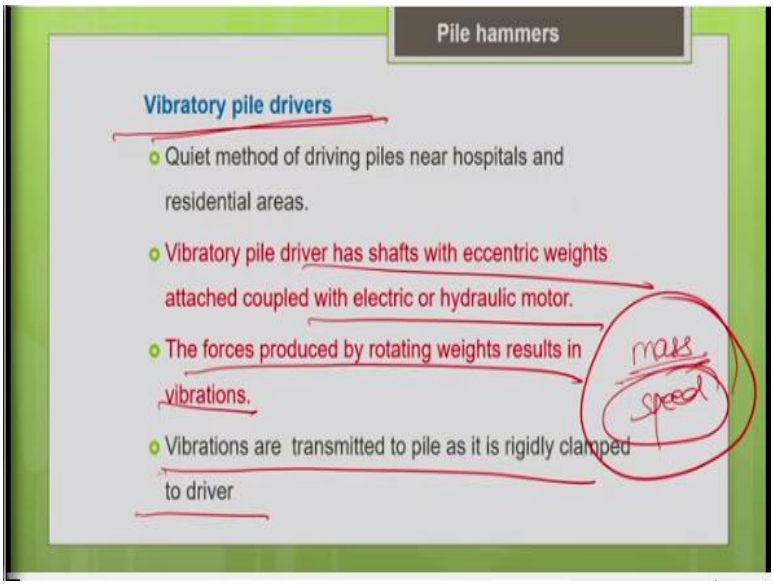

So, the last type of pile which we are going to discuss is about the vibratory pile driver. So, for whatever we discuss on impact hammers, which results in lot of noise production as we discussed earlier. And this method may not be feasible, if you are going to do a pile driving operation in a residential colony or near schools or hospitals where we need silent pile driving method**.**

Your vibratory pile driver is one such quiet method of pile driving. So, basically how do you create the vibration? So, this vibratory pile driver we have a casing, inside the casing there will be a shaft with rotating eccentric weights. These weights will be rotating in the opposite direction. So, this rotating eccentric weights it is rotating with the help of an electric or hydraulic motor.

So, the force produced by the rotating weights result in the vibration. So, this rotating weight results in the vibration generation. So, what will be the amplitude of the vibration or the frequency of vibration? That will depend upon your mass of the rotating weight and speed of the rotating weight. So, greater the mass of the rotating weight the amplitude will be more, greater the speed of the rotating weight your frequency of vibration will be more.

So, that will control your blowing efficiency, that is why we varying your mass and the speed of the rotating weight, you can vary the amplitude and the frequency that will help you to control the driving efficiency. So, depending upon your type of soil, you can vary the frequency. For very

tough soil conditions, for cohesive soil conditions it is preferable to go for a higher amplitude and lesser frequency.

So, according to a soil type and according to the pile type, there are now modern vibratory pile drivers which facilitates you to vary the frequency, you can vary the frequency according to your pile type and the pile soil. So, the vibrations basically you just clamp the vibrator tightly to the pile head. So, from the vibrator, the vibrations are transferred to the pile head, and from the pile the vibrations are transferred to the soil, your vibrations will result in agitation of a pile up and down.

This agitation will reduce the friction between the soil and your pile, that will easily facilitate the penetration of your pile into the ground. So, vibrations are transmitted to the pile as it is rigidly clamped to the driver, so pile is rigidly clamped to the driver. So, from the vibrator the vibrations are transferred to the pile.

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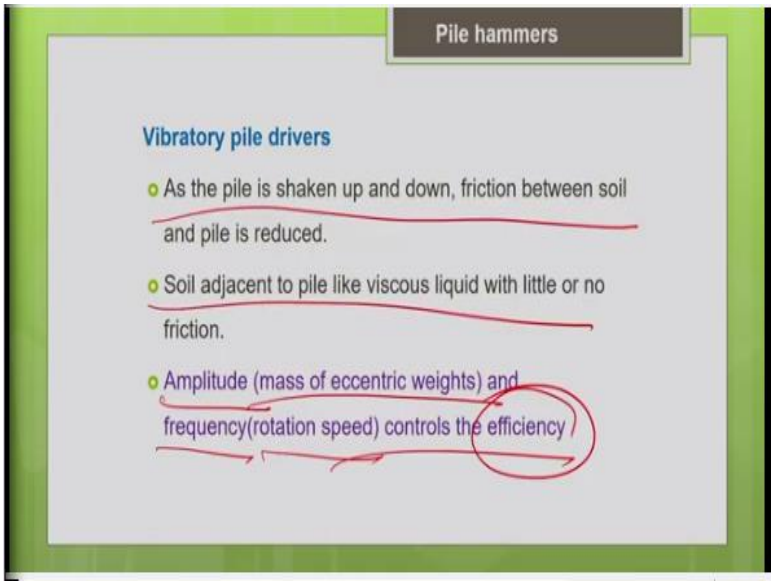

So, as your pile is shaken up and down, consider the friction between the soil and the pile will be reduced, so that will facilitate easy penetration of a pile into the ground**.** Because of the vibration, the soil adjacent to the pile will behave like a liquid, with little or no friction which facilitates penetration of the pile into the ground. Your amplitude of the vibration will depend upon your mass of the weights, eccentric weights inside your vibrator.

And the frequency of the vibration will depend upon the speed of the rotation of the eccentric weights and that is going to control the efficiency of driving. As I told you, depending upon the soil type and the pile type, you can choose the amplitude in the frequency accordingly.

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Unlike your other pile drivers what we discussed earlier, we do not need a crane for the vibratory pile driver, it is a very simple equipment, even a backhoe or excavator can assist in the holding the vibratory pile driver. So, the vibratory pile driver is tightly clamp to the backhoe and then it is tightly you can say it is then tightly clamped to your can see this is a steel sheet, steel sheet pile which is being driven into the ground with the help of this vibratory pile driver. So, this is your vibratory pile driver, so inside this there will be rotating weights which results in the vibration.

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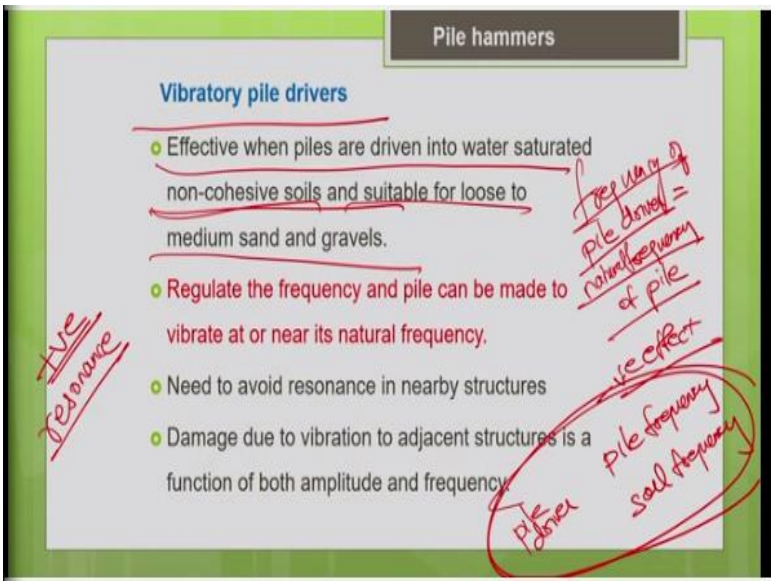

So, for what type of soil this is more preferable, this is more preferable for non-cohesive soil because that will respond easily to the vibration when compared to cohesive soil. So, this is particularly for water saturated soil, this is the right choice. So, this is effective in the piles are driven into water saturated non-cohesive soil and suitable for loose to medium sand and gravel because these kinds of soil will respond well to the vibration.

But nowadays with the help of modern vibratory pile driver where you can even vary the frequency the vibratory pile drivers can be even used for cohesive soil. So, you can regulate the frequency of the pile driving in such a way that it can be compatible with the cohesive soil also. So, there are some modern pile drivers vibratory pile drivers called as resonant vibratory drivers.

So, here we use a concept of resonance, you might have studied the concept of resonance during your schooling**,** basically what is this resonance when two bodies are vibrating at the same frequency, they have set to attain the condition called as resonance, that will result in larger amplitude or larger displacement. A simple example you might have already heard about this is when you try to push a swing in a play area, a child swing in a play area.

So, this swing has its own natural frequency, if you are going to push to swing at it is own natural frequency it will be very easily goes higher and higher. So, that is what is called as resonance, the both are operating at the your pushing frequency and the swing frequency is matched, it means

they are at resonance, then it will be very easier to push. The same concept applies to the pile driving also.

So, every material your pile or any structure every material has it is own natural frequency. So, when it is subjected to any load or earthquake of wind whatever, it is going to respond to that load or vibrate at it is own natural frequency. So, what you do is, when you do the pile driving, you match the frequency of a pile driving with a natural frequency of the pile. So, for that particular pile depending upon the stiffness and the length, it will have it is own natural frequency.

You can determine the natural frequency of the pile and match the frequency of a pile driver with the frequency of the pile. So, you match the frequency of your pile driver to the natural frequency of your pile, you have to estimate what will be the natural frequency of the pile depending upon the mass difference in length. So, you adjust the frequency of a pile driver to be matching with the natural frequency of the pile.

Now what happens it results in the condition of resonance, so it will result in huge displacement of your pile. So, very easily you can drive the pile into the ground, so that is why even for the tougher soil conditions, nowadays you can use the vibratory pile driver because of this advancement in the technology due to the invention of resonance pile driving method. So, you should vary the frequency in such a way it matches with the frequency of a pile.

So, this is one positive effect of the resonance, what will be the negative effect. Say for example but one thing you have to make sure that your pile frequency and the soil frequency. Soil also has it is own frequency, soil and the pile driver this should not match, if this is going to match what will happen? Both the pile in the soil will move together, so there would not be penetration of your pile into the soil this is negative effect.

So, we have to make sure that your pile frequency should not coincide with the frequency of your soil. So, what is the other negative effect of resonance is sometimes if there are some old monuments near the location where you are doing the pile driving. So, if the natural frequency of

the structure coincides with the frequency of a pile driving. In that case, it will result a huge displacement in your structural cracking of your structure.

So, that is why if some important monomers are there, we have to check for the natural frequency of the structure. And then make sure that there should not be any match in a pile driving frequency with the frequency of the structure. So, that is what is discussed in the slide.

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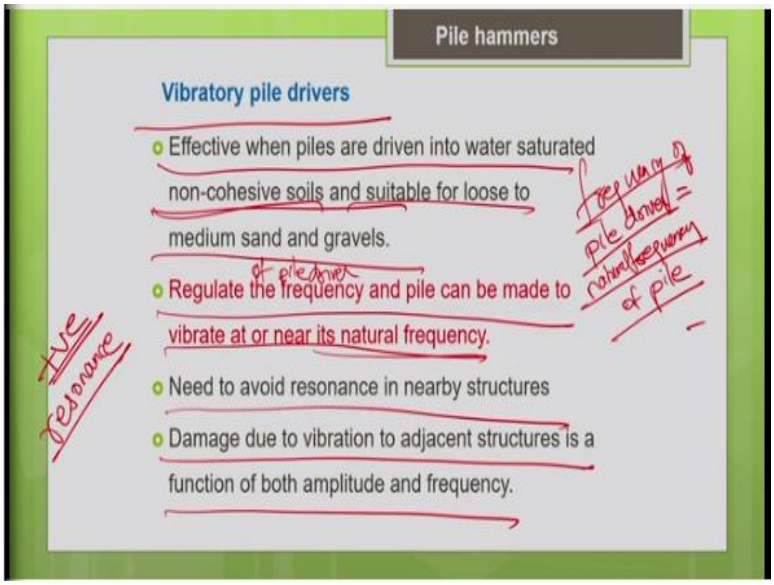

You regulate the frequency and the pile can be made to vibrate at or near it is natural frequency, you regulate the frequency of the pile driver and the pile can be made to vibrate at or near it is natural frequency. So, this will result in positive impact of resonance, which will make your pile driving operation easier. Another important thing is you need to avoid the resonance in the nearby structures, make sure that the frequency of the structure should not coincide with your pile driving.

So, the damage to due to vibration in the adjacent structures will be a function of both amplitude and the frequency. So, make sure it should not match with the frequency of the structure to avoid the negative effect of the resonance.

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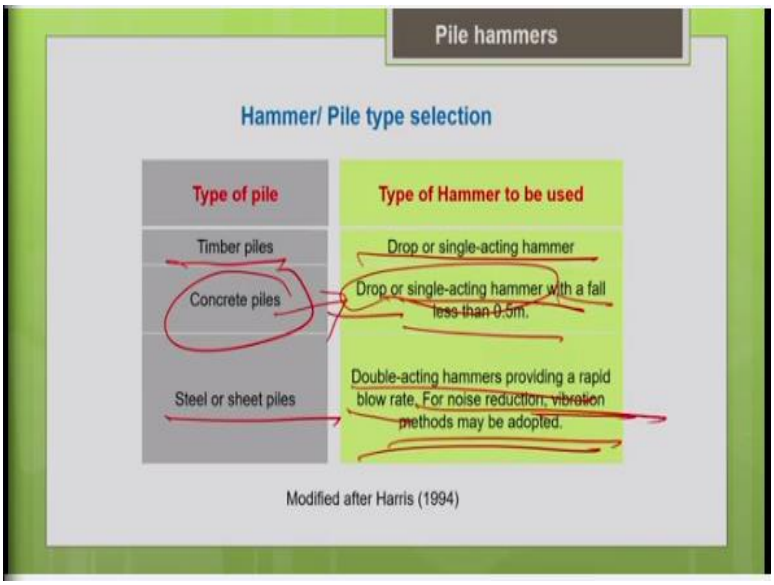

So, we have discussed about the functioning of different types of hammers and let us discuss about how to make the hammer selection. Your pile material type, the soil type everything is going to govern your selection of your pile hammer. So, with respect to material type as I told you particularly for the concrete piles you should be very careful, we should go for heavier hammer, heavier in the sense you can go for drop or single acting hammers which are basically heavier.

So, if you go for heavier hammer, you can reduce the height of fall, that will reduce the driving stresses on the concrete pile head. So, that is why for concrete piles go for drop or single acting hammer with a fall less than 0.5 meter. If you are more concerned about the productivity, you should go for single acting hammer instead of drop hammer, single acting steam hammer. So, next is about a timber pile**,** timber also it is preferable to go for drop or single acting hammer.

But for the steel piles or the sheet piles, I can go for double acting hammer which gives you a rapid blow rate. And if you want the silent driving method you can go for the vibrator methods for noise reduction I can go for vibratory hammers.

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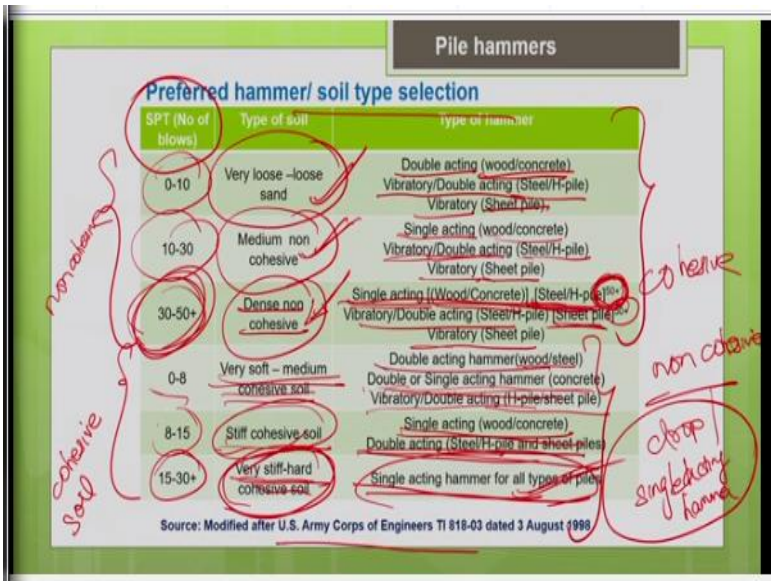

Now how to make the pile hammer selection with respect to your soil type, as I told you we can classify the soil into different categories. So, based upon there are some standard tests to categorize the soil into different categories. Like once this test is your standard penetration test where you find what is the number of blows needed for the standard penetration. So, based upon the number of blows you classify the soils into different categories are shown here.

Basically, you classified into cohesive soil and non-cohesive soil. So, the first three refers to non-cohesive soil and this is a cohesive soil. So, they are further classified into three different categories depending upon a number of blows. So, for 0 to 10 blows, it is very loose to lose sand, for 10 to 30 it is medium non-cohesive sand, for 30 to 50 plus blows it is dense non-cohesive sand as a number of blows increase the densification increases.

So, one basic guideline we need to keep in mind is for very tough soil conditions, it is preferable always go for heavier hammer, which is nothing but your drop hammer or single acting hammer that is always heavier, single acting hammer for tough soil condition and for the heavier pile. So, for lighter conditions, it is preferable to go for double acting hammer. To the maximum possible try to avoid double acting hammer for the concrete piles.

So, with this basic guideline let us discuss what are the guidelines available from U.S army corps of engineers. So, for very loose to loose sand, it is given that for concrete pile or the wood pile you

can go for double acting. So, I mentioned that for concrete pile it is preferable to go for single acting hammer. But if the soil condition is very loose, in that case it is exceptional, you can also go for double acting hammer even if it is concrete pile.

And for steel piles commonly you can see pipe steel piles or H-piles, you can either go for double acting or vibratory hammer. For sheet piles commonly, we use it vibratory pile driving method. Now for medium non-cohesive sand, so in this case you can see that single acting hammer should be used for concrete pile, do not use double acting hammer for concrete pile.

So, double acting you can use it for the steel pile either you can use double acting or vibratory. And for the sheet piles you can go for my vibratory hammer. Now as a densification of the sand increases, though the sand is non-cohesive but the densification increases, indicated that increase in number of blows 30 to 50 plus. Now you can see what is the change in the guideline, for wood or the concrete pile you can go for single acting hammer as we discussed earlier but for very high number of blows say 50 plus.

Even for the steel pile, steel H-pile you need more blow energy, so you can go for single acting hammer. Generally, for steel piles we recommend double acting hammer only but when the number of blows are more it indicates more densified sand. In that case you can go for single acting hammer for steel pile. And for the sheet pile also when the number of blows are more 50 plus you can go for double acting hammer instead just vibratory hammer, fine.

Now we discussed about the non-cohesive sand let us now discuss about the cohesive soil. Cohesive soil is also classified into three different categories now let us start from the bottom. 15 to 30 plus blows indicates very stiff to hard cohesive soil, very tough soil condition in this case as I told you it is preferable to go for heavy hammer, go for single acting hammer always for all type of piles.

So, the blow is medium 8 to 15, so stiff cohesive soil, in this case you can go for single acting hammer for wood or concrete pile and double acting hammer for steel or H-pile. For stiff soil you should note that you should use single acting hammer for all types of piles whether it is a steel pile

or concrete pile for every pile you should go for only single hammer. Because the blow energy needed is very high here, you have to go for heavy hammer.

But for stiff cohesive soil, you can go for single acting hammer for concrete pile and double acting hammer for steel pile. And but here they are not recommending vibratory hammer because it is stiff cohesive. Vibratory hammer can be recommended only for soft, medium, cohesive soil where the blow range is 0 to 8. So, you can see vibratory hammer or double acting is recommended for sheet pile, double or single acting hammer you can recommend for concrete.

Here also you can see you can even recommend double acting hammer for concrete because the soil is very soft medium. In that case only for concrete you can recommend double acting hammer. And for wood or steel you can go for double acting hammer, so these are the basic guidelines, so you can refer these guidelines. So, based upon the material type and based upon the soil type, so you can make the hammer selection.

So, that is why I told you first we have to do some geotechnique investigations basic investigations such as site to categorize the soil type**.** Once you know the soil type then only you can make the selection of your pile hammer accordingly.

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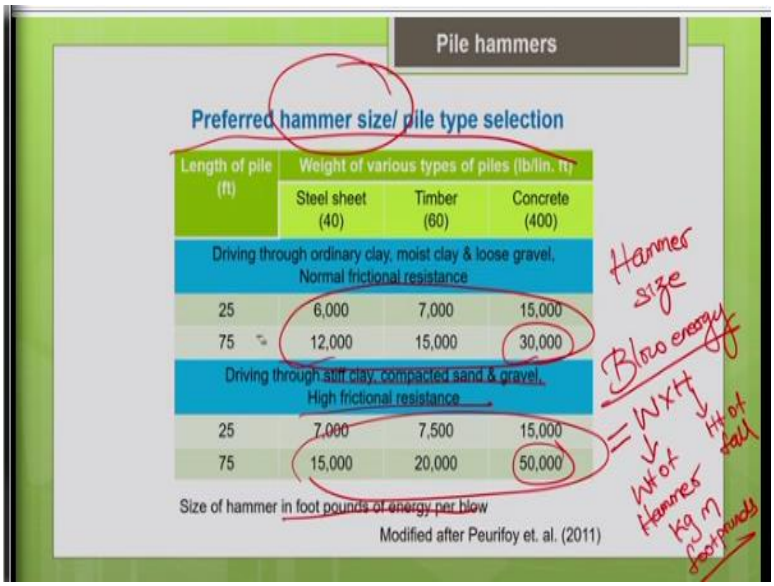

So, makes this about the how to select the pile hammer based upon your weight of your pile, length of your pile and the material type. So, hammer size, here we are going to select the hammer size, so hammer size is generally defined in terms of blow energy, hammer size is defined in terms of blow energy, so how do you determine the blow energy? It is nothing but W into H, W is your weight of hammer and H is your height of fall, so kg meter or whatever.

In this the unit is given as foot-pounds, so that is a unit of blow energy, this is how you define the size of a hammer. So, for very tough soil conditions and for bigger size pile, heavier pile you need a very high blow energy. So, you need a bigger size hammer. So, you can see this table where they have classify the soil into 2 types, one is soil with normal frictional resistance. Like your ordinary clay, moist clay and loose gravel and other one is a soil with high frictional resistance thus that is nothing but stiff clay compacted sand and gravel.

So, now obviously you can say that for tough soil conditions with high friction resistance you need more blow energy when compared to normal friction resistance. The blow energy requirement you can see the difference, so, here the blow energy is very high when compared to this value. So, based upon the soil type the blow energy requirement that is a size of hammer requirement varies. And another important thing to be noted is based upon the length of pile.

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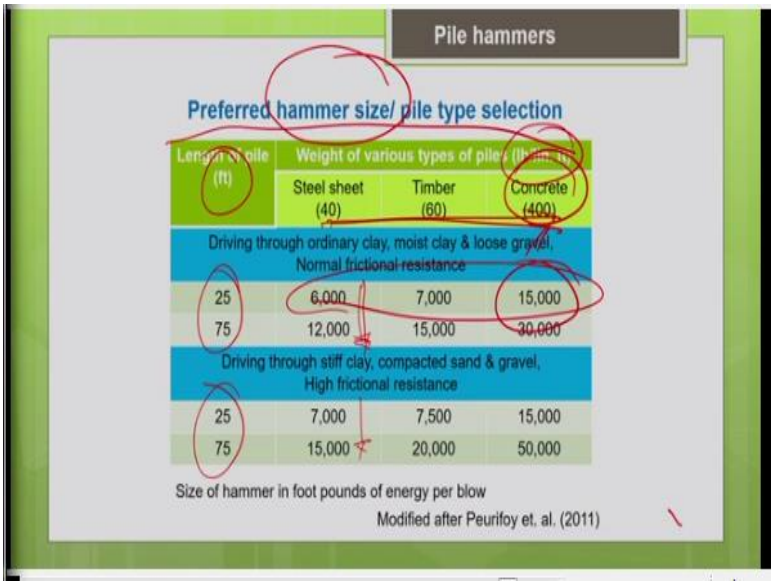

As your length of pile increases you can see that the blow energy requirement increases this is your pile length is given in feet. And another important thing to be noted is as your weight of pile increases, here they have given the weight per unit length that is pounds per linear feet. As your weight of the pile increases you can see that your blow energy requirement also increases.

And obviously for the concrete piles you can say you need a high blow energy when compared to steel pile and timber pile, it depends upon the weight, weight per unit length. So, your pile hammer selection depends upon the soil type, depending upon your pile type, your pile length, pile material type and the weight of your pile. All these things are going to affect your hammer selection.

Apart from this whether there is an restriction on noise, whether you have overhead space for placing all these supporting equipment ok, what is the productivity needed, all these things are also going to govern your pile hammer selection. So, we have come to the end of this lecture, let me summarize what we have discuss in this lecture.

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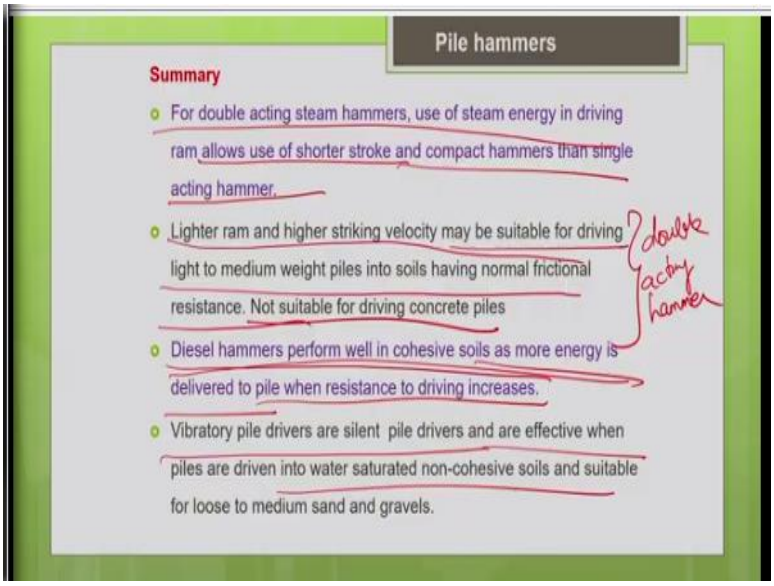

For double acting hammer, use of steam energy in driving ram allows use of shorter stroke and compact hammers than the single acting hammer. So, double acting hammers are basically smaller in size and they go with shorter stroke when compared to single acting hammer. So, they have basically recommended for the soil with normal friction resistance and for light to medium weight piles.

So, lighter ram and higher striking velocity of the double acting hammer will be suitable for driving light to medium weight piles into soil having normal frictional resistance. Here we are talking about double acting hammer, so it is not suitable for driving concrete piles. Generally for concrete piles I need a heavier pile, so that I can reduce the height of fall and also the blow rate of double acting hammer is very high which can easily shorter your concrete pile.

For concrete pile go for a hammer which is very heavy which can offer you more blow energy at a lesser height of fall. Diesel hammers perform well in cohesive soil, as I told you in the tough soil conditions where the driving resistance is high that will result in greater rebound of the hammer which will offer more energy for pile driving. That is why diesel hammer perform well in cohesive soil as more energy is deliver to the pile when resistance to driving increases.

So, vibratory pile drivers are silent pile drivers and are very effective for loose soil conditions or water saturated non cohesive soil. So, these are the important points which were discussed in the lecture.

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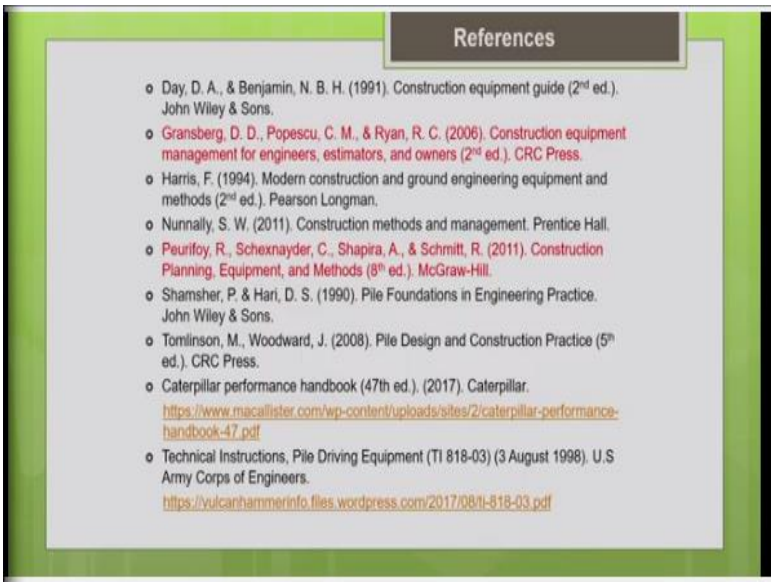

These are the references which I have referred for the lecture preparation. So, in the next lecture we will be discussing about the cranes, the lifting equipment cranes. So, what is the lifting

mechanism of the crane? What are all the different types of cranes merits and demerits, all those things we are going to discuss in the next lecture, thank you.