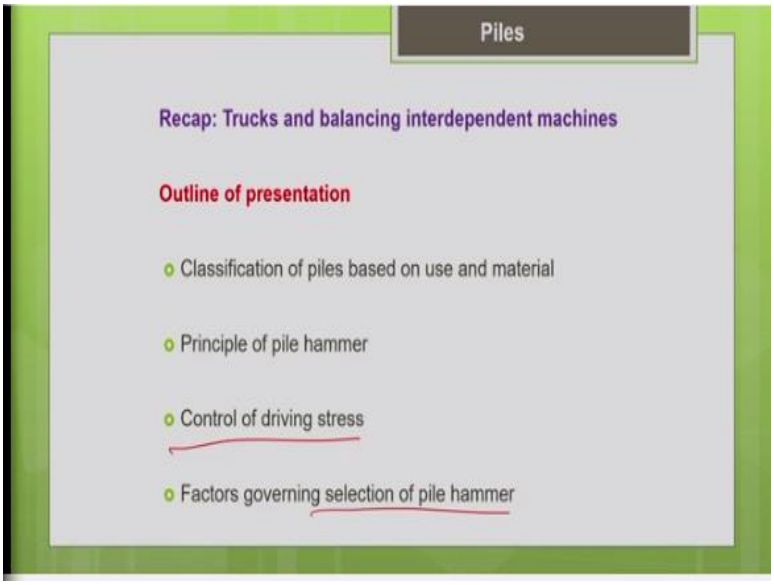
Construction Methods and Equipment Management
Prof. Dr. Indu Siva Ranjani
Department of Civil Engineering
Indian Institute of Technology-Guwahati

Lecture-16
Piles and Pile Driving Equipment (Part 1)

Hello everyone, I welcome you all to the lecture 16 of this course construction methods and equipment management. In today's lecture we are going to discuss about the piles and the pile driving equipment.

(Refer Slide Time: 00:39)



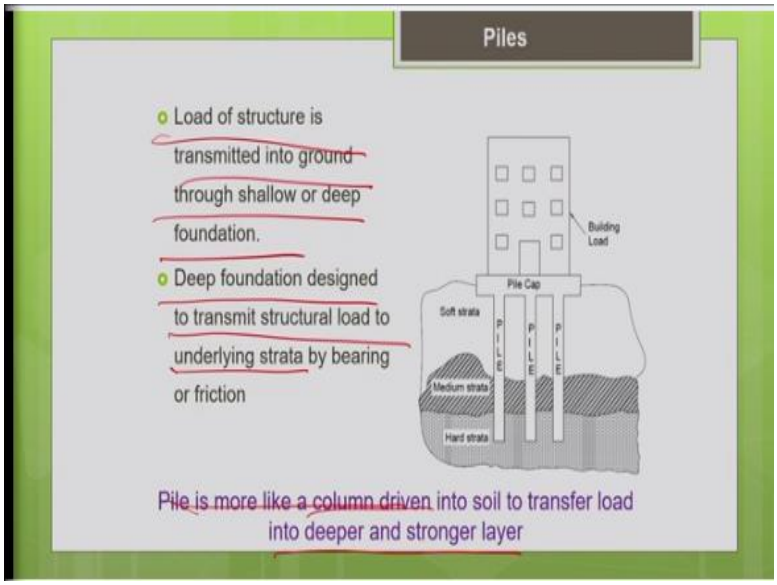
So, in the last lecture, we have discussed about the trucks, and how to balance the interdependent machine safe trucks and the loaders. How to balance them in terms of size and number, so that we can optimize the productivity, that is what we have discussed in the last lecture. Now let us look into the outline of today's presentation. In today's presentation, we are going to discuss about the different types of piles.

So, I will just give you a brief overview on what are all the different types of piles, because we can classify them based on the application, based upon the material type, based upon the method of fabrication, based upon the installation process. So, there are so many ways by which we can classify them. So, I will just give you an overview of how to classify and what are the merits and demerits of different types of piles.

So, then we will move on to what is the principle of the pile hammer. So, what is the principle of pile driving operation, and as you know that particularly the precast piles, they are subjected to more amount of driving stress. Say when you drive the pile into the ground, say we use a pile hammer, so for the driving mechanism, it is subjected to a huge amount of driving stress**.**

So, what are the methods to control the driving stress? That is what we are going to discuss. And also, I will give you a brief overview on what are all the factors which governs the selection of a pile hammer. So, based upon the type of the pile or based upon the size of your pile, so there are different factors which are govern in the selection of the pile driving hammer, so we are going to discuss about that in the upcoming slides.

(Refer Slide Time: 02:07)



So, as everyone knows, the load of any structure is transferred to the ground to the foundation. So, this foundation can be a shallow foundation or deep foundation. Piles are deep foundation they are examples for deep foundation. So, they are capable of transferring the load from the structure through a weak stratum and it can carry till the depth where a hard bearing stratum is available.

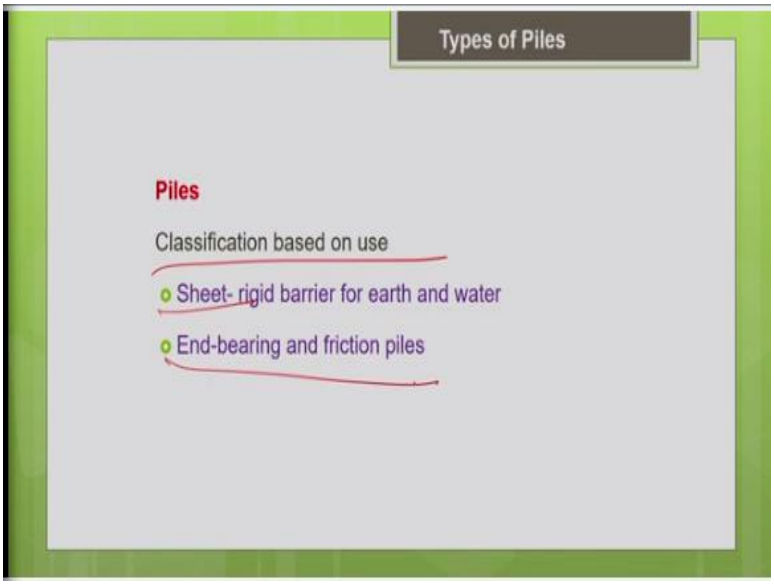
So, the load of the structure is transmitted to the shallow or deep foundation as I discussed just now. The deep foundation that is a pile is designed to transmit the structural load to underlying strata. And the load transfer can be either on the basis of end bearing or basis of fiction, that we

are going to discuss in the upcoming slides. So, basically your pile foundation you consider it will act like a column, pile is like a column driven into the soil.

It transfers the load from the structure deep into the harder and stronger layer, which can bear the load. So, when do we go for the spell foundation? Basically, when we have weak soils or soil with poor bearing capacity, we need to transfer the load till we reach a depth where you confined a hard load bearing strata. So, till that depth we need to transfer the load, so for that we need a deep foundation like pile.

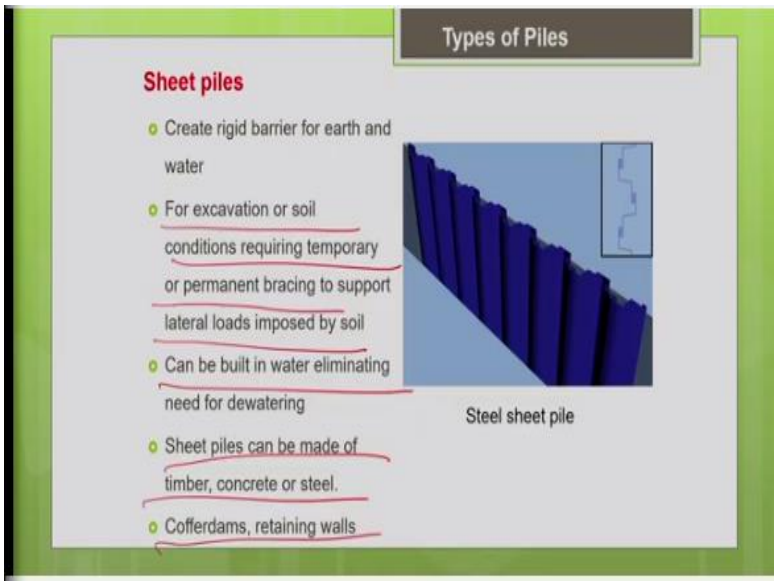
So, the other requirement maybe is a design load is very huge. Say for example you need to design a foundation for a skyscraper or a multi storey building, where the design load is very huge. In that case people commonly go for the pile foundation.

(Refer Slide Time: 03:38)



So, based on the application, so commonly, there are different types of uses of piles. So, I am just going to discuss few common applications, so one is a sheet pile and other one is your end bearing pile and friction pile.

(Refer Slide Time: 03:52)

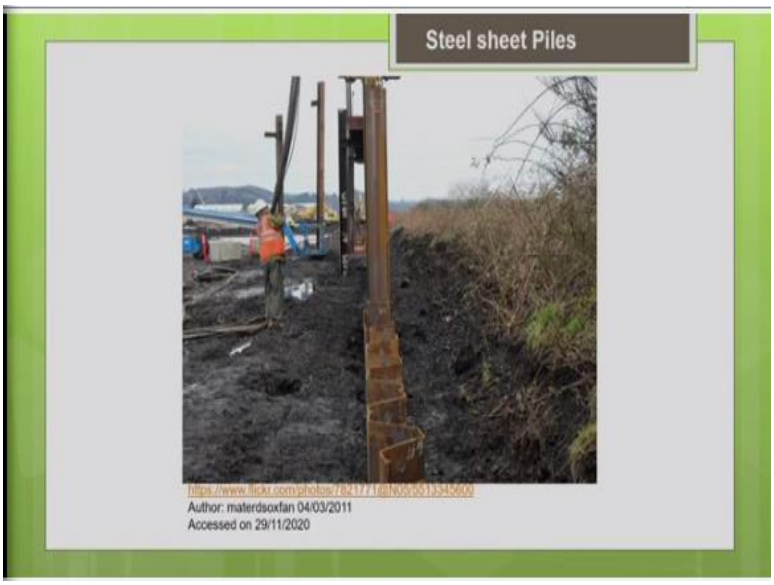


First let us see what are these sheet piles? The sheet piles so we might have seen this kind of steel sheet piles, so they are with interlocking joints, you can see that. So, they act like a rigid barrier for earth and water particularly during excavations or trenching. So, to protect the trench from the collapse, to prevent the trench from the collapse of soil, we go for this kind of sheet piles.

For excavation or the soil conditions requiring temporary or permanent bracing to support the lateral load imposed by the soil, we go for this kind of sheet piles. So, it acts like a rigid barrier supporting the lateral load from the soil, it can also be used in water, like a cofferdam. It helps to act like a barrier for the water it provides a dry working area or dry working environment, so eliminating the need for dewatering, it can also be built in the water.

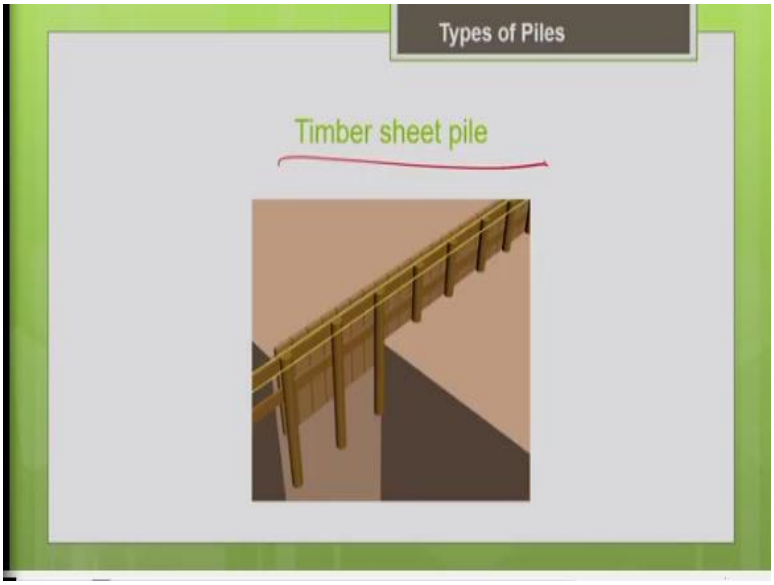
So, you can use any type of material like you can go for timber sheet piles or steel sheet piles or concrete sheet piles, so it can be made out of different types of materials. So, commonly you can see applications and retaining walls and cofferdams as I discussed just now.

(Refer Slide Time: 05:02)



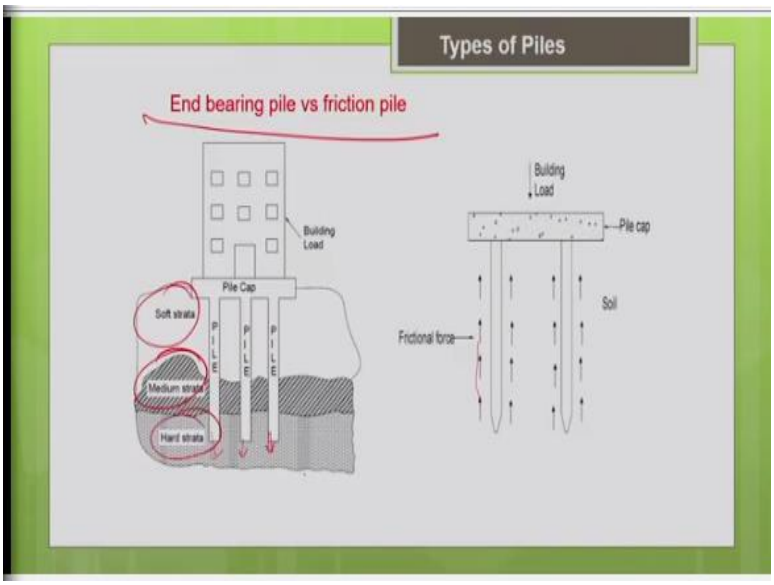
So, this is again a picture of the steel sheet pile, you can see the interlocking joints. So, this is mostly driven with the vibrating hammer, what is this vibrating hammer all these things? We will be discussing in the part 2 of this lecture, so where we will be discussing about different types of pile hammer. So, this helps to support a lateral load from the soil, helps as a barrier to the earth.

(Refer Slide Time: 05:26)



This is the picture of the timber sheet pile, as you know that timber is the oldest material. So, oldest building material we have been using this material for so many centuries, even now we use it wherever the timber is abundant.

(Refer Slide Time: 05:39)

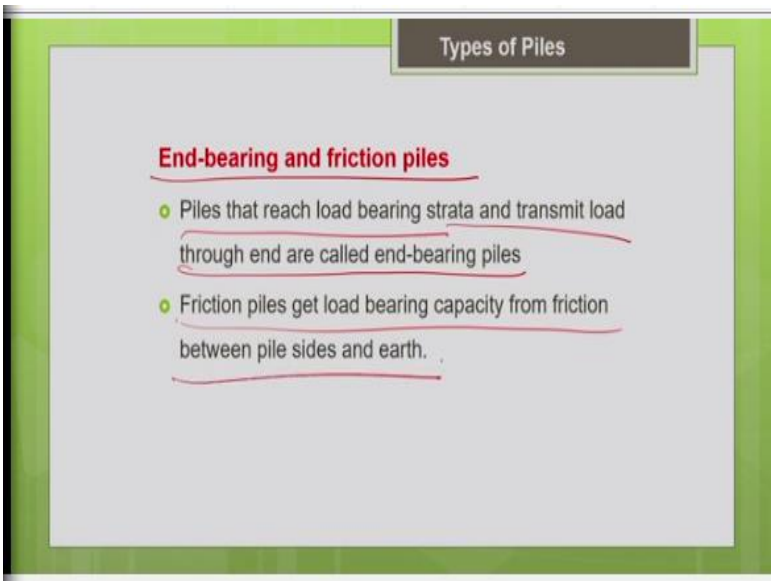


So, other types of applications are end bearing file and the friction pile, based on the mode of load transfer. So, particularly for the soil with poor bearing capacity and we go for this end bearing pile. So, the end bearing pile has to transfer the load through the weakest strata till it reaches it hard bearing strata which can carry the load. And the load is transferred through the end that is why it is called as the end bearing pile.

In the case of friction pile the load is transferred through the friction between the sides of the pile and the surrounding soil, so that is friction pile. So, if the end bearing strata the hard bearing strata is reachable it is within the reachable depth, then we can go for the end bearing pile otherwise we have to go for the friction pile only**.** If the hard bearing strata is at a very greater depth, it is not reachable, then we can design a friction pile.

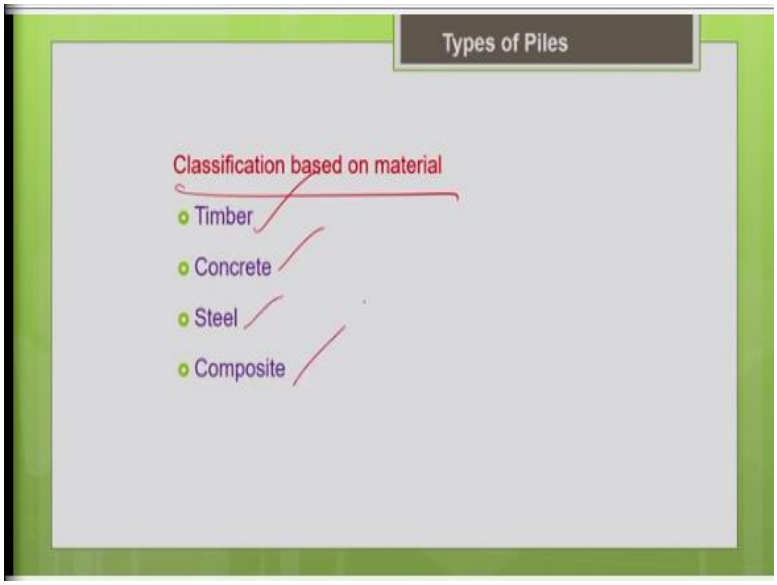
The most of the piles you can see that they can transfer the load both through the friction mechanism as well as to the end bearing mechanism so that is also possible.

(Refer Slide Time: 06:43)



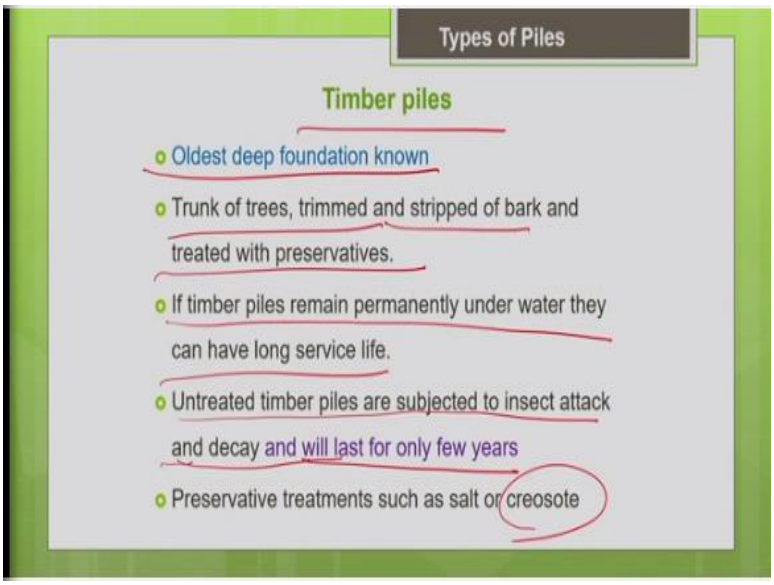
So, this is what we discussed just now. Piles that reached a load bearing strata and transmit the load through the end are called the end bearing piles. Friction piles get the load bearing capacity from the friction between the pile sides and the earth**.**

(Refer Slide Time: 07:00)



Now we have discussed the few types of piles based on the application or the use. Now let us see the classification based on the material type. So, we can classify it into timber, concrete steel and composite piles.

(Refer Slide Time: 07:13)



So, timber pile, as I told you this is the oldest material, I can say it is the oldest deep foundation known. So, it is very commonly used because easy to use, it is not expensive, easy to cut it and splice it, there are so many merits with it timber piles**.** How do you basically use it? You just use a trunk of the trees cut it, trim it and strip of the bark, why should we strip of the bark? When we use it as a friction pile there is possibility of slip between the bark and the trunk, so that is why we should strip of the bark.

And treat it with preservatives, that is very important because these piles are more susceptible to rotting and insect attack as everyone knows. So, particularly when the timber piles are subjected to fluctuating water table. So, you can see the issues of rotting and insect attack, this is because for the rotting mechanism, you need the presence of both water and the air. So, that is why timber piles which are permanently submerged in the water, they are not susceptible to rotting.

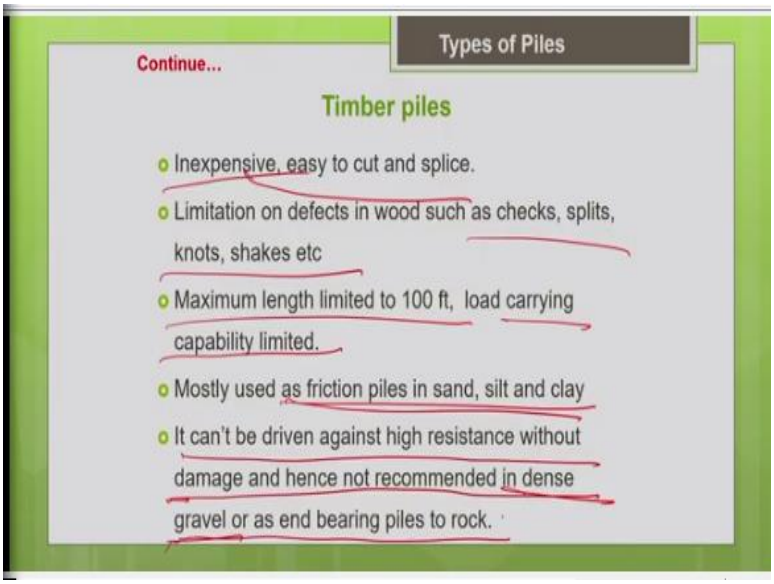
They are not susceptible to insect attack; there are so many structures with the timber piles, which are servicing for so many years without any damage, without any rotting or insect attack when they are submerged in the water**.** But the problem arises only when it is subjected to the fluctuating water table because you know that the presence of water and air is necessary for these mechanisms.

So, that is why in those cases where you know that it is going to be subjected to fluctuating water table, you should definitely go for the preservatives to prevent it from rotting**.** So, if timber piles

remain permanently in the water, they can have a long service life, that is what we discussed just now. And the untreated timber piles are subjected to insect attack and decay and they will last only for a few years.

So, both type of treatment we can offer to the timber piles to protect it from the insect attack and rotting. So basically, in the olden days used to soak the timber in the natural saltwater. So, the natural saltwater is best preservative, but nowadays we go for modern methods like this to creosote with pressure treatment. So that is found to be very effective for the treatment for insect attack and the rotting.

(Refer Slide Time: 09:34)



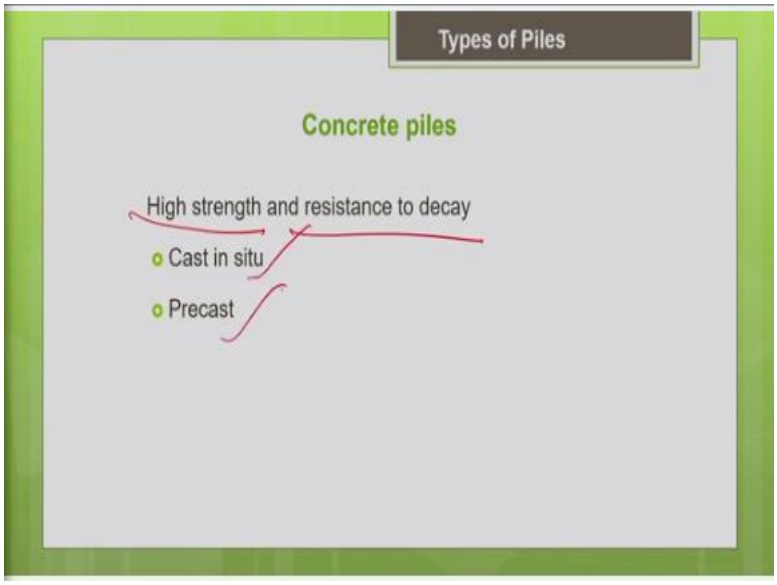
So, let us look into the merits and demerits of this timber piles. Basically, the merit is, it is inexpensive, easy to cut and splice, that is a major advantage. But the demerit is obviously we know that lot of defects was there, natural defect was there in the timber, let checks, splits, knots and shakes. So, we have to quantify the number of defects in the timber before assessing it is suitability for using it as a pile.

Where we have to quantify and whether the defects are within the permissible limit as given by the standards, we have to check before it is used as a pile. And also, there is a restriction on the maximum length and the load carrying capability is limited, you know that when compared to

concrete or the steel piles, it is load carrying capacity is limited. So, that is why mostly we use it as a friction pile in sand, silt and clay.

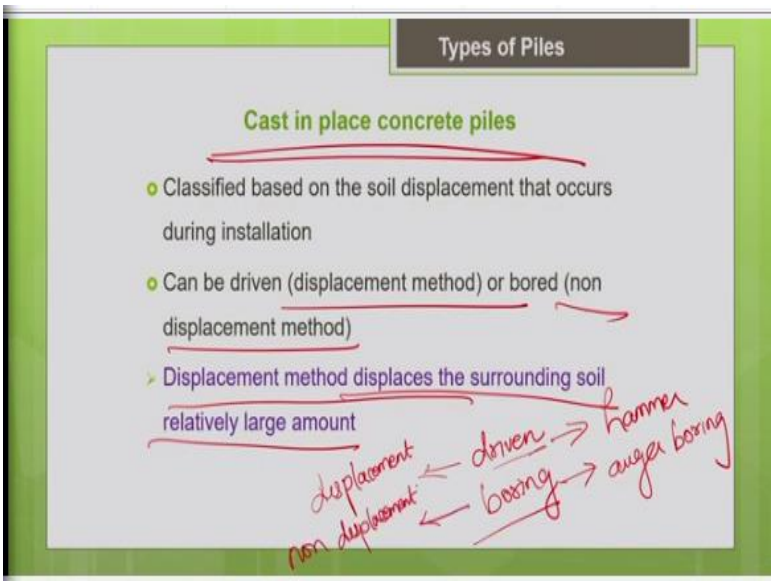
We do not use it as an end bearing pile or we do not use it in very tough soil conditions like dense gravel. Then timber pile is likely to get damaged easily when we drive it against high resistance. So, when we driving soils with high resistance, it is likely to easily get damaged, that is why we use it only as friction piles in sand, slit and clay. It cannot be driven against high resistance without damage and hence not recommended in dense gravel or as end bearing piles to rock.

(Refer Slide Time: 10:55)



So, the next is about the concrete piles. Obviously, when it compared to the timber pile, it is load bearing capacity is high, there is a high strength and as good resistance to decay, there is no issues of decay. Now so there are based on the method of fabrication, you can either the casted at your project site or you can make it in the factory. So, accordingly you call it a cast in situ concrete piles or precast concrete piles.

(Refer Slide Time: 11:22)



So, what is this cast in situ concrete piles, what are the methods of making cast in situ concrete piles? Here also based on the process of installation, you can classify it further into displacement method and non-displacement method. See, when you do the installation process, say if your installation process is going to disturb the surrounding soil to a greater extent, say if it is going to displace the surrounding soil to the greater extent, then it is called as displacement method.

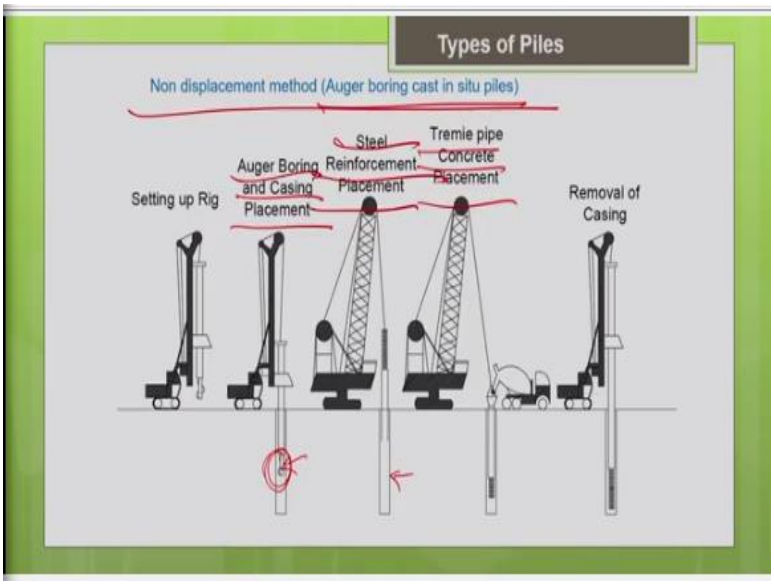
So, if the disturbance to the surrounding soil is minimum, then it is called as non-displacement method. So, basically there are two types of methods**.** Displacement method means, it will displace the surrounding soil to a relatively larger amount. So, say for example, doing the driving, say in the case of cast in place concrete piles. So, you will be commonly driving your steel casing into the soil you have to drive the steel casing with a hammer.

So, what are the different types of hammer use? As I told you in the next lecture we will be discussing in detail. As of now what you need to know is we will be blowing a hammer on the top of the steel casing, so into the soil. When you do this driving operation, what happens is it will displace surrounding soil to a greater extent, say if it is going to be clay soil. So, due to the displacement you can see there will be huge buildup of pore water pressure in the clay surrounding the installation point.

That will result in the healing of the soil around the installed pile. So, this kind of the displacement may happen, so that is why we call them as a displacement method. So, there are two options to make the cast in place concrete pile, one is your driven method, driving, other one is a boring method. Driven means I am going to drive the casing here we are going to drive because it is cast in place concrete clay, will be driving the casing with the hammer, that is why it is called as the driven method.

Other one is boring method, so very commonly we use this auger boring method to make the hole into the ground. So, the first one the driving method is a displacement method, because it is going to displace the surrounding soil to a greater extent. But the boring method is the non-displacement method.

(Refer Slide Time: 13:42)



First let us discuss in detail about the non-displacement method. So, the commonly adopted mechanism or a methodology is the auger boring we are going to discuss about this in this lecture. This picture clearly shows you how the auger boring is done. First you set up the rig**,** then you can say this is the auger bore, it has a spiral or the helical the drilling bit at the bottom which can be rotated by the motor and it is usually accompanied by a casing.

So, when you provide the casing it helps to protect the soil also from the collapse and acts like a formwork to your concrete. So, this is the auger boring method, you can see this is the spiral or the

helical blade arrangement. So, this one can rotate with the help of the motor. So, based upon this rotary method, you can easily make a hole into the ground, this is the rotary boring method.

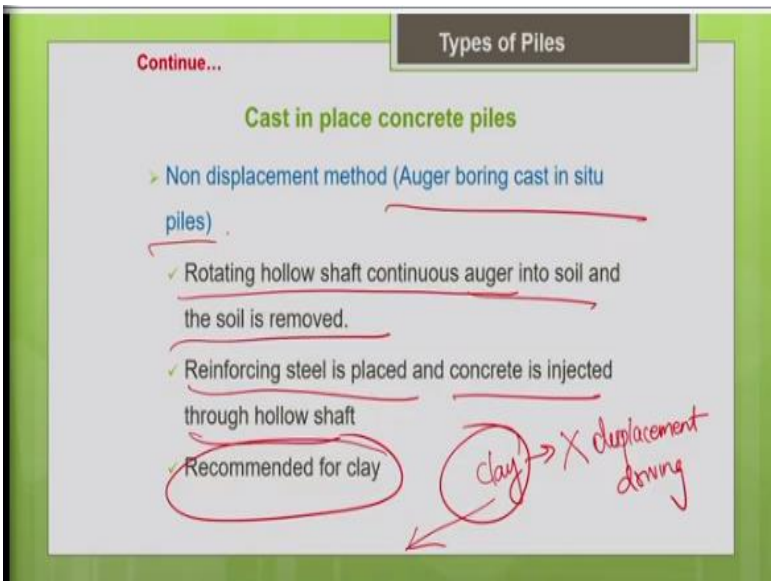
You make the hole into the ground and place the casing, so the placement of the casing and the boring is done together. Casing is nothing but a steel pipe, it will act like a formwork it will act like a formwork. So, that to prevent the collapse of the hole and also it acts like a formwork for a concrete placement. Then with the help of the supporting equipment like crane, as I told you for the pile driving mechanism we need loads of supporting equipment.

Like the crane to lift your casing, to lift reinforcement cage and to place the tremie pipe, for all these things we need the supporting equipment, so now what to do? Once a boring is done, the next step is placement of the reinforcement inside the borehole you place the reinforcement inside the borehole. Now, what we do is next step is the concrete placement. So, very commonly we go for this tremie pipe method of concrete placement.

Using the tremie pipe, you place a concrete to the greater depth. And now you can extract your casing, so that you can reuse the casing. So, this is what is it the commonly adopted method the boring method for making the case in situ concrete. So, let me summarize, first thing is you are going to use it auger for boring the hole into the ground and you remove the soil also.

While boring itself you place the steel casing which will act like a formwork**.** Then with the help of the crane place reinforcement followed by the placement of the concrete using the tremie pipe method. Then once the concrete is placed you can remove the casing, so then you can reuse the casing for the next piling.

(Refer Slide Time: 16:18)



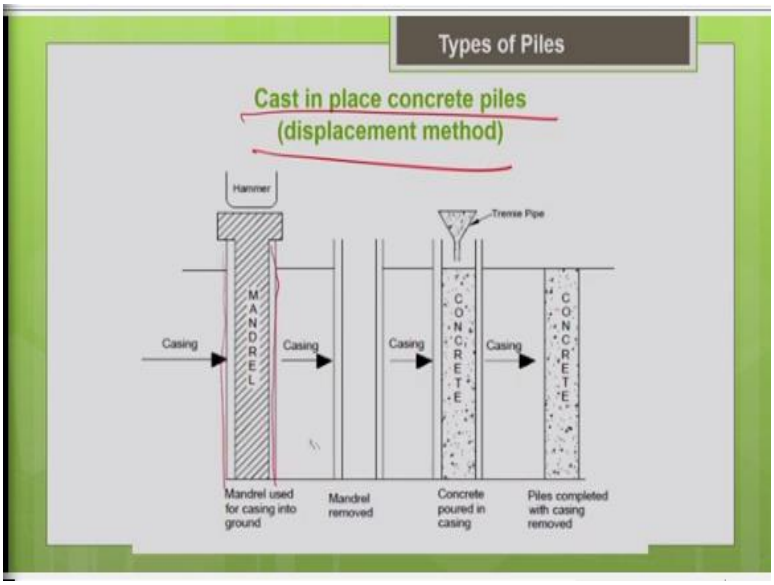
So, let me summarize, first you need to rotate the hollow shaft continuous auger into the soil is the rotary method as I told you. So, you have the rotating hollow shaft continuous auger. So, it has a spiral or helical auger as I showed you, which can easily bore the hole into the ground and it can remove the soil out of the hole. So, the soil is removed and the reinforcing steel is placed and the concrete is injected with the help of a tremie pipe.

So, this method we can recommend basically for the clay soil. So, basically for the clay we should not use displacement method the driving method cannot be used for the clay terrain. This is because when you try to drive the formwork as a steel casing into the clay. As I told you earlier it displaces the soil to the greater extent there will be huge buildup of the pore water pressure in the clay when compared to other type of the soil which results in healing.

So, that is why particularly for the clay you should go for a non-displacement method and auger boring is a best choice. Now let us see here the video clipping on how the auger boring method is done**. (Video Starts: 17:37)**, so in this video, you can see how the boring method is done first, so with the help of this boring method, you can make a hole into the ground and also you can extract the soil from the ground**.** You can see this casing which helps to remove the soil, you can see it clearly. **(Video Ends: 19:49)**

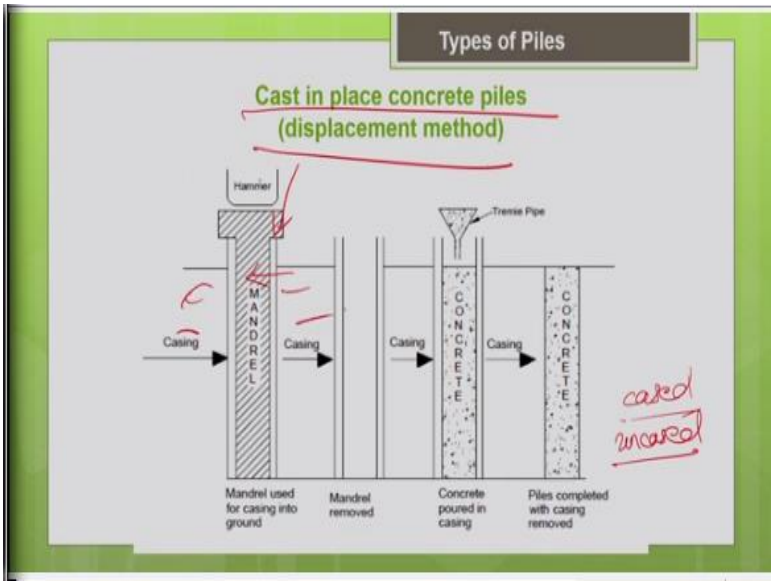
So, followed by that you can see how the reinforcement casing is placed with the help of the crane. So, after the reinforcement casing is placed, you can see how the concreting is done with the help of tremie pipe. So, this is how the bored cast in place concrete piles are done.

(Refer Slide Time: 20:08)



Next is we are going to discuss about the cast in place concrete piles using displacement method. So, first is we are going to drive the steel casing into the ground, steel casing is nothing but the steel pipe, it can be either open at the bottom or it can be closed at the bottom. So, drive the steel casing into the ground this is your casing, you can see that.

(Refer Slide Time: 20:33)

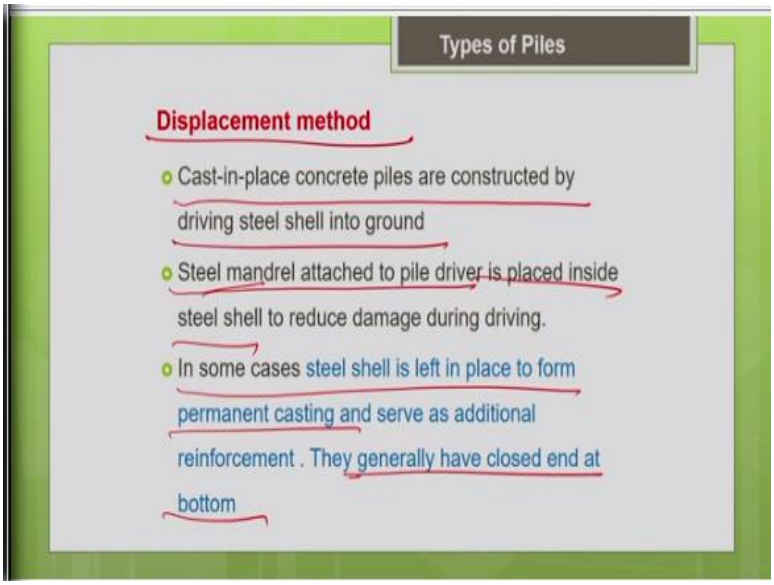


Now how do you drive it with the help of a hammer, you blow the hammer. Since there are chances are the casing may get damaged, and you have to reuse the casing for the further piling. So, that is why commonly you can see that inside the casing they put this mandrel this is the mandrel. So, then you can blow the hammer on the top of the mantel to avoid the damage to the casing.

So, now you blow the hammer on the top of the mandrel and the casing is driven into the ground. Once it is driven to the required depth, you remove the mandrel, now place your reinforcement follow by the tremie pipe concreting. So, mostly for the pile foundation as it is for the greater depth we prefer tremie pipe method, so you do the tremie pipe concreting. o, after that you can remove the casing if needed or in some cases they leave the casing permanent, so that it can act like an additional reinforcement to a pile.

So, if you leave the casing it is called as cased pile or if you remove the casing it is called as uncased pile. So, basically when the casing is closed with bottom, so it means that you are going to leave it permanent. So, the casing which is open at the bottom, we remove it and reuse it. So, this is a displacement method, because this driving mechanism will displace the surrounding soil.

(Refer Slide Time: 21:53)

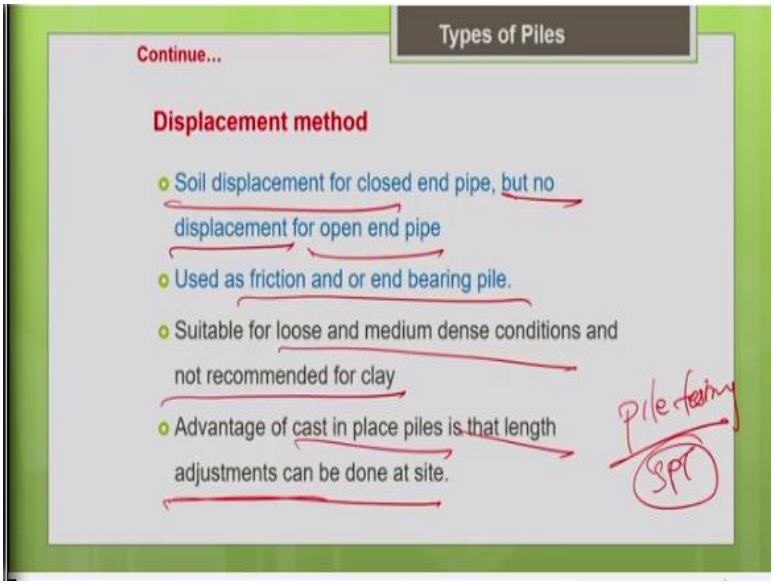


So, let me summarize what we discussed earlier on the displacement method. So, cast in place concrete piles are constructed by driving the steel shell into the ground, shell is your casing and the steel mandrel is attached to the pile driver is placed inside the steel shell. So, why the mandrel

is placed, so that you can reduce the damage to your casing, when you blow the hammer on top of it.

In some cases, steel shell is left in place, it can act like an additional reinforcement. So, they generally have closed end at the bottom if you are going to leave it permanent, they will have the casing will have the closed end at the bottom.

(Refer Slide Time: 22:34)



So, generally when we go for the closed end pipe, obviously there will be more soil displacement, surrounding it. But if you go for open end pipe, there would not be much displacement of the surrounding soil. So, mostly it can be used as either fiction pile or as end bearing pile because use it in both ways. You can use it for loose and medium dense conditions and not recommended for the clay.

As I told you, you never go for displacement method for the clay because it will result in huge buildup a pore water pressure in clay heaving. So, another advantage of all these cast in situ piles is that you can do some length adjustment of the pile at the site. Even if you are not able to predict the length requirement, if you are not able to predict the exact hard bearing strata, the location of the hard bearing strata.

And if you are not able to predict the length requirement accurately, we can make some adjustments at this site but for the precast piles which are made in the factory. So, such kind of adjustments are not possible at the site, you can go for either cutting or splicing, and that is very difficult with the concrete piles. That is why when you go for precast piles, we have to accurately determine the length of the pile needed.

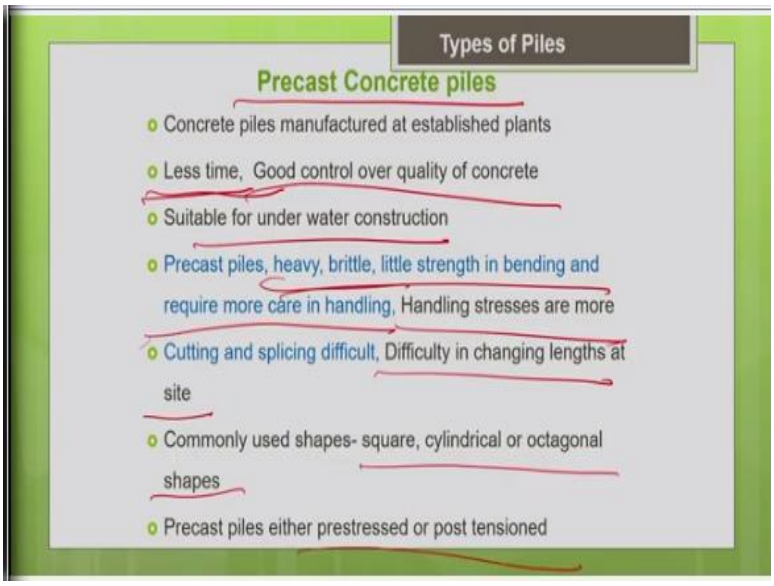
So, that is why we need to do a thorough prior investigation you have to carry out the pile testing program. So, you have to do some preliminary pile testing to know the exact length needed and also to assess the load bearing capacity of the pile. And also, you should know some geotechnical investigations to know the complete soil profile. So, you need to know the various end bearing strata and also you need to know carryout all the tests.

Say for example, you need to know the standard penetration test. All these tests will help you to know the soil behavior which will help you in the pile design. That is why prior pile testing is very much important before you do the actual piling operation in your project site. So, in addition to this, there is also other methods where, they use this bentonite slurry for the piling method, what they do is?

They use of bentonite slurry to act like a foam up to the soil. So, this will be more cost effective when compared to the steel formwork. So, soil has a pore bearing capacity, they use this bentonite slurry, so that it will help to stabilize your soil and prevent the collapse of the soil. The bentonite slurry also helps in flushing you the borehole. So, the thing is, you can have a thorough flushing of the borehole.

So, that there would not be any muck or the left-out material at the bottom end which may reduce the end bearing capacity of the pile, so that is advantage of going for bentonite slurry. So, this is also one of the commonly accepted methods for cast in situ concrete piles.

(Refer Slide Time: 25:21)



So, far we have discussed about the cast in situ concrete piles. So, there are two ways you can go for the displacement method there is the driving method or you can go for the non-displacement that is boring method, and we have discussed about the auger boring. So, now we are going to discuss about the precast concrete piles. So, they are going to be made in the factory in control condition.

Since it is made in the factory you will have a good quality control, you will have a good control over the quality of the concrete than at the construction project site and you will be requiring less time only productivity will be high in the factory. This is because you can even go for accelerated methods of curing, extreme curing to accelerate the strength gain process. So, you need less time when compared to the real cast in situ process.

And for complicated concreting procedures like underwater concreting it is preferable to go for precast concrete piles rather than cast in situ which is more complicated. But what will be their demerit? Demerit is these concrete piles are likely to be very huge, so it will be very heavy. Handling of the piles is very difficult, so particularly, when you handle the concrete piles, they are likely to be subjected to more amount of handling stresses and they are likely to be damaged.

So, that is why handling has to be done in a very careful manner. And you have to provide some additional reinforcement to take care of the handling stresses, that is very important. But for the

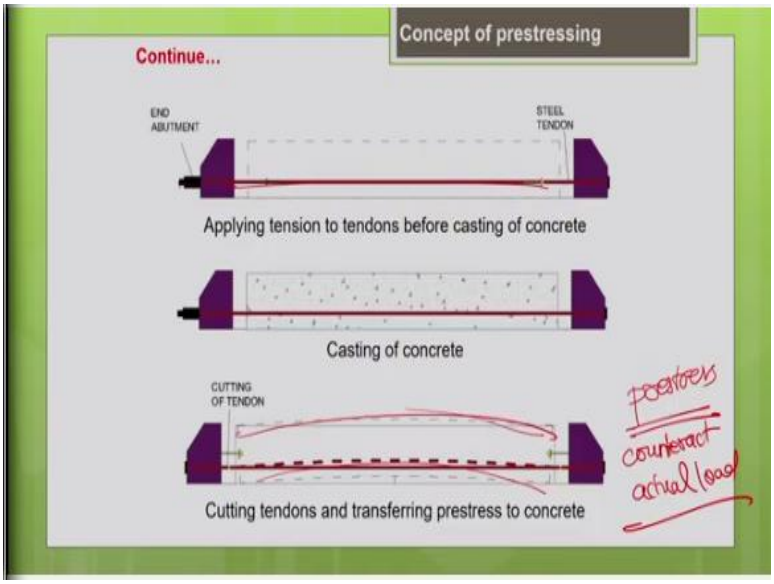
cast in situ pile, we do not need additional reinforcement for the handling stresses. But for the precast pile when you design it, we have to add some additional reinforcement for the handling stresses.

And we cannot go for a very lengthy pile, you know that concrete is weak in tension and it has a very poor bending strength. So, that is why there is a limitation on the length of the concrete pile also. So, that is what is given in the slide also, heavy, brittle, little strength in bending and require more care in handling, so handling stresses are more. And another important thing is, it is very difficult to do cutting and splicing with a concrete pile.

That is why we have to accurately predict the length needed. So, properly do the soil investigation to look at the end bearing strata and decide the length of the pile because there is difficulty in changing the lengths at the site. So, there are different shapes available square, cylindrical, octagonal, so different shapes of concrete piles are available. And another important thing to be noted is we can go for this pre-stressing method**.**

To improve it is load bearing capacity and to improve it is resistance to handling stresses, and it is improved implement in resistance to the deflection we can go for pre-stressing method pre-stressed the precast piles are very common.

(Refer Slide Time: 28:09)



So, what is this basic concept of pre-stressing? I will just introduce to you what is the basic concept. Basically, what we are trying to do is we are deliberately introducing some internal stresses in the concrete. So, that before the external load application, we are introducing some internal stresses So, that later the structure can counteract the external loads when it is subjected to the load application.

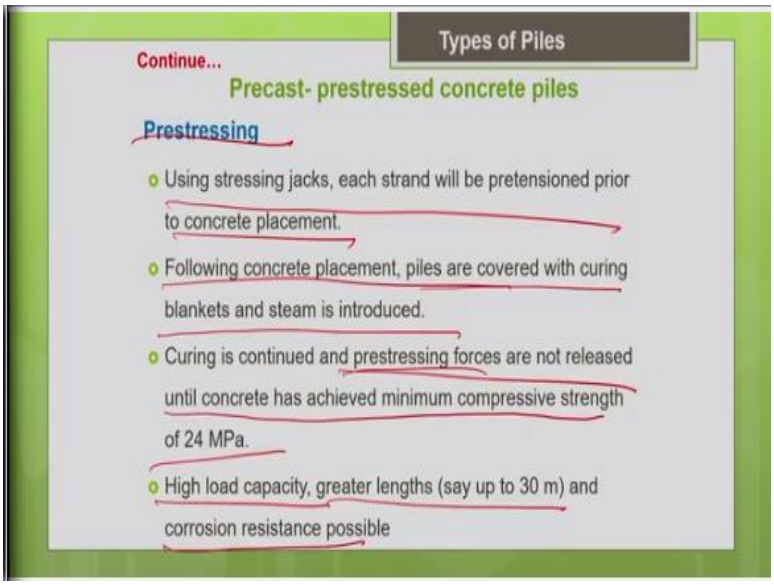
So, these internal stresses will counteract the external load, that is what is a basic concept of the pre-stressing. So, what we are doing here is, we are applying tension to the tendons you can see you are applying tension to the tendons with the help of a stressing jack. So, now do the casting process, now the concreting is done. Till the concrete attains the minimum strength desired strength say 24 MPa, you are not supposed to release the stressing.

So, once the concrete attains it is minimum strength desire strength of say 24 MPa, you can cut the tendons and release the stress. So, once you release the stress what is happening? The tendons will try to come back to it is original length, but the concrete which is already hardened will prevent that. So, it will transfer some amount of stress into the concrete, that is called as pre-stress.

So, we are transferring stress into the concrete, even before the load application you can see how it is subjected to stressing. So, what happens is, when it is subjected to the actual load, so this pre-stress develop will counteract the actual load. So, that is why your load bearing capacity will increase as well as if these piles cannot undergo deflection easily and the handling will be easier. It is not easily subjected to handling stresses, it can easily take the handling stresses, it is not susceptible to damage during handling.

So, that is a main advantage of pre-stress concrete pile. So, if you are going to apply the tension before the casting is done, it is called as pre-tensioning. If you are going to apply the stress after the concrete casting is done, it is called as post tensioning. Both the ways you can improve the load bearing capacity of the piles. So, basically when you go for this pre-stressing method, you can increase the length of the pile.

(Refer Slide Time: 30:49)



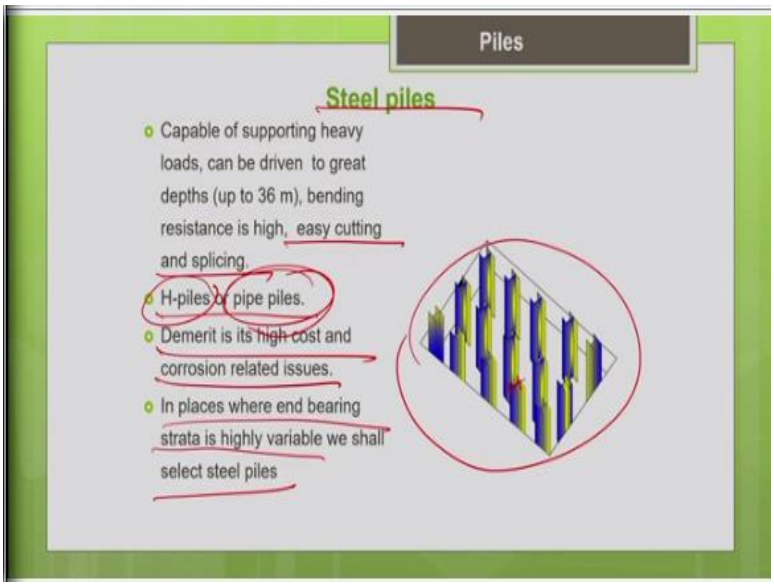
Because as I told you concrete piles, say for example, the precast concrete piles, it is a normal conventional reinforced concrete pile. If the length is say, now commonly we do not go beyond 15 meters. But if you go for pre-stressing method, we can even go up to 30 meters because you can easily resist the handling stresses, so that is one advantage of pre-stressing. So, let me summarize what we discussed earlier in the previous slide.

So, here what are we doing pre-stressing, using the stressing jacks, each strand will be pre-tensioned prior to the concrete placement, that is why it is called as pre-tensioning. So, following the concrete placement, the piles are covered with the curing blankets and steam is introduced they accelerate the curing process. You continue to curing and the pre-stressing forces are not released until the concrete has achieved minimum compressive strength of 24 MPa.

Till that time, you should not release the stresses it will be under the stressing jack only. After the concrete attains a minimum strength of 24 MPa, now you release the stresses. So, as I told you once the stresses are released the tendons will come back to try to come back to the original length which will be prevented by the hardened concrete. So, this will result in development of pre-stress in the concrete which is going to counteract the external load when the structure is subjected to external load application.

So, it results in high load bearing capacity and you can go for greater lengths say up to 30 meter and also it results a better corrosion resistance, when compared to conventional concrete piles.

(Refer Slide Time: 32:24)



So, with this let us move on to the steel piles under the concrete piles we are discussed about cast in situ as well as precast concrete piles. So, now let us discuss about steel piles, the main advantage of steel piles is, it is load bearing capacity is significantly high when compared to concrete piles**.** Particularly it is a unit load bearing capacity, it is going to be very high.

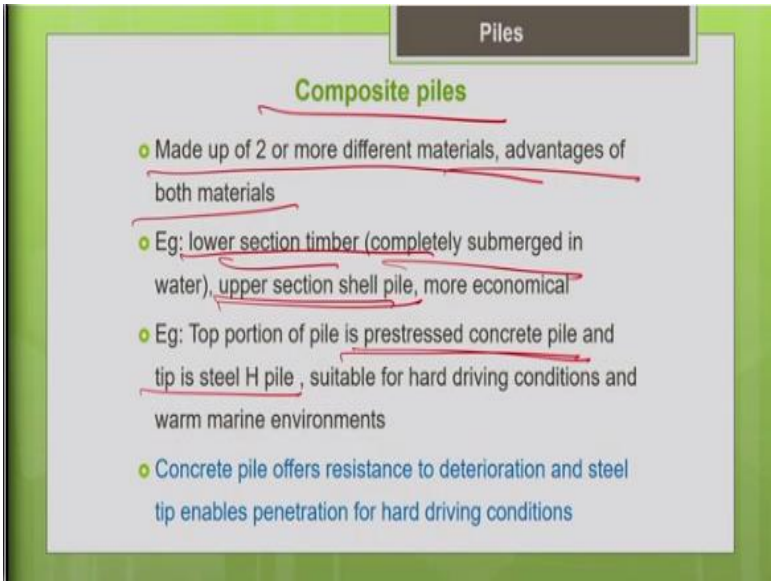
And it has a very good bending resistance that is why you can go for a very greater depth even more than 30, 35 meters, I can go for steel piles. So, very commonly used in the say marine environment where you need greater depths. Another advantage is cutting and splicing is very easy with the steel piles, that is why if your end bearing strata is going to be highly variable, it is not easy to predict the length of the pile.

In that case, it is preferable to go for steel piles, because cutting and splicing is easy with the steel piles when compared to the concrete piles. So, the most commonly adopted forms or H-piles or the pipe piles, so very commonly, you can see the H-piles and the pipe piles usage. And one thing to be noted is the H-pile is very good in driving, even in hard soil conditions you can easily drive this H-pile into the hot soil.

So, in marine environment, we always prefer this steel H-pile at least the tip should be the steel H-pile because it is very much needed for hot driving. But the demerit is it is high cost and corrosion related issues you know that obviously for the steel pile. So, that is why commonly what they do is, they increase the cross section of the steel, so that it can take into account the corrosion related damage.

And also, we can go for other methods of corrosion protection measures like corrosion resistant coatings or cathodic protection, there are different measures, we can also go for it. As I told you already in places where the end bearing strata is highly variable, you cannot predict the length of the pile needed correctly, then go for the steel piles because it is easy to cut it and splice it. Another important thing you should know that with this H-pile, when you drive the H-pile, the amount of displacement to the surrounding soil will also be less when compared to the pipe piles.

(Refer Slide Time: 34:50)



Next is about the composite piles. So, nowadays people are very much interested to go for composite materials, so that we can take the benefits of both the materials in the same pile. So, it is made up of two or more different materials, we are able to enjoy the benefits or advantages of both the materials in the same pile. So, the commonly used composite piles I can give you some example.

Say timber and steel combination is also used, say the lower section, I can go for timber. Because as you know that, say for example you are going to select the pile which is going to be submerged in water, the portion which is going to be submerged in water you can go for timber pile. Because when it is completely submerged in water, timber is not susceptible to rotting or in a decay.

That is why for completely submerged portion I can go for timber which is more economical, but for the top portion you can go for the shell pile or the steel pile, so this way you can economizing the cost. Another example I can say which is more commonly use is pre-stressed concrete pile with a steel H-pile or the tip at the bottom, why do we go for this steel H-pile as a tip?

Because it is very good for hard driving conditions, as I told you for sea for marine conditions when you need hard driving go for a steel H-pile tip, it will be easy to drive. So, on the top you can have the say pre-stressed concrete pile which is more economical as well as it is load bearing capacity and the corrosion resistance is high. So, these are the common combinations, there are many other combinations also of composite piles.

(Refer Slide Time: 36:29)

Now let us see what is the basic selection criteria for the pile, how will you select a pile? Obviously, it depends upon the type of soil, so that is why you need to do the proper geotechnical investigations to know the soil profile. So, whether it is going to be clayey terrain or it is going to

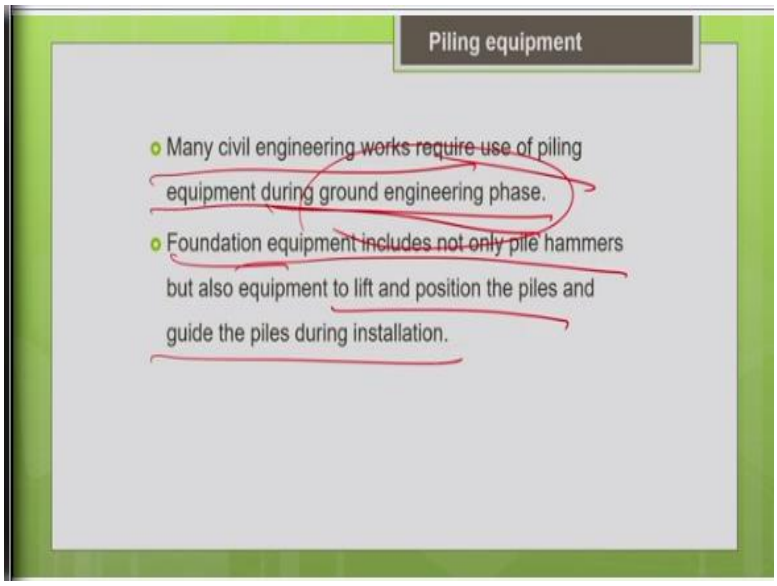
be a sandy or silty or rocky or it has and what is the complete profile you need to know it, so before you select a pile.

So, the pile type depends upon the soil type and also the availability of material. So, whether the material which are going to use for making the pile is available in that locality that is also important. It is always preferable to use the material which is available in the local place, so that you can do the cost optimization. Length of the pile needed, that is very important, as I told you, there is a limitation in the timber pile length.

There is a limitation with respect to the precast pile, pre-stressed precast piles and steel piles, everything has it is own range of length possible. So, depending upon your length needed and you have to go for the pile type selection. Construction schedule, your productivity, sometimes we do not have much time to make cast in situ concrete pile. If you want to speed up your project, in that case you have to go for precast piles.

And what type of structure it is to be supported by the pile, so how much design load it has to take? So, what should be the load bearing capacity because obviously the first for a steel pile, pre-stressed concrete pile and timber pile. So, according to that we have to base upon the design load expected you have to make the selection. So, obviously we have discussed all the merits and demerits, you have to look into that and make the selection. Finally, everything is going to be govern by the cost. So, that also has to be taken into account when you make the selection.

(Refer Slide Time: 38:13)

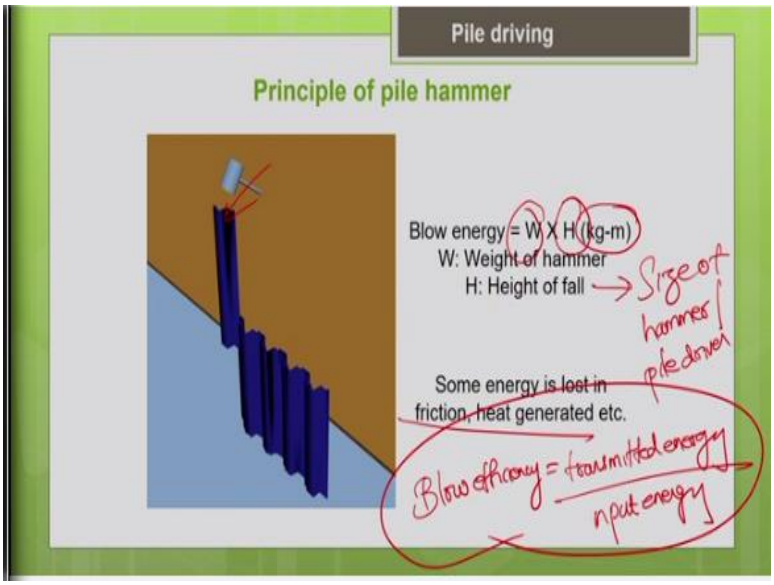


So, I have just given you a brief overview about the pile types, because we are going to spend more time to learn about the pile driving equipment in this particular course, that is why I have limited the time spent for the types of piles. So, let us now see what are the piling equipment needed. So, the pile hammers are the piling equipment, so they are pile hammers are not only the piling equipment, we need a lot of supporting equipment for the pile driving operation.

So, like you need the cranes to hold the pile and the pile hammer and also to hold the lead, everything in the right position for holding it and lifting it we need lots of supporting equipments. Everyone knows we use a pilling equipment particularly during the construction of the foundation or the basement, that is during the ground engineering phase.

So, you can say this usage of pile driving equipment in many civil engineering works, particularly during the ground engineering phase. And this foundation equipment includes not only the pile hammer, but also it includes the equipment to lift and position the piles and guide the piles during the installation. So, a lot of equipments are involved, we will be discussing that in the next lecture in detail.

(Refer Slide Time: 39:31)

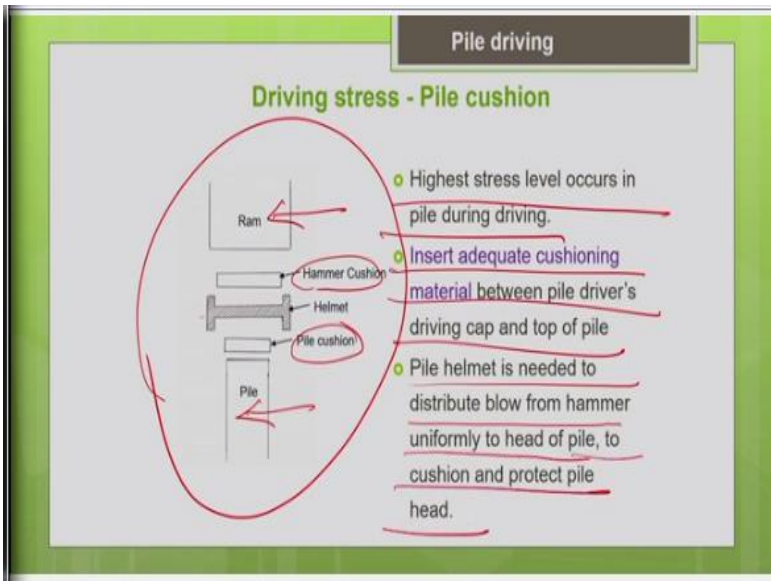


First let me introduce to you what is the basic principle of pile driving. So, it is just like how you drive a nail into a wall with a hammer, the same way you are going to drive a pile into the ground with a hammer**.** So, you are going to blow the hammer on the top of the pile, so what is the blow energy? So, it is going to depend upon your weight of the hammer and the height of the fall of the hammer, so that is what is going to give you a blow energy in Kg meter.

So, this is how the size of the hammer or the pile driver is commonly pile driver or pile hammer it is commonly expressed in terms of blow energy it can deliver. Obviously, it depends upon your weight of the hammer and it depends upon the height of the fall. So, one thing we know it already is the entire energy what you deliver it is not going to be transmitted for the driving operation.

Because some will be lost in friction, some will be lost in the heat generated and some will be lost in the rebound of the hammer. So, only some portion of the energy maybe transmitted, so that is what is called as blow efficiency. Blow efficiency is nothing but it is a ratio of transmitted energy to the input energy. So, we always prefer to maximize this blow efficiency, so that will help you to maximize your productivity.

(Refer Slide Time: 41:01)



So, everyone knows particularly the precast piles or likely to be subjected to more amount of stress while driving it**.** They are subjected to more amount of handling stresses as well as when you drive the pile into the ground they are subjected to more amount of driving stresses. That is why all the stresses should be taken into account when you design your pile**.** So, highest stress across in the pile mainly during it is driving than when compare to during it is service life.

So, mainly during the driving it is being subjected to more amount of stress. So, how to control the driving stress? So, the commonly adopted method is, we have to introduce some cushioning material between the pile and the bile hammer so that is a basic thing we can do it. Particularly for the concrete piles as you know, concrete piles are weak in tension and they are more brittle.

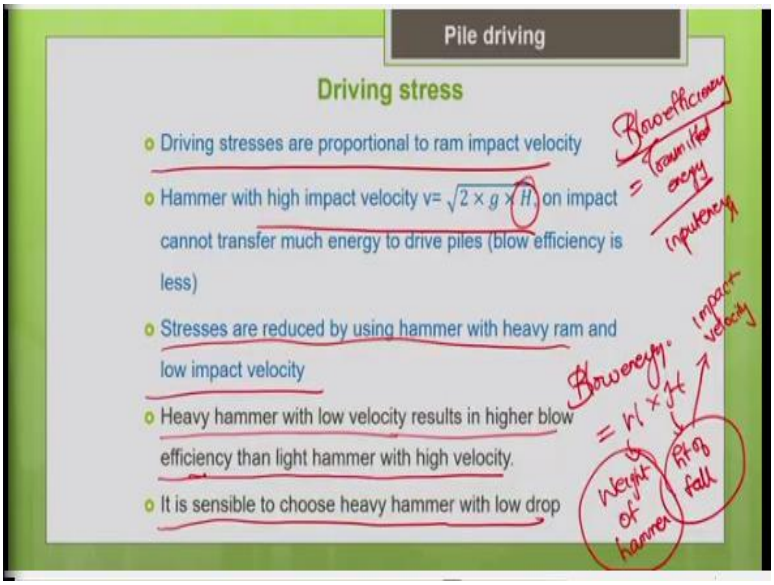
They are likely to be shattered very easily when you subject it to a very high impact, that is why we have to protect the concrete pile from the driving stress by using adequate cushioning material. So, commonly used cushion is wood timber cushion so you have to choose a sufficient thickness depending upon the length of the pile needed, so we should never go below 10-centimeter thickness**.**

And we should replace the cushion at regular intervals as gets worn out. So, insert adequate cushioning material between the pile driver cap and the top of the pile. So, this is a common setup

which you can see to control the driving stress, so why we can see this is your pile and this is your hammer. So, you have two cushions, one is your pile cushion, other one is your hammer cushion.

And there is also a H shaped helmet which helps you to distribute the load uniformly over the head of the pile. So, that there is no stress concentration at a particular point on the pile head, so we can distribute the stresses uniformly using this arrangement. So, the pile helmet is needed to distribute the blow from the hammer uniformly to the head of the pile to cushion and protect the pile head. So, this is what is a common arrangement we follow for the now protection of a concrete piles.

(Refer Slide Time: 43:09)



So, another important guideline which you should keep in mind to control the driving stress is, the driving stress is will be very high when the impact velocity is high, that depends upon your height of fall. So, as everyone knows the blow energy is nothing but your product of W into H, W is your weight of hammer and H is your height of fall or the stroke.

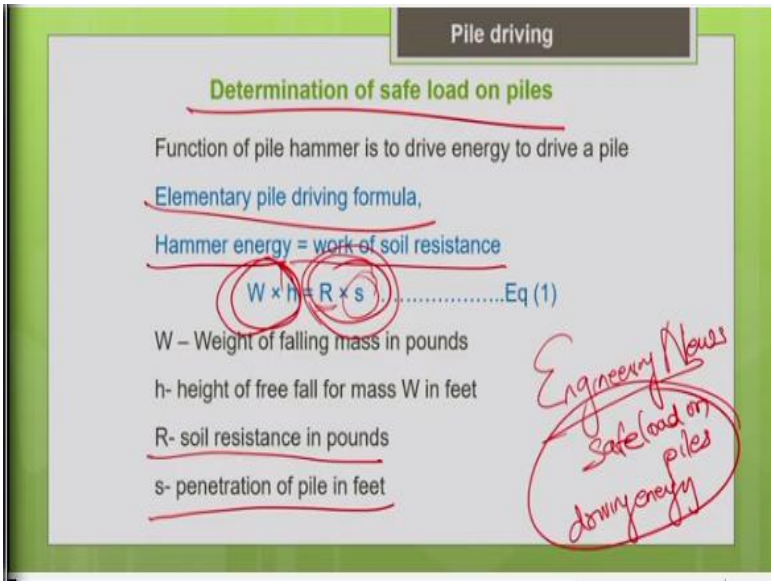
So, if you want to increase the blow energy of your pile, it is preferable to increase the weight of hammer but do not increase the height of fall. Because if you increase the height of fall this will increase your impact velocity and your pile head is subjected to lot of stresses**.** This may result in damage of your pile, if you increase it impact velocity, that is why it is preferable to go for heavier hammer and shorter stroke, so that is what is discussed in this slide.

So, the driving stresses are proportional to the ram impact velocity and your impact velocity depends upon your height of fall v = $\sqrt{2gH}$, H is your height of fall. So, that is why and the studies of found that your blow efficiency already we have discussed what is blow efficiency. Blow efficiency is nothing but the ratio of transmitted energy to input energy, so this will be high if the height of fall is this.

So, the blow efficiency is going to be maximum when the height of fall is less. So, we have to reduce the stress by using hammer with heavier ram and low impact velocity. So, heavy hammer with low velocity results in higher blow efficiency than light hammer with high velocity. Hence it is sensible to use with heavy hammer with low drop, so basically if you want to increase your blow energy better go for heavier hammer**.**

But do not increase a height of fall, particularly for the concrete piles which are weak in tension they are easily likely to get shattered if we increase the height of fall. So, there is a restriction on the height of fall for the concrete pile, so we have to follow that. And reduce a height of fall and increase weight of hammer to get to your desired blow energy, that is a right strategy. And that will also increase your blow efficiency, that is what is proved in earlier studies that the transmitted energy is more if you reduce the height of fall and increase your weight of hammer.

(Refer Slide Time: 45:51)



So, now let us see with how to determine the safe load on the piles? As a piles are likely to be subjected to more amount of stress during driving. We need to determine what is the safe load allowable on the pile that is very important. There are very many popular relationships of formulae which have been derived already in this context. We just go into discuss one such formula called as engineering news formula, it is very formula, engineering news.

To determine what is a safe load on the piles and also you can find what is the driving energy needed for the pile, both these since I can determine from this engineering news formula. And this is basically derived from the elementary pile driving formula which is nothing but your hammer energy equal to the work of soil resistance. That means what is the function of a pile hammer, it is going to offer you the required blow energy to drive the pile into the ground**.**

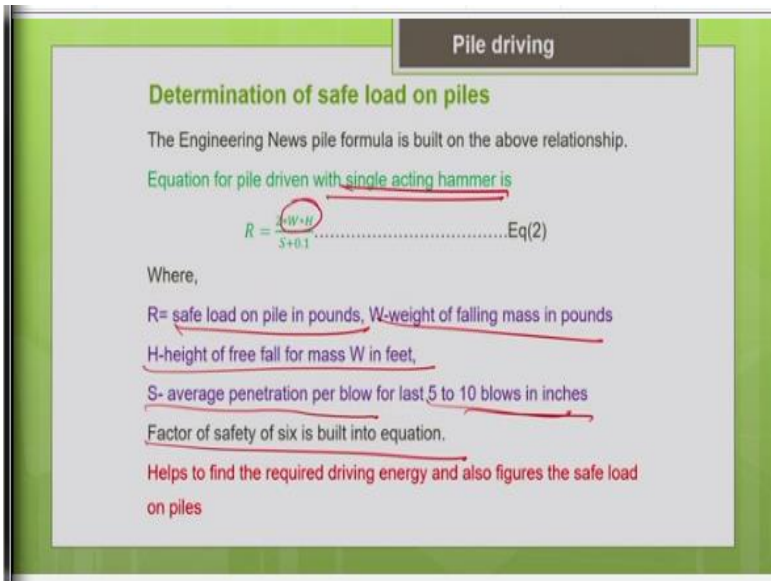
So, when you drive the pile into the ground, the pile has to overcome this oil resistance and make the desire depth of penetration, that is a work done**.** So, hammer energy is nothing but W into h and the resisting energy is nothing but R into s, what is R? R is a soil resistance in the pounds and s is the penetration of the pile in feet. So, basically you have to blow the hammer on the top of the pile so you offer the blow energy and get the work done.

Hammer energy = work of soil resistance

$$W \times h = R \times s$$

So, what is the work done, you have to overcome the soil resistance and do the desire penetration for the pile so that is what is the work done. So, hammer energy is equal to the work of soil resistance, that is nothing but the product of the soil resistance and the product of the penetration of the pile in the feet. So, from this elementary formula driving a formula.

(Refer Slide Time: 47:49)



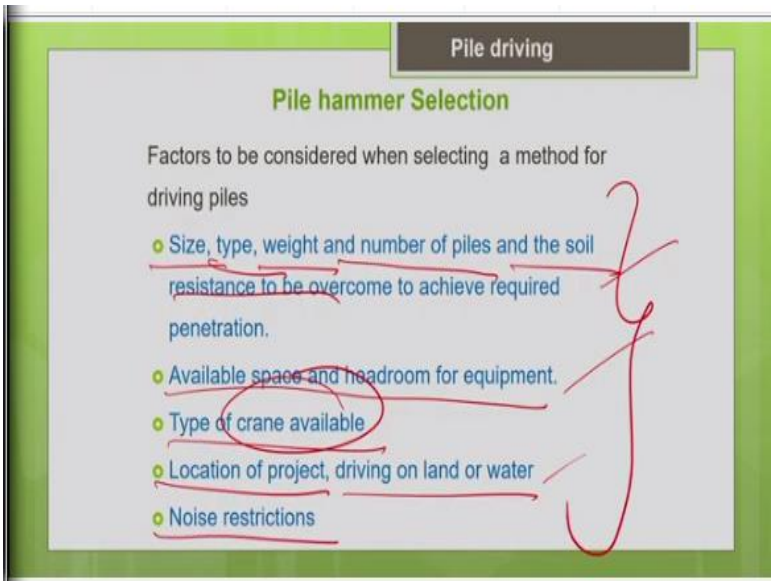
The engineering news formula have been derived which is commonly accepted formula to determine the safe load on the pile. This is nothing but 2 w H by S + 0.1 and this is for single acting hammer, if it is going to be a double acting hammer where the mechanism is different, the formula has to be modified**.** So, the main objective is introduce to you that there are many relationships available to help you to find what is the safe mode available on the pile for different types of hammers you can find different relationships available**.**

$$\mathbf{R = \frac{2 \times W \times H}{S+0.1}}$$

And you can make you suffer**.** So, basically in this formula they have incorporated a fact of safety 6, that means 6 times load will be supported by the pile. So, R is the safe load on the pile in pounds, w is the weight of the hammer that is a falling mass in pounds, H is a height of free fall for the mass w in feet and S is a average penetration per blow for last few blows say 5 to 10 blows in inches, so this is a formula derived for single acting hammer.

So, if you want to determine the safe load on the piles or if you want to know the desired driving energy needed, you can make use of this equation.

(Refer Slide Time: 49:03)



So, now let us see what are all the basic factors which governs the pile hammer selection**.** So, obviously we have to select the pile hammer depending upon the type of a pile**.** So, what will be the size of a pile, weight of a pile according to that you have to choose a weight of the hammer. So, the common guideline is your weight of the hammer should be at least equal to the weight of a pile that is a common guideline, ideal case**.**

But if the concrete piles are going to be very heavier and those equal weight hammers are not available in the market, then at least select the hammer whose weight is equal to one third of the weight of the pile**.** So, basically weight of the pile, your size of the pile and the material type all these things are going to affect your selection of a hammer. Because the hammer which is select for your steel pile and the hammer which is select for your concrete pile will be different.

Because concrete piles are easily likely to get damaged, so that is why we have to be very careful in selection of hammer for the concrete pile. So, when you discuss about the different types of hammers you will understand these factors better. I am just introducing these factors to you. So, in the next lecture after we discussing detail about all the types of pile hammers we will again discuss how you are going to select the pile hammer for a particular soil type and for a particular pile type so**.**

So, what are the guidelines will be discussing again, these are just a brief overview before we move onto part 2**.** So, you know that pile hammer selection is going to depend upon the size of a pile, type of a pile that is material type, the weight of a pile and how many piles you are going to drive the productivity needed the project time schedule say everything is going to govern.

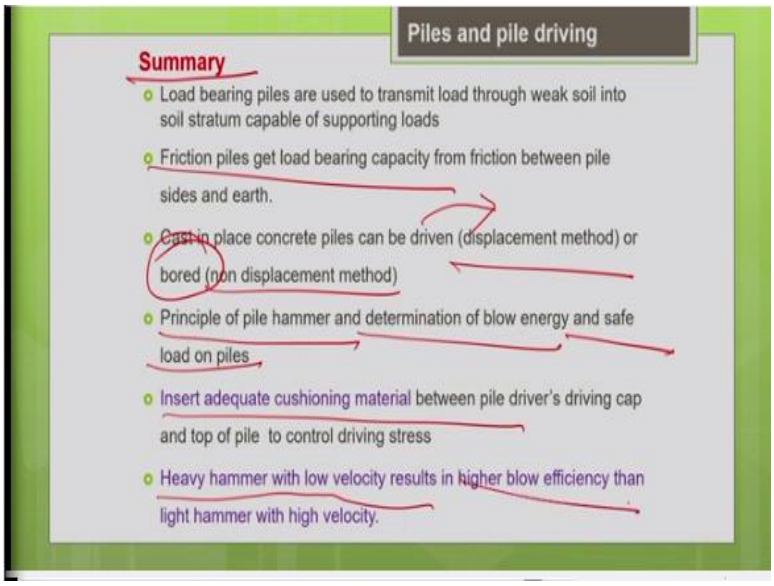
And the important thing is soil type, whether it is going to be very hard terrain condition. The high frictional resistance or a loose soil with a less frictional resistance all these things will decide your hammer selection. Because accordingly you need a blowing energy requirement will vary. And as you know for this piling process we need lot of supporting equipment like crane to hold the pile, to hold the hammer everything in position and to lift it**.**

So, we need whether the available space and headroom is available for the equipment we need to check. And based on the type of crane available, the crane should have the lifting capacity, sufficient lifting capacity, lift your pile, to lift your hammer and even lift your need which will help you to hold everything in proper alignment. So, you should have sufficient capacity, location of a project whether you are going to do the driving operation on land or in water.

Say if it is going to be in water you may need to have some equipments with closed coverings. Noise restrictions, say you know that when you drive the pile into the ground with a hammer, it is going to produce a lot of noise**.** So, if you are going to do the driving operation in a residential area pr near a residential structure or near hospitals**.** So, there will be restriction on noise.

So, in that case we have to select the method which will produce relatively less noise, we have to go for silent pile driving methods like vibratory methods**.** So, we will see what is that later so there are so many factors which governs a selection of your pile hammer.

(Refer Slide Time: 52:27)



So, we have come to the end of this lecture, let me now summarize what we have discuss so far earlier. So, we have discussed about different types of piles, so classification based on it is use, based upon the load transfer, based upon the material type and based upon the course of fabrication. So, based upon the installation process from different perspectives we have classified the piles.

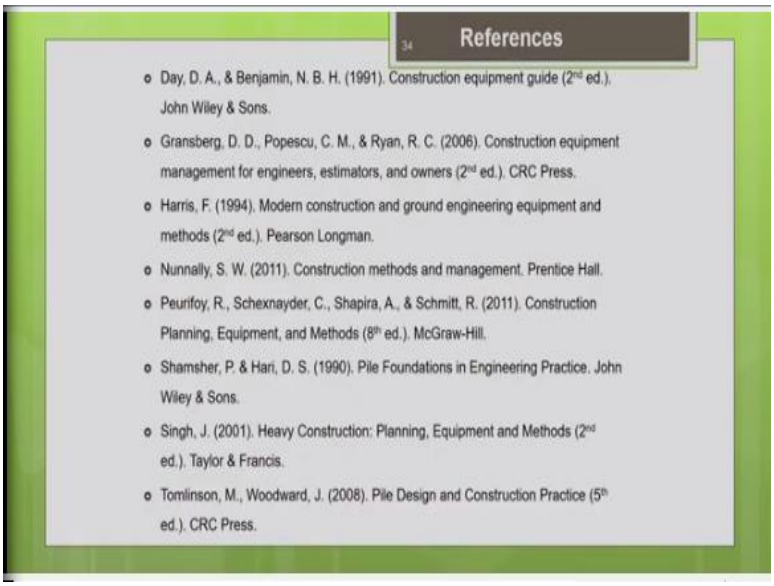
So, based on load transfer, so the load transfer can be occurring either to the end then we called as an end bearing pile or it can be through the friction between the surface of the pile and the surrounding soil, then we call it as a friction pile. then cast in place concrete piles based upon the displacement it is going to result the create to the surrounding soil you can call it as a displacement method or you can call it as a non-displacement method**.**

There are two approaches by which you can go for cast in place concrete pile making either you can go for driving method with hammers or you can go for boring method. So, we have discussed the principle of the pile hammer and how to determine the blow energy of the hammer because that is going to define the size of a hammer and how to determine the safe load on the piles.

And how to control the pile grain stress we have to insert adequate cushioning material between the pile and the hammer particularly for the concrete pile is very important to protect the pile head from the damage. And another important guideline you should always keep in mind is it is preferable to go for heavy hammer with low velocity. So, we should go for a shortest stroke, so

that will result in higher blowing efficiency and it will also protect your the concrete pile from damage due to impact.

(Refer Slide Time: 54:11)



So, these are the important references which I have referred for this lecture. In the next lecture as I mentioned earlier we will be discussing about what are all the different types of the pile hammers available, their mechanism**.** And how to make the selection of the pile hammer according to the pile type and according to the soil type**.** So, how to make the selection? That is what we are going to discuss in the next lecture, thank you.