Construction Methods and Equipment Management
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Lecture - 19
Lifting Equipment – Cranes (Part 2)

Hello, everyone. I welcome you all to the lecture 19 of this course construction methods in equipment management and today's lecture, we will be discussing about tower cranes. So, in the last lecture, we have discussed about the different types of mobile cranes like lattice boom crawler mounted crane, lattice boom truck mounted crane and truck mounted telescopic boom crane.

So, we have classified the mobile cranes based on the mounting, based upon the boom type and we have discussed the merits and demerits of different types of cranes. Now, in today's lecture, we will be discussing specifically about the tower cranes.

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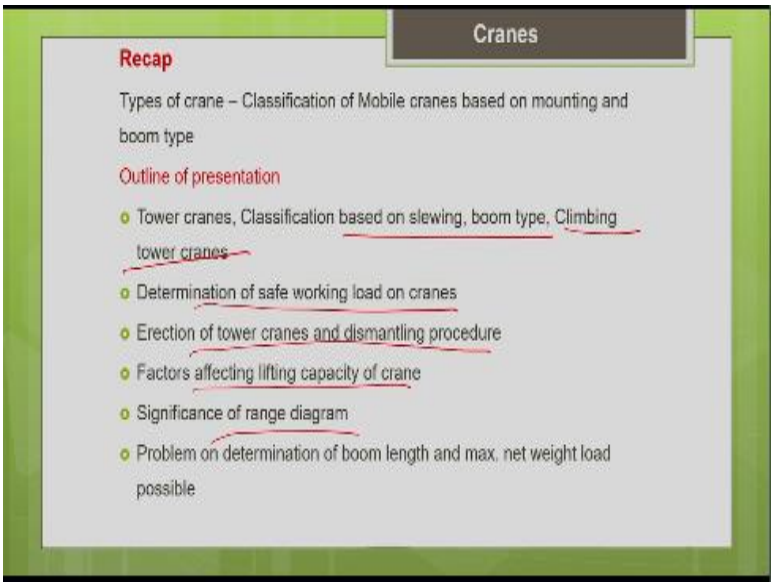

So, what are the different types of tower cranes? So, classification based on the method of slewing of tower crane the method of the boom type and about special tower cranes like climbing tower cranes, its application and all those things will be discussed today. And we will also see how to determine the safe working load on the crane for the tower cranes and we will see what is the erection procedure and dismantling procedure for the tower cranes.

And what are all the factors which affect the lifting capacity of the crane will also be discussed. I will highlight you the significance of the crane range diagram and we will work out a problem on determination of boom length of the crane for the particular project. For a particular working range, how to determine the boom length needed? And also want to see what is the maximum net weight with a weight load possible for a particular crane.

So, these things will be discussed in the today's lecture. So, I hope everyone might have seen tower cranes already.

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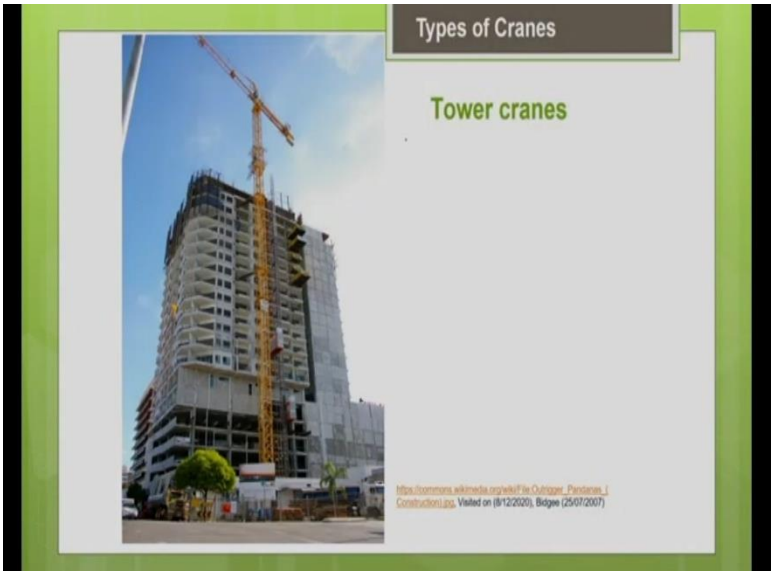

So, this is a picture showing the tower crane. So, it is a very special type of crane more commonly used nowadays for all the high-raised buildings, skyscrapers and big infrastructure projects. You can commonly see this tower crane usage. So, you can see how closely the tower crane is placed near the structure and it is braced at appropriate intervals to the structure. So, that it can take the overturning moment.

So, the overturning moment will be transferred to the structure for the stability of the crane. So, particularly when the free-standing height of the tower crane is very high, we need to take the support from the nearby structure. So, we need to brace it to the structure to transfer the load to the structure for the safety of the crane. So, when do we generally go for this tower cranes?

Basically, in congested areas where the mobility of the mobile cranes is not feasible, we go for the tower crane. So, another important requirement may be; sometimes, we need to reach a very high vertical reach. So, the height needed, the height requirement will be very high which is not possible to be achieved with the conventional mobile cranes. In that case, we can go for the tower crane because tower crane gives you the advantage of unlimited height capability. So, that is another advantage of tower crane.

And you can have a very wide working range with the tower crane because you can place it very close to the structure and you can even place it inside the structure. So, that facilitates you to have a better working range with the tower crane. It all depends upon the position of the tower. So, let us see where this tower crane is commonly used.

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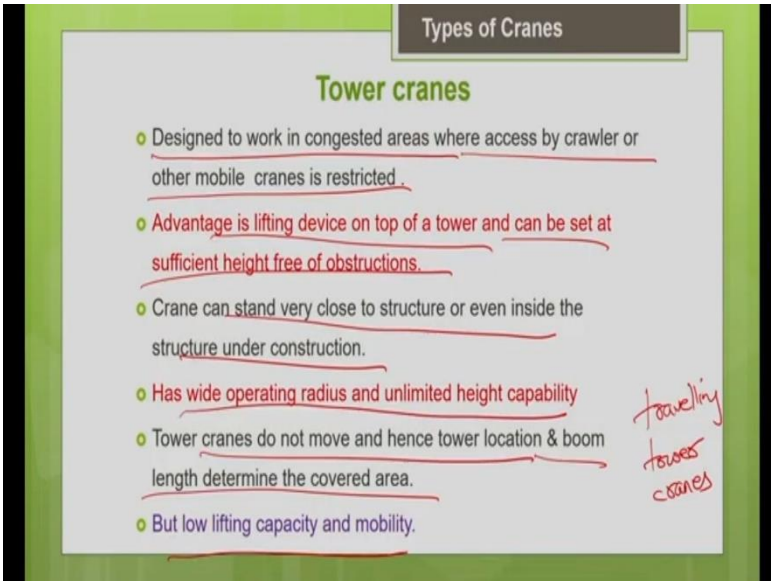

So, this is mainly designed to work in congested areas. Where the access by the other mobile planes like crawler mounted cranes is restricted, you can go for the tower crane. So, main advantage is, your lifting device is on the top of the tower and it can be set at a sufficient height free of all abstractions. So, you can have a very high vertical reach, unlimited height capability as I mentioned you, is possible with the tower crane.

And you can place the crane very close to the structure or even inside the structure at the construction that will help you to have a better working range. As wide operating radius, unlimited

height capability, these are all the merits of the tower crane. So, basically the tower cranes mobility will be limited. Most of the tower cranes which you commonly see are only static tower cranes. They do not move.

So, where you decide the location of the tower, we should be very careful in deciding its location because that is only going to decide your working range possibility. So, the boom length determines your covered area. So, other than the static tower cranes, you also have the travelling tower cranes like crawler mounted or rail mounted.

In certain project sites where you need to mobilize, where you need to have the mobility of your tower crane to various locations within your site, say, they prefer to have the rail track laid and we can have the tower crane moving over the rail track. So, sometimes, the cost of erection and dismantling of the tower crane is going to be very high when compared to the cost of the rail track. So, that is why in that case they go for the rail mounted tower crane. So, that they can reduce the cost of erection, dismantling.

The demerit is low lifting capacity when compared to mobile crane because it is lifting a great height. So, generally the lifting capacity will be lower for the tower cranes when compared to the mobile planes which is operating from the ground and the mobility is also mostly as I told you, they are mostly static; their mobility is limited.

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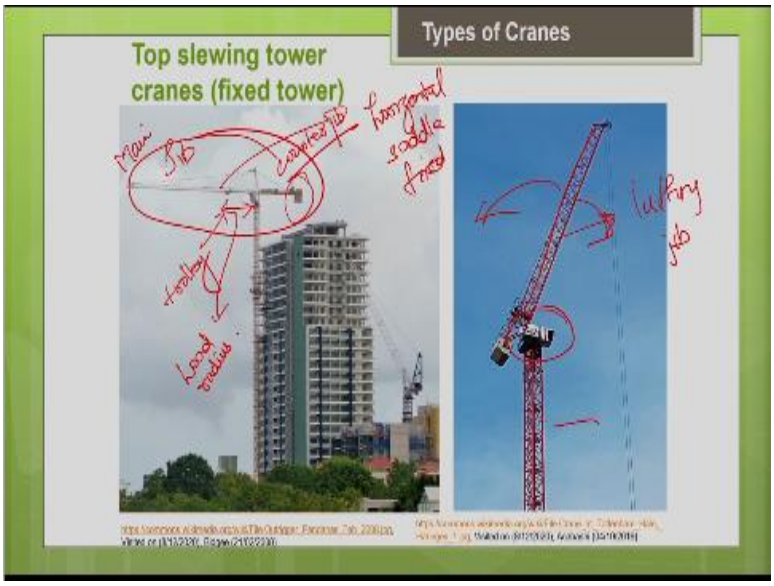

So, based on the method of slewing, so, you can classify the tower crane into top slowing tower crane and bottom slewing tower crane. In top slowing tower crane as you can see the picture, you have the turn table or the slewing ring at the top. The tower will be fixed. The tower is fixed that is not going to slew only the top portion your turn table, your jib, this is your main jib and this is your counter jib.

This is your main jib which carries the weight. Here, you can see the trolley. So, this trolley, you can travel along the jib. It can move or travel along the jib that is how you can vary your load line and the load radius. So, by this trolling, you can vary the load radius. So, basically, the top portion will move. The top slewing tower, you can see that the turntable is at the top, the operator cab and the main jib, the counter jib, everything will slew but the tower will be, the vertical tower is fixed.

So, and you can see that it is properly braced to the structure at regular intervals as I told you. From the safety perspective, we have to brace it to the structure to transfer the load to the structure and you can see that in the counter jib, you have the counterweights to balance. Also, you have the counterweights at the base also. For balancing the moments, you need to put the counterweights in the counter jib as well as at the base.

So, basic thing is your top slewing means the top portion the entire top portion will rotate. It can give you 360-degree slewing. So, here the jib is fixed. This is kind of horizontal jib. We call it as

horizontal jib or saddle jib or fixed jib. That means you cannot change the angle of inclination of this jib but here, this one is called as a luffing jib. That means you can change the angle of inclination of the boom.

You can change the angle of inclination of the boom that is how you change the load radius in this case. So, but both the cranes are top slewing here. The turntable is at the top and only the top portion will slew. The tower will be fixed.

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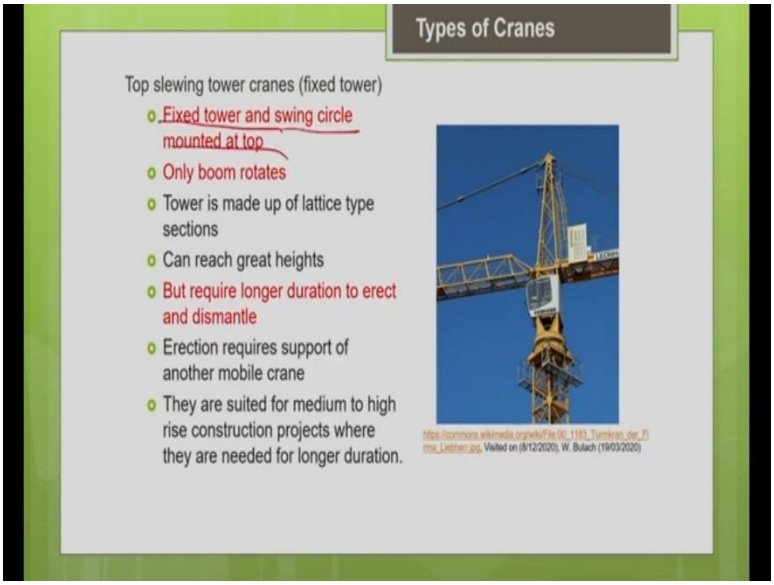

So, top slewing tower cranes has fixed tower and a swing circle mounted at the top. You have the turntable at the top. Only the boom will rotate. Your turntable, your operator cap, boom that means your main jib and the counter jib will rotate and the tower is made up of lattice type sections. I hope, you already know about lattice type sections. You can see the steel pipes connected. So, these are lattice boom sections.

They can reach great heights. Generally, these top slewing cranes are used for greater heights. The mobilization of the crane to the project site, erection and dismantling takes more time for this lattice boom cranes. That is why if you need this crane for a longer duration of the project site, it is going to be economical. It requires longer duration to erect and dismantle and for the erection of this crane, we need the support of another mobile crane.

Another mobile crane is needed for erecting and dismantling this crane. So, they are generally suited for medium to high-raised construction projects where they are needed for longer duration. Longer duration, this can be justified. The erection cost, dismantling cost, mobilization cost can be justified if you need the crane for a longer duration at the project site. So, another important thing to be noted is all these tower cranes should have a proper foundation.

You should have a proper foundation. You should design its foundation very carefully, heavy reinforcement.

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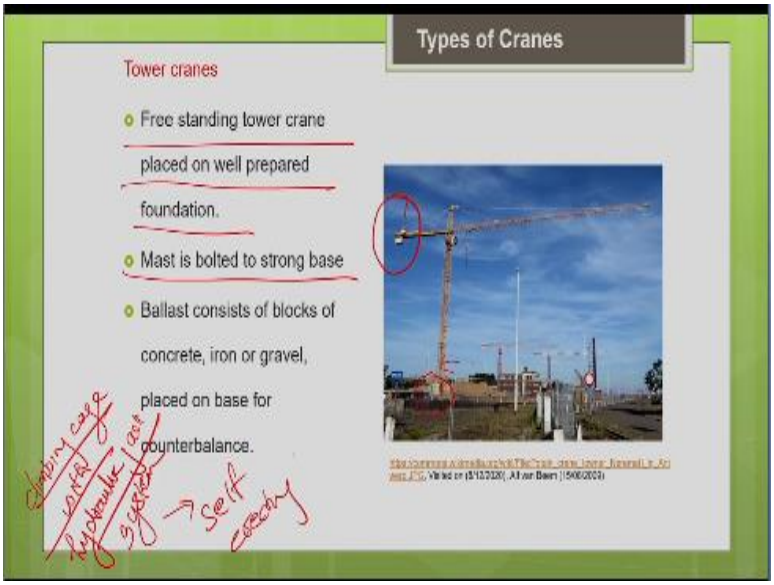

So, that the load can be transferred through the travel to the foundation. You should go for heavy foundation and the tower sections will be bolted on with collars and external bolts to the foundation. You can see that. That is what is summarized in this slide. The free-standing tower crane is placed on well-prepared foundation. The mast is bolted to the strong base and you should put the appropriate counterweights for the stability of the crane.

The counterweight is at the counter jib at the top as well as at the base. So, what are the common counterweights we use? Generally, the blocks of concrete, iron or gravel. So, they are placed for the counterbalance for the resisting moment. So that, your overturning movement can be balanced with this resisting moment. So, nowadays, we have even for this top slewing crane and we have this climbing cage.

Climbing cage or climbing collar with hydraulic jack system. So, with that facility in modern cranes even if it is top slewing tower crane, the erection is made now fairly easy because with the climbing cage crane without much assistance from another crane, they are self-erecting in nature, self-erecting. So, we will discuss about the erection of this tower crane with the climbing cage later.

So, but what you need to know is nowadays, in the modern tower cranes even if it is top slewing, it comes with the climbing cage or the climbing collar which helps you to do the self-correcting process which is relatively easier and faster.

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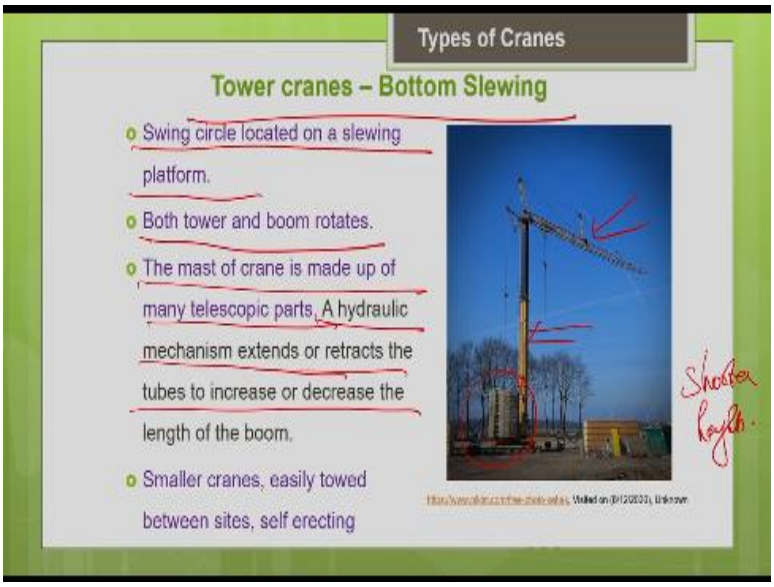

Now, let us discuss about the bottom slewing tower crane. So, in the bottom slowing tower crane, you can see that the slewing ring, the turntable is at the bottom. So, the slewing circle is located on this slewing platform. Here, the entire structure will rotate that means tower will rotate and the boom will also rotate but you can see that there is no counter jib and counterweight is on the top. All the weights are placed at the base only.

So, these are generally smaller cranes because as the tower itself rotates, you cannot brace it to the structure. So, if you want to go for greater height, you have to brace it to the structure. You have to get the support from the nearby structure. For the stability of the crane, for a free-standing height

of greater than say, 120 meters, we have to definitely go for brazing to the nearby structure but since the tower is also rotating, it is not possible to have the brazing with the nearby structure.

Hence, there is always a height limitation for this particular type of bottom slewing tower crane. So, these generally are designed for shorter heights only. They are designed for shorter heights but the main advantage is, it can be easily mobilized to the site because there are many the hybrid varieties available like you can easily fold it and take it on the public highways or foldable type or telescopic type where you can just extend or retract the length of the boom.

All these provisions are now possible which the facilitates see, easy mobilization and easy erection and dismantling. So, that way this is going to be very easier if you need the crane for a shorter duration at the project site, this will be the right choice. So, in this case, both the tower and the boom rotate, the mast of the crane is made up of many telescopic paths. A telescopic model is also available.

With hydraulic jack mechanism, you can either extend or retract the tubes to increase or decrease the length of the boom. So, you can increase it or decrease it with the telescopic mechanism as we discussed earlier for the telescopic boom crane, the same way. So, these are generally smaller cranes, easily towed between the sites and they are self-erecting in nature. So, their mobilization and erection are very easy when compared to the top slewing tower crane but the demerit is, there is a height restriction.

You cannot go for height beyond 100 meter or 120 meters because beyond 120 meters, we need support from the nearby structure that cannot be done for the rotating tower.

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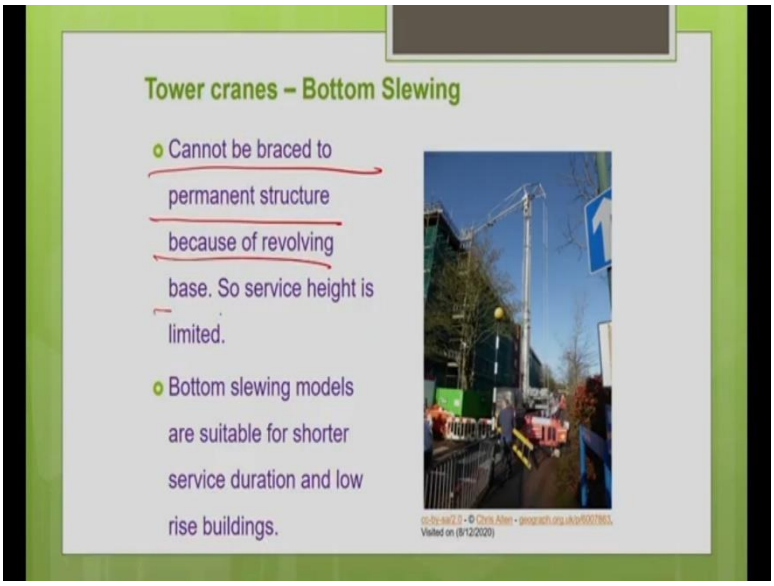

So, that is what is discussed here. It cannot be braced to the permanent structure because of the revolving base. So, the service height is limited. So, bottom slewing models are suitable for shorter service duration and low-rise buildings. For low rise buildings, you can generally go for this particular model.

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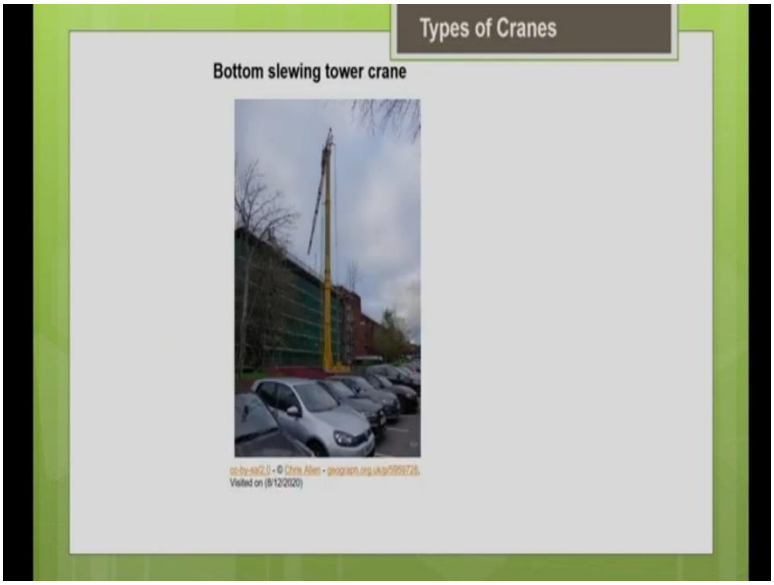

This is again a picture of the bottom slewing tower crane.

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So, as I told you, there are many hybrid models available nowadays which can be easily mobilized to the project site, foldable type which can be taken on the public highways also. You can take it on the public highway to and mobilize it to the project site. So, you have to use the outriggers since whenever it is tire mounted, you have to definitely go for the outriggers. You can see that to enhance the stability and the lifting capacity of the crane.

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So, after you mobilize it to the site, you can easily self-erect. You can see the self-erection mechanism with hydraulic jack system. So, these are very simpler and easier cranes to mobilize and erect. These are the pictures of the bolted slewing.

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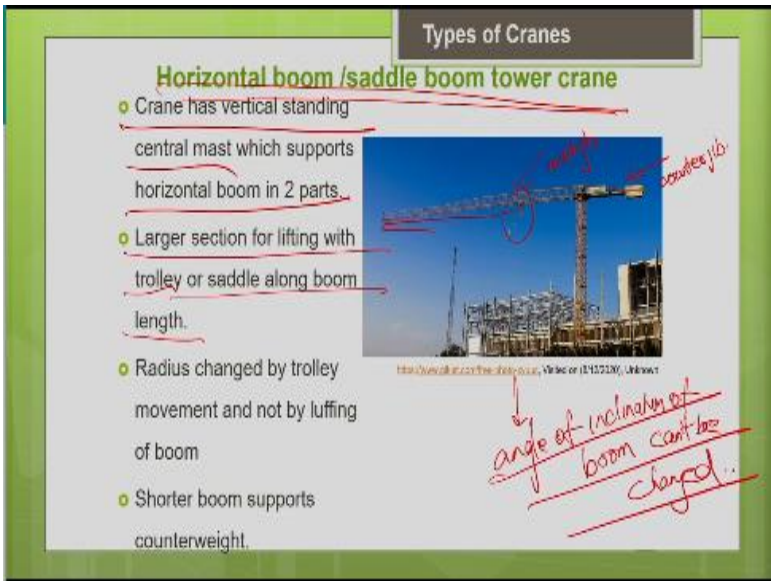

So, next is a horizontal boom or saddle boom tower crane. So far, we have discussed about the classification of the crane based on the method of slewing, top slewing and bottom slewing. Now, we are going to discuss the classification based on the type of the boom. As I mentioned earlier, we have horizontal boom or saddle boom where the boom is fixed, you cannot change the angle of inclination of the boom. Angle of inclination of boom cannot be changed in this case.

So, this is called as a main jib where you carry the load and this you call the counter jib where you put the counterweights and the counterweights are also at the base as I mentioned earlier. So, you can see that the crane has a vertical standing central mast; which suppose a horizontal boom in 2 parts. One is a main jib; other one is a counter jib. The largest section for lifting with the trolley, you can see the trolley here so, or the saddle along the boom length that is called as a main jib. You can change the load radius by the trolling action.

You can move this trolley and thereby, you can change the load radius but you cannot do the luffing operation or change the angle of inclination of boom cannot be changed. The shorter boom that is a shorter jib supports the counterweight. As I mentioned earlier, you have to design the proper foundation for the tower crane.

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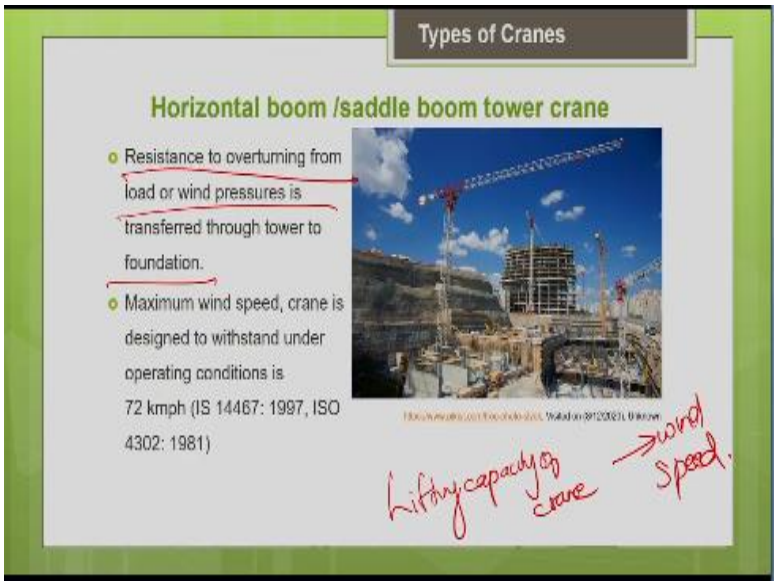

It is very important because your resistance to overturning from load or the wind pressure everything is transferred through the tower to the foundation. So, particularly for the free stranding tower cranes, you should be very careful with the foundation because the entire load is going to be transferred through the tower to the foundation and also, know that the lifting capacity of the crane depends upon the wind speed.

So, generally, when the manufacturer gives the rating, the load rating for the particular crane, he assumes certain conditions that say, for example, mobile crane, he assumes that the surface is level. If it is going to be tire mounted, he will assume that you are going to use outriggers in completely extended form and the surface is going to be level and the air is going to be calm.

So, assuming these conditions only, he would have given the actual rating of the crane but if in your project say, the conditions are going to be different from these ideal conditions then you have to reduce the lifting capacity accordingly. Say, for example, if the surface is not level, then we have to reduce lifting capacity. Say, if it is going to be tire mounted crane; if you are not going to use the outriggers, then you have to reduce lifting capacity.

Say, if the wind speed is going to be high, according to the wind speed, the amount of lifting capacity should be reduced in a proportional manner. So, how much reduction that is guidelines would have been given by the manufacturer? So, the wind speed also should be taken into account

when you design the lifting capacity of the crane that is very important because it adds to the overturning movement.

So, as per the ISO code, we also have the ISO code where the regulations are given. The maximum wind speed, the crane is designed to withstand under the operating conditions is 72 kilometre per hour. So, beyond this, we are supposed to stop the operation of the crane. So, many of the crane accidents happens because of the high wind speed. When the crane operation is continued; when the wind speed is high, many accidents are reported to have occurred.

So, that is why we should note the lifting capacity of the crane according to the wind speed and if the wind speed is very high, you should stop the operation of the crane and when the wind speed is high, you should not apply the brake. You should allow the boom to swing in the direction of the wind. We should release the brake and we should allow it to slewing in the direction of the wind. Otherwise, it will result in the damage of your breaks.

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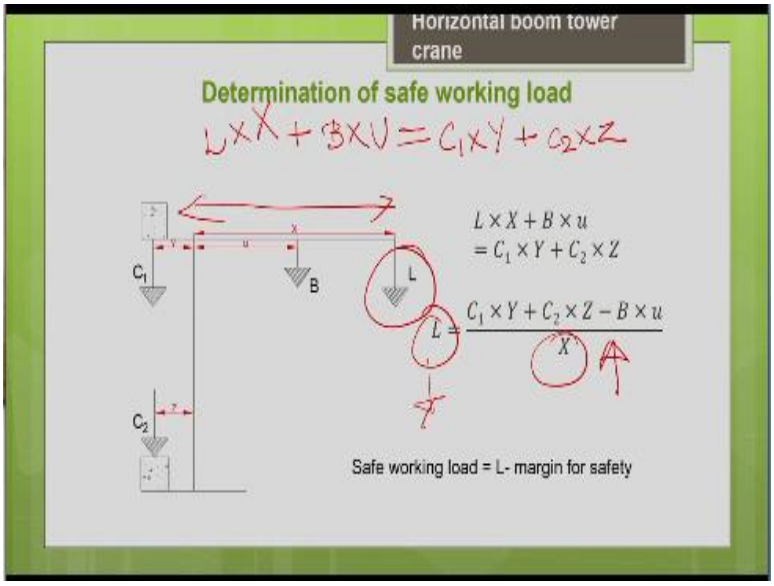

Now, let us see how to determine the safe working load for the tower crane? This is horizontal boom tower crane. So, you can see, we have to just equate the overturning moment to the stabilizing movement to find the safe working load. So, what is the overturning moment here? The load the boom is carrying, here, you can see L into the distance between the load line and the fulcrum point is X.

L into X plus the weight of the boom is B and the distance from the centre of the boom to the point of fulcrum is u. So, these are the thing which adds to the overturning moment because I have not taken the wind load. Equal to the stabilizing moment, the resisting moment is from the counterweights. So, one counterweight is in the counter jib. Other one is at the base. So, C 1 is the weight of counterweight into the distance to the point of fulcrum Y plus C 2 is the counterweight at the base C 2 into distance Z.

$$L \times X + B \times u = C_1 \times Y + C_2 \times Z$$

If you simplify, you will get the L. So,

$$L = \frac{C_1 \times Y + C_2 \times Z - B \times u}{X}$$

So, you can note that as X increases, as the radius increases, your lifting capacity reduces. As the radius increases, your lifting capacity releases. So, that is why at minimum operating radius, your lifting capacity will be more. At the maximum operating radius, your lifting capacity will be less because the stability of the crane is disturbed.

Stability of the crane is affected at higher operating radius when the load line is near the centre of axis of rotation. When the load line is near the centre, you can say that the crane will be more stable. So, lifting capacity is more. When the load line is away from the centre that means; when the radius is more, your stability will be less. So, the lifting capacity will be less.

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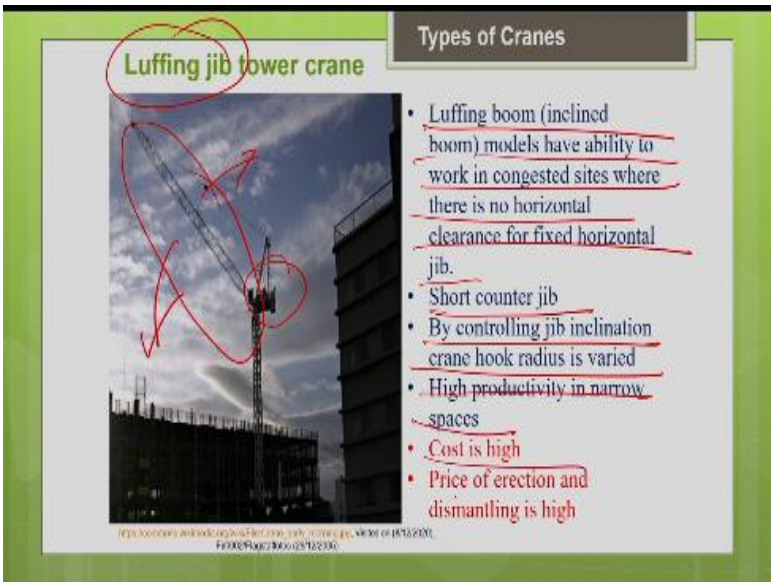

So, we have discussed so far, about the horizontal jib or the saddle boom or the fixed jib crane. Now, we are going to discuss about the luffing jib tower crane. So, luffing jib as the name indicates, you can change the angle of inclination of the boom. You can change the angle of inclination of the boom accordingly you can change the operating radius. So, when do we need this crane?

Basically, when you are working in congested spaces; when you are working near already existing building nearby structure is there; where the fixed boom will not have the sufficient space to move about. When there is a restriction in the space availability, then we have to go for the luffing boom. Luffing boom or the incline boom models are the ability to work in congested sites where there is no horizontal clearance for the fixed horizontal jib and you can note that it will have a shorter counter jib.

The counter jib is shorter. By controlling the jib inclination, the hook radius or the load radius, you can vary. Particularly in narrow spaces, this will give you higher productivity but the cost is high. The erection and dismantling cost are also high for this particular crane.

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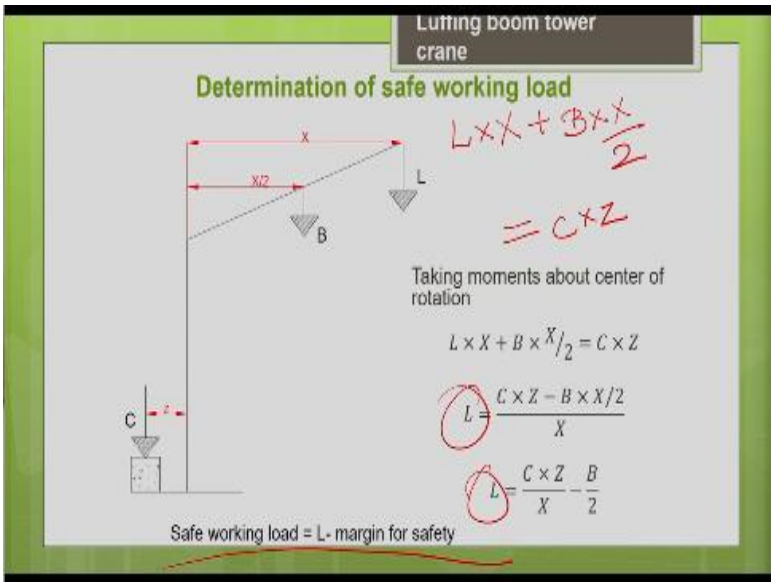

Now, let us see how to determine the safe working load for the luffing boom tower crane. The same way to equate the overturning moment to the stabilizing moment.

$$L \times X + B \times \frac{X}{2} = C \times Z$$

So, to find a safe working load from this L, you have to detect the margin for safety. According to the guidelines, you have to detect the margin for the safety.

$$L = \frac{\mathrm{C} \times \mathrm{Z} - \mathrm{B} \times \frac{X}{2}}{X}$$

$$L = \frac{C \times Z}{X} - \frac{B}{2}$$

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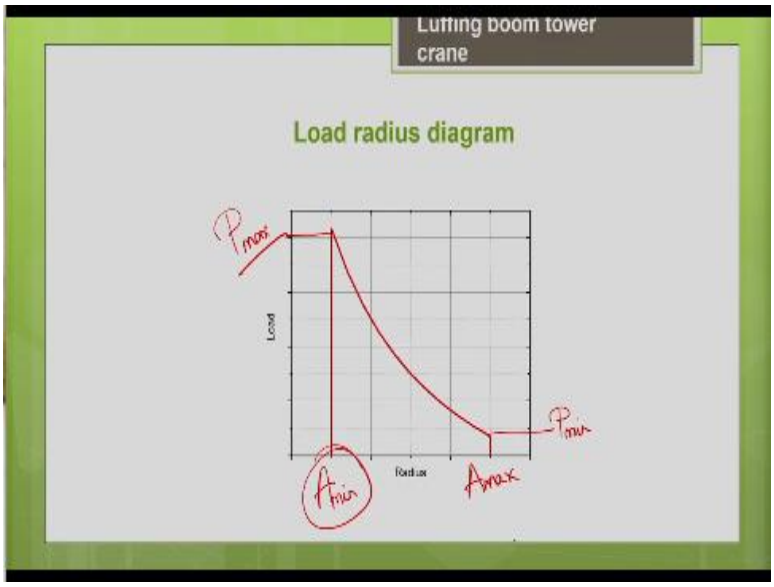

So, if you plot the load radius diagram, you can see that when the radius is maximum say, when the, here, this is minimum radius, this is maximum radius. When the radius is maximum, the load is, the lifting capacity is minimum. When the radius is minimum, the lifting capacity is maximum. You can note that. So, with increase in operating radius, you can see that the lifting capacity gets reduced.

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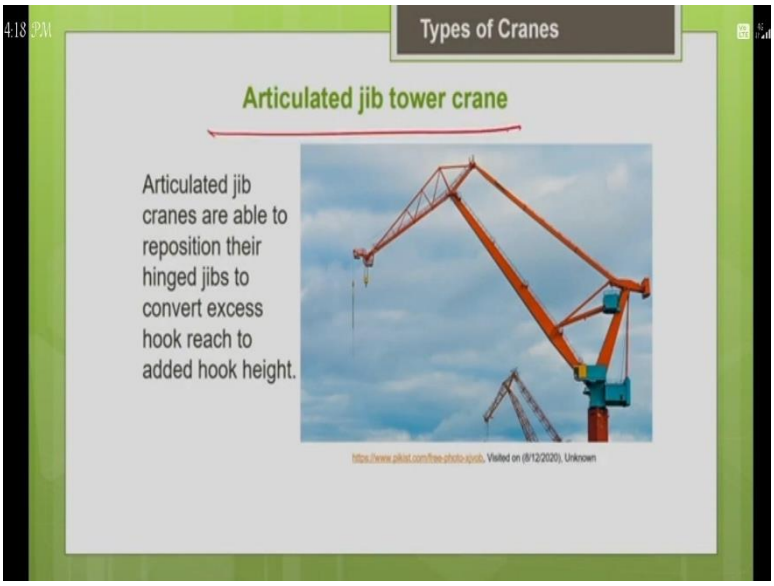

There is another type of jib apart from the horizontal boom, luffing boom. You also have this articulated jib tower crane. You can see the picture. See, these articulated jib cranes are able to reposition their hinged jibs to convert the excess hook ridge to added hook height that means so, you can reposition the jib in such a way that. So, whenever you do not need excess horizontal reach, you can convert the horizontal reach into vertical height.

You can convert it into hook height. You can make the adjustments accordingly. You can just reposition the hinge. So, that the excess horizontal reach can be converted into vertical height. The excess horizontal reach can be converted into vertical height so, according to your requirement but these are also very costlier cranes articulated jibs.

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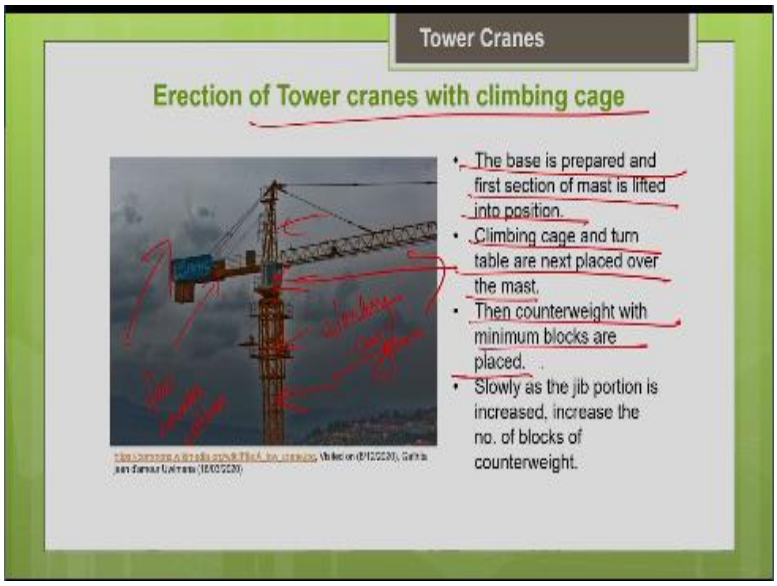

Now, let us see how the erection of the tower crane is done with climbing cage. In modern tower cranes, we have this climbing cage facility which facilitates the self erection process of the crane. So, basically, what you have to do is first, you have to prepare the foundation for the tower cream that is very important. You have to prepare a heavy foundation for the tower crane according to the requirement, put heavy reinforcement and then both the tower sections to the foundation after construction of the first few sections of the tower crane.

Now, what you do is, you erect your turntable or this slewing ring, operator cap and the tower top. For all these things, we need the support of another mobile crane. With the help of another mobile crane, you erect the turntable, climbing cage, this is your climbing cage, climbing cage with the hydraulic jack system. You will be seeing a hydraulic cylinder here which helps the lifting.

So, the first, you put the foundation few sections of the tower mask you erected, bolted to the foundation then erect your climbing cage, your turntable or the slewing ring and the operator cap. And the tower top, you erect it. Then now, you put the counter jib with few counterweights. First, you put few counterweights, then slowly increase the jib portion.

As you increase the jib portion sections, you can increase the number of blocks here; number of counterweight blocks. Now, when this is done, till this, you need the support of another mobile

crane. After this, you can do the erection process yourself with the climbing cage help without the help of another crane. So, that is the advantage of the climbing cage. So, let me summarize.

So, basically first what we do is; the base is prepared with the proper foundation and the first section of the mask is lifted into position with the help of another mobile crane. Climbing cage and the turntable are takes place over the mast. Then the counterweight, there is a counter jib with the minimum blocks are placed, then slowly increase the jib portion and correspondingly increase the number of blocks of counterweight in the counter jib also.

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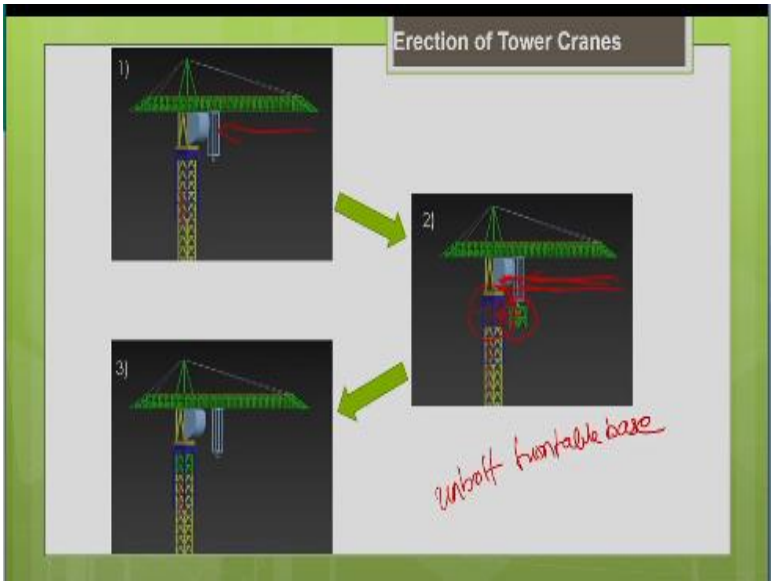

Once this is done, then you can do the self-erection of the tower crane. So, how to do that? First, what you do is, you have to introduce a new section to increase the height of the tower crane with the help of trolling action. You know the trolling rate. There is a trolley here in the main jib. By the trolling action so, you can bring the, you see, here you can see, this is a new section.

The new section is brought closer to the tower with the help of the trolling action. Now, what you do is unbolt your turntable base, unbolt your turntable base, unbolt it and lift it with the hydraulic jack in the climbing cage. This blue colour one is your climbing cage. So, this has a hydraulic cylinder, hydraulic jack system, you can see here. So, now, you unbolt the turntable and lift it with a hydraulic jack. So, that you can create the space to introduce a new section.

You are going to create a space below the turntable. So, that you can introduce a new section below the turntable. Now, once the space is created, now, you introduce a section into this space into this climbing cage. Now, you bolt the new section to the turntable as well as to the remaining portion of the tower. So, that is how the new section is now connected. So, like this, you can keep on adding the sections.

Every time, you have to do the trolling action and bring the new section near the tower and lift the turntable, unbolt the turntable, lift the turntable with the hydraulic jack, then introduce a new section, then again bolt it. Like this, you can keep on adding the section for the erection of the tower crane. This is called as a self erecting procedure. Similarly, if you want to dismantle it, you do the entire thing in the reverse order.

So, you can remove the section one by one with the tower crane. After the desired height is reached with the help of another mobile crane, you can remove the jib and the counter jib portion. That is how they dismantle it with the climbing cage. So, with the climbing cage, the process is relatively easier and the time consumption is also less. We do not need the support of another mobile crane for the entire process of erection. Only for the initial stage, we need the support of the mobile crane.

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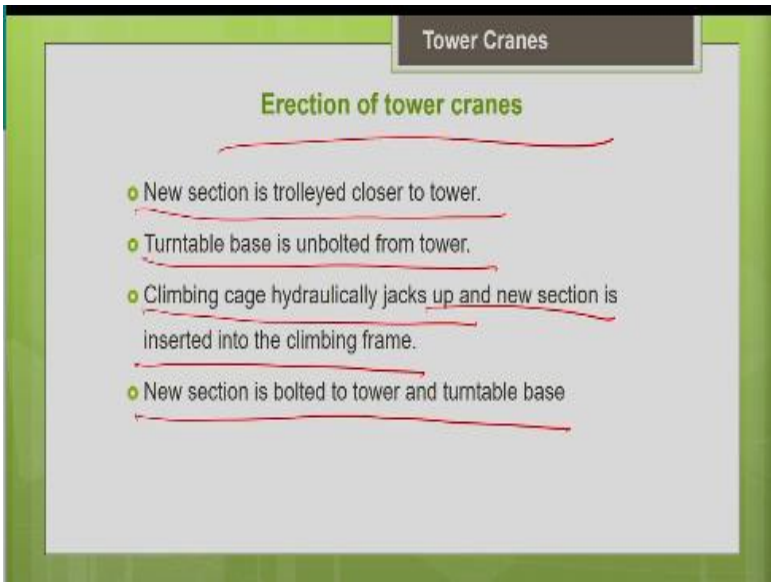

So, let me summarize what we discussed here for the erection of tower crane with the climbing cage. So, first, you bring the new section, it is trolleyed closer to the tower. Now, the turntable base is unbolted from the tower. Climbing cage hydraulically jacks up and a new section is inserted into the climbing frame. The new section is bolted to the tower and the turntable base. So, every time, you introduce a new section below the turntable base that is how you can increase the height of the tower crane.

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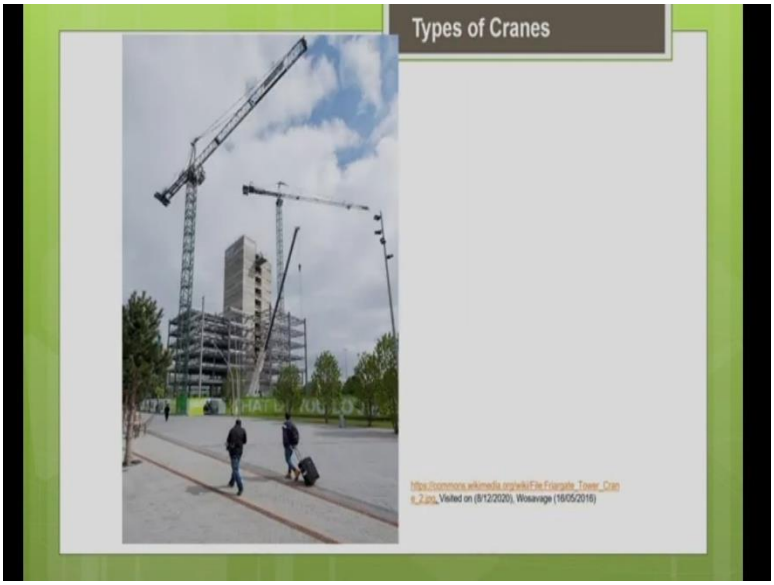

So, always for the erection of tower crane, you can see the mobile cranes are always standing nearby. It will help in the erection of the tower crane.

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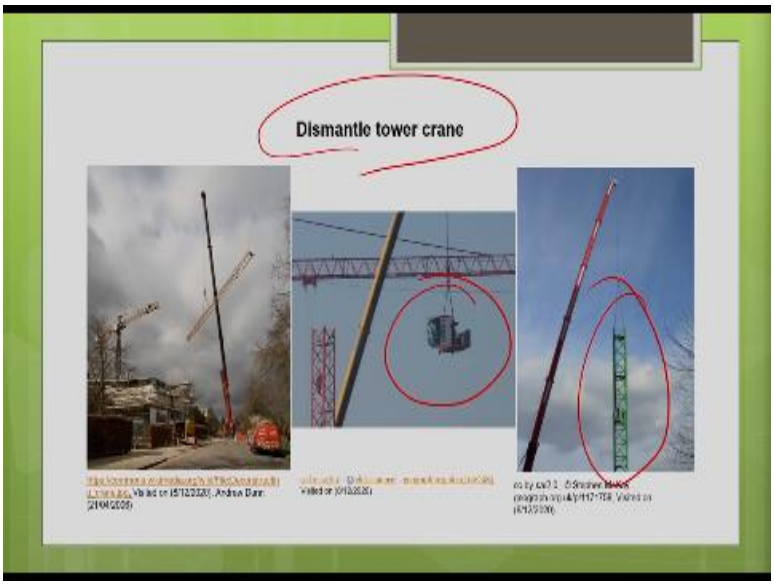

So, dismantling procedure of tower crane, say, if it is going to be climbing cage, it is going to be easy. If there is no climbing cage, we need the support of another mobile crane for the entire process. Say, first, you have to remove the trolley part you have to remove the trolley. So, after removing the trolley, you remove the counterweights. You remove the counterweights then you remove the jib. So, then you remove the counter jibs.

So, after that, you remove the operator cap and the tower top and the turntable, remove that portion. So, turntable with the operator cap and the tower top will be removed. So, after that, we remove all the sections one by one with the help of another mobile crane. So, this is how the normal dismantling procedure of the tower crane goes. You need the support of another mobile crane for the entire procedure if you do not have the climbing cage.

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So, another important thing, you need to know that is the maximum free standing tower crane height permissible is 60 to 120 meter. So, beyond 120 meters, the tower crane should take the help from the structure. You should properly brace it to the nearby structure to transfer the overturning movement to the structure from the stability point of view. So, after 120 meters, definitely should provide the lateral bracing. The crane must be tied to the structure and the construction.

So, even with brazing, you cannot go beyond 300 meters; maximum brace height possible is only 300 meters. Beyond 300 meter even with brazing, it is not allowed from the stability point of view.

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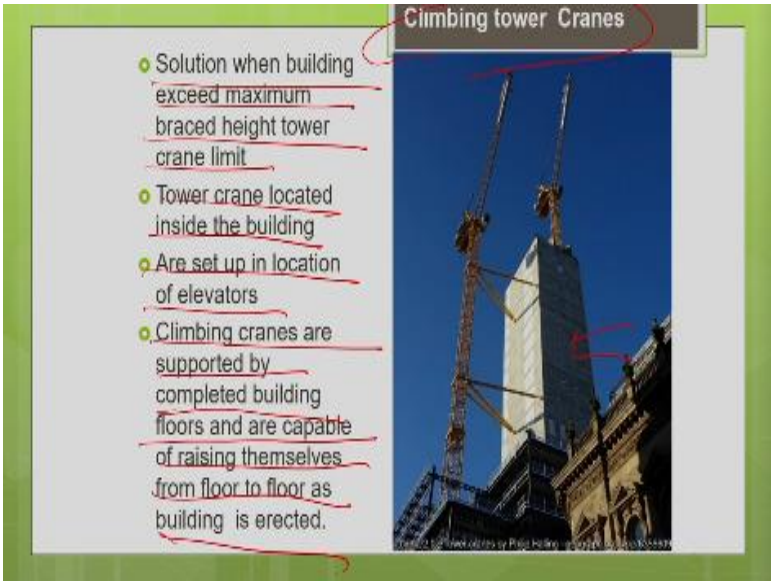

Say, for example, you need a tower crane for a structure which is greater than 300 meters. So, in that case, what is the option available? There are certain special cranes called as climbing tower cranes which can grow along with the structure. These grains are generally shorter but it will grow along with the structure. So, basically, what this climbing tower grains will do is; it will take the support from the actual structure which you are going to construct.

We usually provide it in the opening of the lift or the elevator. So, in that location, you can place this tower crane. Initially to start with, it will take this support or the base from the foundation of the structure, actual foundation of a building. From the foundation of the building, it will take its base. Then as few floors are completed, then what you do is, you detach this tower crane from the foundation of the structure and then on to the desired flow level, you should shift it and attach it with the special collars to that particular floor.

So, that is why when you design this particular structure itself, you should know that it has to support the crane also and then load from the crane also that has to be taken into the structural design of the structure. So, as the structure grows, you keep on shifting the tower crane. You detach it from the particular floor and attach it to a new floor with a special collar arrangement and this is possible with a hydraulic jack system.

So, that is how it keeps on growing and finally, it will stand at the top of the tower. Now, either you can leave it as such for the maintenance purpose or you can remove it. If you want to remove it, what you can do is; if you have a mobile crane which can reach this particular height, then with the help of the mobile crane, you can remove it or if you do not have the mobile crane which can reach this height, then what you do?

You have to construct a simple derrick on the roof top. That derrick can be constructed with the help of already existing climbing tower crane. So, now, with the help of derrick after the construction of derrick, you can dismantle this crane. This dismantles the climbing tower crane. Then after dismantling the climbing tower crane, you can dismantle the derrick also and then both the things can be transferred either to the lift or through even in certain cases, they even take the help of a helicopter to transfer the components.

So, depending upon the requirements, you can remove the components of the crane from the structure. So, let me summarize what we discussed just now. The solution when building height exceeds the maximum braced height tower limit is your climbing tower crane. This tower crane is located inside the building. Mostly it is set up in the location of elevators or the lift. So, that you can use that for the construction of the lift.

Climbing cranes are supported by the completed building floors and they are capable of raising themselves from floor to floor as the building is erected. That is why I told you, this crane will grow along with the structure.

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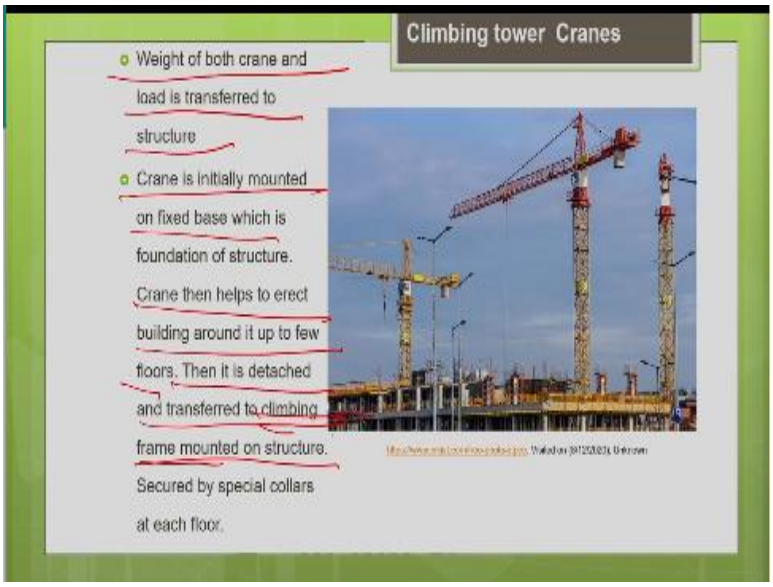

Weight of both the crane and the load, the crane is transferred to the structure. So, the crane is initially mounted on the fixed base which is the foundation of your structure. Crane then helps to erect the building around it up to few floors. So, after the completion of the floors, the crane will be detached from the foundation and then it will be transferred to the climbing frame mounted on the structure. So, you can keep shifting the crane from floor to floor as needed with the help of the climbing frame as we discussed earlier with hydraulic jack system. So, to every floor, you can secure it with special collars at each floor.

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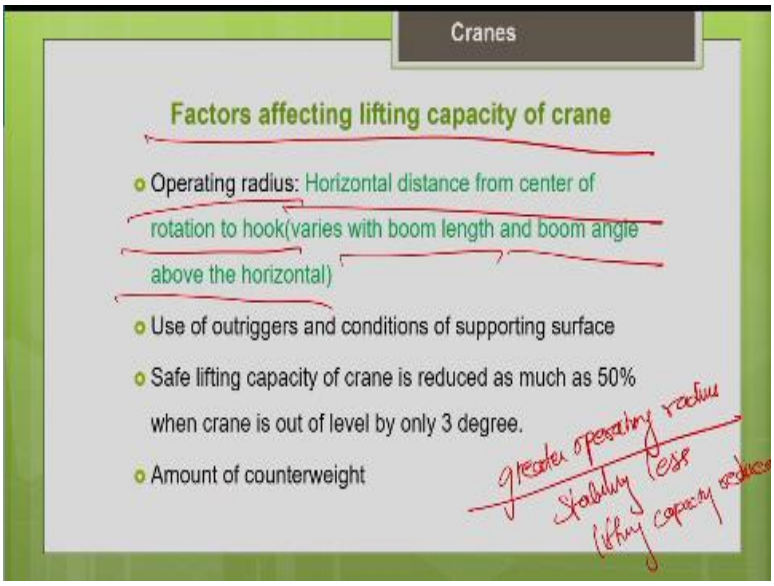

So far, we have discussed about the different types of tower cranes on the basis of method of slewing, top slewing, bottom slewing and on the basis of the type of boom, horizontal boom, luffing boom and articulated jib and special tower cranes like climbing tower cranes particularly for very tall structures. All these things are discussed. Now, let us move on to the next topic, what are the factors what are the affects the lifting capacity.

Generally, for any crane, what are the list of factors which affects the lifting capacity of the crane. So, what is the operating radius? As you know, operating radius is nothing but your distance from the centre rotation, centre of axis of rotation of the crane to the hook point that is here. That horizontal distance is called as the operating radius. So, that is going to vary with your boom length. Greater the boom length, operating radius will be more.

It depends upon the boom angle also. So, if you are going to have a luffing boom so, your boom angle is going to determine your operating radius. So, as I told you earlier, at greater operating radius and we have even seen the load radius diagram for the mobile cranes as well as for the tower cranes. So, we have seen that greater operating radius, your stability of the crane is less at greater operating radius. As the load lane moves away from the centre of the crane, the stability gets reduced.

So, the lifting capacity gets reduced. This, you should always keep in mind. At greater operating radius, lifting capacity is less because the stability is less. At lesser operating radius, you can see that stability is more; lifting capacity is more and use of outriggers, if it is going to be a tire mounted crane. If you do not use outriggers, your stability is affected. So, lifting capacity is reduced and the condition of the supporting surface, your surface should be level.

You have to level the surface. The soil bearing capacity should be good. Otherwise, your lifting capacity will get reduced. It will affect the safety of your crane. I have even shown you a picture the crane toppled over because of the poor or weak soil. So, safe lifting capacity of the crane is reduced as much as 50% when the crane is out of level by only 3 degree. When the level of the surface is gets reduced by 3 degree, you can see that the lifting capacity of the crane is reduced as much as 50%.

So, the amount of counterweights what you are going to use that is also going to decide the lifting capacity of the crane because that is only going to resist your overturning movement and apart from this, you should also consider the structural frame capacity. Every crane has its own structural limitations. Beyond that it is not possible to load the crane because other than the tipping failure, there is also structural failure. Your boom can break down.

Your boom can totally collapse. So, that can also happen if you overload the crane. So, the structural strength of the crane should also be considered when you consider the lifting capacity of the crane.

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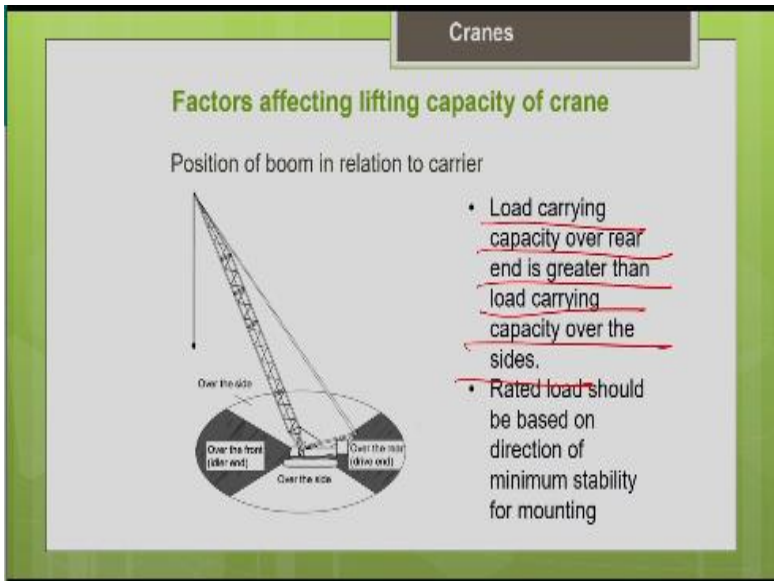

Another important thing is, as the boom of the crane rotates so you can see that the lifting capacity possible varies. You can divide it into four quadrants. You can see in this picture. When the boom is in the front end or the boom can be in the rear end or boom can be to the right side or left side so, boom can be in the side of the carrier or boom can be in the front end with respect to the carrier or boom can be the rear end with respect to the carrier.

So, based on the studies, it is found that when the boom is in the rear end, when the bomb is in the rear end, the stability of the crane is more. It all depends upon the position of the centre of gravity of your system. As a boom shifts, the centre of the gravity of the system also gets shifted. So, when it is in the rear end, the crane is in the more stable position because of the centre of gravity location.

In that case, you can see that the lifting capacity will be more when compared to the sides. Load carrying capacity over the rear end is greater than the low carrying capacity over the sides. It all depends upon the position of the centre of gravity of the system and generally when the manufacturer gives you the load rating, they consider the direction of the minimum stability for mounting. So, we have to consider the minimum stability for mounting and accordingly only, they will do the rating.

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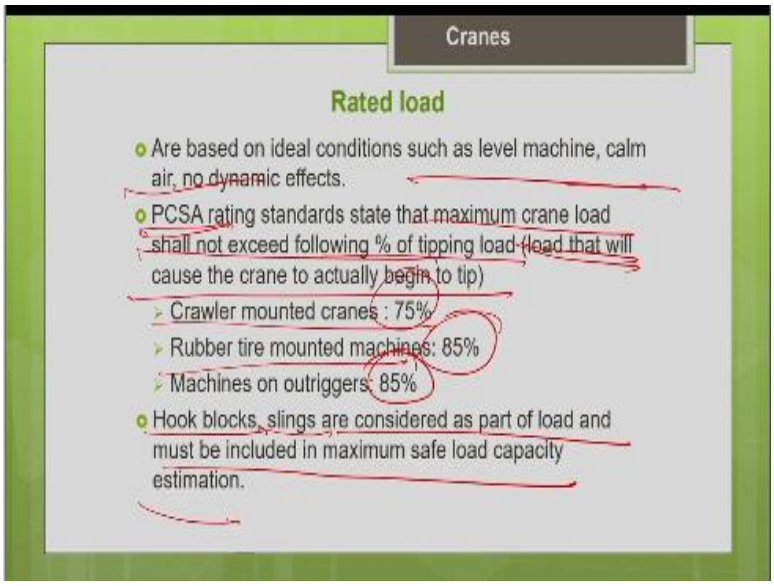

So, the rated load as I told you, the crane rating, the load rating is done based on ideal conditions assuming that the machine is level; the surface is level; the air is calm; the wind speed is not high; there are no dynamic effects. Based on this assumption only, rating is given. If your conditions are going to be different, so, the lifting capacity must be reduced accordingly. So, as I told you in the earlier lecture, there is an organization called PCSA Power Crane Shovel Association.

So, this organization is common for both shovels and the crane. Both are treated as the same family only cranes and shovels. So, cranes have development of standards and guidelines for the cranes and shovel. So, according to the guidelines of PCSA, you should know that the maximum crane load shall not exceed following percentage of tipping load. Tipping load is nothing but the load that will cause the crane to actually begin to tip that is what is tipping load.

We have already discussed about tipping load in the earlier lectures. You can recollect that. So, for crawler mounted, depending upon the mounting, the safety margin is decided. For crawler mounted cranes so, you should never exceed; the load shall not exceed 75% of the tipping load. For rubber tire mounted cranes, the load should not exceed 85% of the tipping load and for the machine outriggers 85% of the tipping load.

So, when you estimate the lifting capacity of the crane, you have to also consider the hook blocks and the slings also as a part of the weight. So, when you estimate the lifting capacity of the crane,

the weight of the hook block, the weight of the sling and all the accessories what you use for lifting, everything should be considered as a part of the load and must be included in the maximum safe load capacity estimation.

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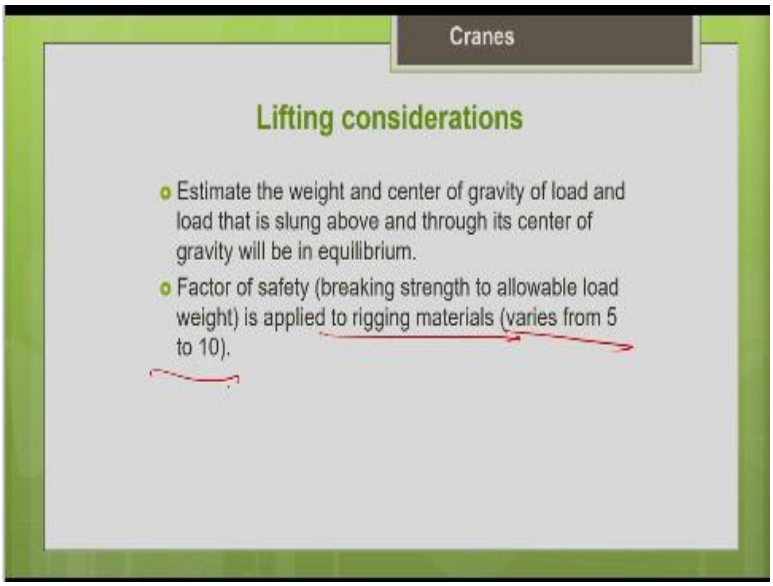

So, another important thing is; when you do the rigging of the load so, it is better to find the centre of gravity of the load and rig it at that point. So, that the load will be in a stable equilibrium from the safety perspective. This is another guideline and many times, you can see that some accidents happen even because of the rigging failure. So, that is why even the rigging materials according to the standards, you should have a good factor of safety ranging from 5 to 10 to avoid accidents due to rigging failure.

So, the factor of safety recommended for the rigging material is from 5 to 10. So, estimate the weight of the load, centre of gravity of the load and the load that is slung above and through its centre of gravity will be in equilibrium that you should always keep in mind. Rig it at its centre of gravity.

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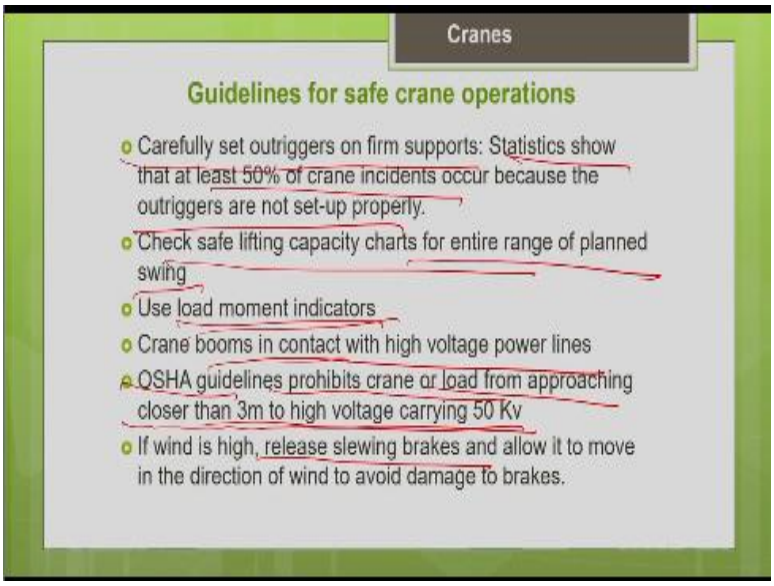

There are also some guidelines given for the safe crane operations because you know that there are so many accidents related to crane reported very commonly. So, that is why we should follow some safe guidelines when you operate the crane. So, carefully set the outriggers on firm supports because statistics shows that at least 50% of crane incidents occur because outriggers are not extended properly that is why we have to carefully set the outriggers and is also check for the soil condition.

If the soil is going to be weak, provide some timber mats or steel mats and on that, you can place with the outriggers. Check the safe lifting capacity charts for the entire range of planned swing that is very important. You know that lifting capacity will vary with the operating radius and the lifting capacity varies depending upon the position of the boom with respect to the carrier. So, you have to check for the entire range of the planned swing and in modern cranes, you have this load moment indicators also.

So, if the load is getting exceeded at a particular operating radius, it gives you the warning or some alarm or indication is given. So, that we can check for the safety. Such kind of indicators are available nowadays and some of the accidents are reported due to electrocution when the crane booms are in contact with the high voltage power lines. So, that is why according to OSHA, some specific guidelines are given that we should prohibit the crane or the load from the approaching closer than 3 meters to high voltage carrying 50 kilowatts.

So, this guideline, you should keep in mind. OSHA guidelines prohibits crane or the load from approaching closer than 3 meters to high voltage lines carrying 50 kilowatts and another important thing is; wind load should also be considered. If the wind speed is very high say, as I told you as per the highest score, if it is greater than 72 kilometre per hour, you should stop the crane operation and according to the wind speed prevailing that particular area, the lifting capacity should be reduced.

And when the wind is high, you should release the slewing break and allow it to move in the direction of the wind to avoid the damage to the brakes.

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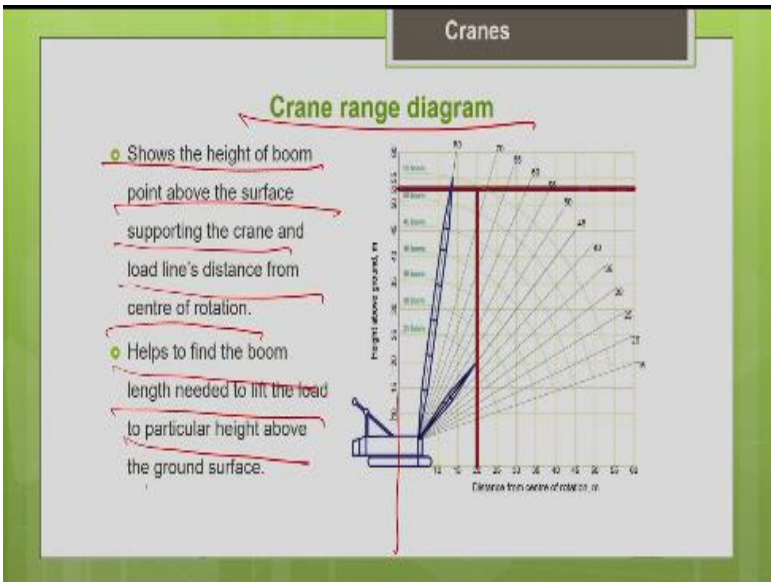

So, let us see what is the significance of this crane range diagram. As a name indicates if you know what is your working range needed, you can find what is the boom length needed to satisfy the working range in my project site. That is the purpose of the crane range diagram or in the reverse way, for a particular boom length, with this particular boom length, what is the maximum working range, horizontal range and the vertical range I can have? That information I can get it from the crane range diagram.

So, what you have in this crane range diagram in the x axis is a distance from the centre of axis of rotation of the crane to the load line, distance from the centre of axis of the rotation of the crane

and what you have in the y axis is the height of the boom tip above the ground. Say, for example, if you know that your operating radius working radius needed, maximum working radius needed is 20 meters and if we want to, say, for example, I need to reach a height of say 53 meters.

The maximum height reach needed is say 53 meters. Then what is the boom length needed for my particular project? I can determine from this range diagram. These curved lines indicate your boom length. You can see the curved lines indicate the boom length. So, you can see for 20-meter operating radius and for the vertical height of say, 53 meters, the boom length what I need is approximately 55-meter boom length I need.

So, what is the minimum boom length needed for this working range requirement? I can find from the range diagram. So, and also, you can see that then as a boom angle varies, what is happening to the operating radius? You can see that. As a boom angle varies so, what is happening to the operating radius? You can check here. So, either way, you can use the range diagram.

So, if you know what is the maximum range needed, what is the boom length needed, I can find it or for a particular boom length, what is the maximum working range possible that also I can find it from this chart. So, this crane range diagram shows the height of the boom point above the surface supporting the crane and also, what you have in x-axis is the load line distance from the centre of axis of rotation.

It helps you to find the boom length needed to lift the load to particular height above the ground surface. If you know, this is my vertical reach requirement, what is the boom length needed? You can find it from this particular chart. So, let us know to work out the problem to find what is the minimum boom length needed for a particular working range. I will see how to use the crane range diagram which will help us to determine the minimum boom length needed for a particular working range in a project.

And also, we need to find what is the maximum net the load possible for a particular crane. So, that also, we can determine in this problem. First let us read the question.

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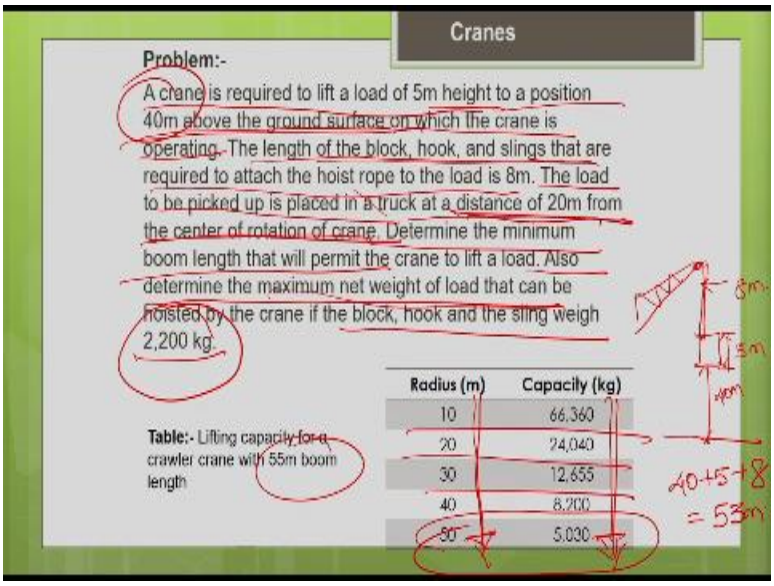

So, here, a crane is required to lift a load of 5-meter height. The height of the load is 5 meters to a position of 40 meters above the ground surface on which the crane is operating that means the lifting height needed is 40 meter above the ground. The lifting height needed is 40 meter above the ground and the length of the block hook and the slings that are required to attach the hoist rope to load is 8 meters. So, that is also provided to you what is the length of the block, hook, slings?

And the load has to be picked up from a truck, the load is to be picked up is placed in a truck and that is at a distance of 20 meter from the centre of axis of rotation of the crane. So, the horizontal reach, the operating radius needed is 20 meters. So, that means the crane has to pick up the load from a truck which is placed at a distance of 20 meter from the centre of axis of rotation of the crane.

So, the horizontal range needed is 20 meter and the load has to be lifted to a height of 40 meter above the ground surface. This is the range given. For this particular working range, what is the minimum length of boom of the crane needed that is what we are going to determine now. So, determine the minimum boom length that will permit the crane to lift the load. Also, determine the maximum net weight of the load that can be hoisted by the crane.

If the block, hook and the sling weight 2200 kg, as I told you when you consider the lifting capacity of your crane, you should include the weight of the hook, block, sling, everything, the rigging

device also. This is because your crane has to lift that also. So, that also has to be included in the lifting capacity of your crane. So, and its weight is given as 2200 kg. So, now, we are going to determine what is the maximum net weight of load that can be hoisted by the crane, safe net weight of load on the crane.

So, you can get the information from the load charts so, which are provided by the manufacturer. So, the load charts are available for different boom length of the crane. So, these values are taken for a particular boom length of say, 55 meters. You can refer any equipment handbook to get the different load charts for the particular crane model. So, you can see as operating radius increases, your lifting capacity is reducing.

You can see that as operating radius increases, your lifting capacity is reducing. Operating radius is nothing but the distance horizontal distance from the centre of axis of rotation of the crane to the load line. As the load line moves away from the centre of the crane, your stability is reduced. So, lifting capacity is reduced. So, at the higher operating radius, your lifting capacity is reduced. So, these values, you can take it from the equipment handbook from the manufacturer for the particular model.

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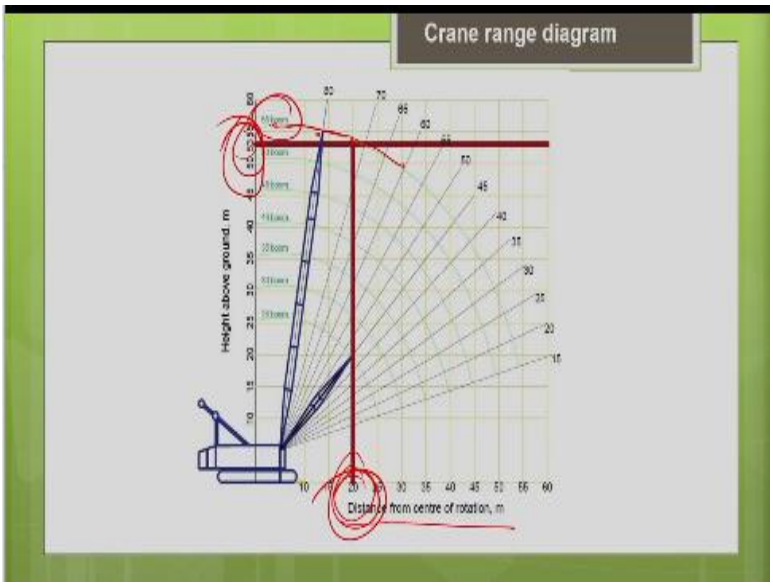

Now, with the help of the crane range diagram, I can determine what is the boom length needed for this particular project. So, it is given that the crane has to pick up the load from a truck which

is placed at a distance of 20 meter from the centre of rotation of the crane, 20 meters. So, the horizontal reach, the radius, distance from the centre of axis of rotation of the crane to the load line is 20 meters. And what is the vertical height needed?

The vertical height needed is, you have to lift the load to a height of 40 meter above the ground surface. So, the load has to be, if this is the ground surface, the load has to be lifted to a height of 40 meter above the ground surface and the height of your load is given as. What is the height of the load? 5 meters and above this, you have the sling and the rigging device.

The length of the block, hook and slings that are required to attach the hoist stroke to the boom, you have the crane boom here to which it is attached. This height is, this is your crane boom assume. So, the height of this is given as 8 meters. So, in the crane range diagram, so, what you have in the y axis is here, height of the boom tip above the ground level. You have the height of boom tip above the ground level.

So, now, you can see what is your required height of boom tip above the ground level is 40 plus 5 plus 8. So, that is nothing but 40+5+8 that is giving you value as 53 meters. This is the height needed, 53 meters for the height of boom tip above the ground level 53 meters and for the horizontal distance of 20 meter. To reach, for this vertical reach and for this horizontal reach or this working range, what is the boom length needed?

The intersection point, you can see, it is closer to boom length of 55 meters. So, the boom length chosen is 55 meters.

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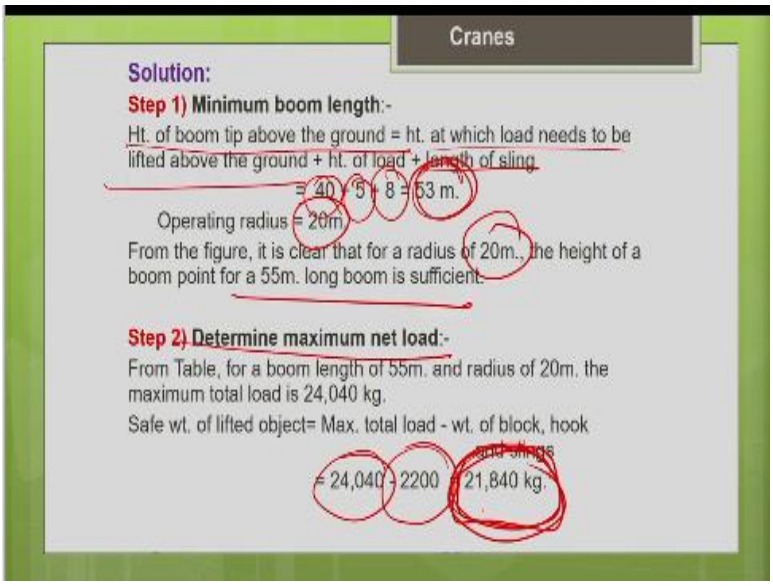

So, that is what is given here. The height of boom tip above the ground equal to height at which the load needs to be lifted above the ground, it is 40 meters. Height of the load is 5 meter plus the length of the sling is 8 meters. You add everything; you get 53 meter that should be the height of boom tip above the ground that is what you need for this particular project. And the operating radius, the horizontal radius is 20 meters.

So, from the crane range diagram, for these 20 meters and 53 meters, we have chosen the boom length of 55 meter. So, what is the minimum boom length needed is 55 meters. Now, you determine what is the maximum net load now using the load chart. For the 55-meter boom length, the load chart is given to you and for the 55-meter boom length you can vary the radius by changing the angle of inclination of the boom. Say, now, the radius I mean the working radius needed is given as 20 meters.

So, for the operating radius of 20 meter, the lifting capacity possible; the maximum lifting capacity possible at this 20-meter radius is 24040 kg that you can take it from the load chart given by the manufacturer. So, maximum total load permissible is 24040 kg. So, from this, you have to detect the weight of your sling and the hook block everything. So, this is the actual weight of the load you can lift excluding the weight of the hook block and the sling, other accessories.

So, what is that the maximum lifting load possible from the safety of the crane for this particular boom length for this operating radius, it is 21840 kg. This is how you have to determine what is the maximum load possible for the particular crane at this particular operating radius.

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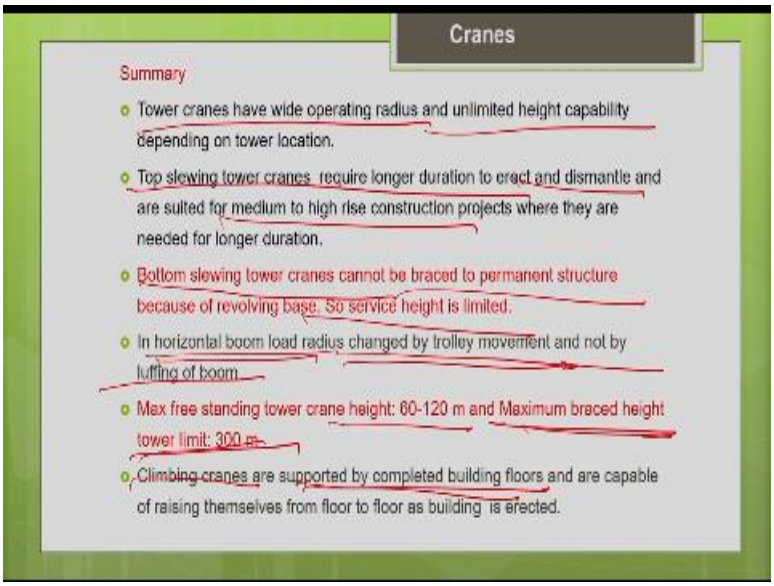

So, now, we have come to the end of this lecture. Let me now summarize what we have discussed earlier. So, the tower cranes, you know that it can give you wide operating radius because you can place it very close to the structure and you can place it even inside the structure which is being constructed and it gives you unlimited height capability depending upon the tower location that is the main advantage of the tower crane.

And there are different types of tower crane based on the method of slewing, you can classify into top slowing and bottom slewing. Top slewing tower crane requests longer duration to erect and dismantle and you can use it for a high-raised building. For medium to high res construction projects, you can use it where you need it for a longer duration because its erection, dismantling will take more time.

So, you use it for a project where you need it for a longer duration. So, bottom slewing tower cranes, you have a height restriction. This is because here the tower will also rotate. You cannot brace it to the permanent structure. So, you cannot go for a greater height. So, the service height

of the bottom slewing tower crane is limited. Based on the type of the boom, you can classify it into horizontal boom, luffing boom and articulated jib.

So, in horizontal boom, you change the load radius by the trolley movement. So, you have a trolley which can move along the jib where you change the trolling moment. By the trolling moment, you can vary the working radius, load radius but you cannot do the luffing of the boom that is not possible with the saddle boom crane and one thing note that the maximum free standing height permissible, there is 60 to 120 meter.

Beyond 120 meters, we have to brace the crane to the nearby structure. So, it has to take the support from the nearby structure to transfer the overturning moment due to wind and the other load. So, even with bracing, I cannot go beyond 300 meters. Maximum brace height tower limit is 300 meter. And we discussed about the climbing tower cranes. So, particularly for structures which are beyond 300 meters, we can go for the option of climbing tower cranes.

They are supported by the completed building floors. As your structure grows, your tower crane will also grow with the structure. They are supported by the completed building floors. That is why when you design the floor of the structure, you have to take into account the weight of the crane and the load, it is going to carry. So, they are capable of raising themselves from floor to floor as the building is erected.

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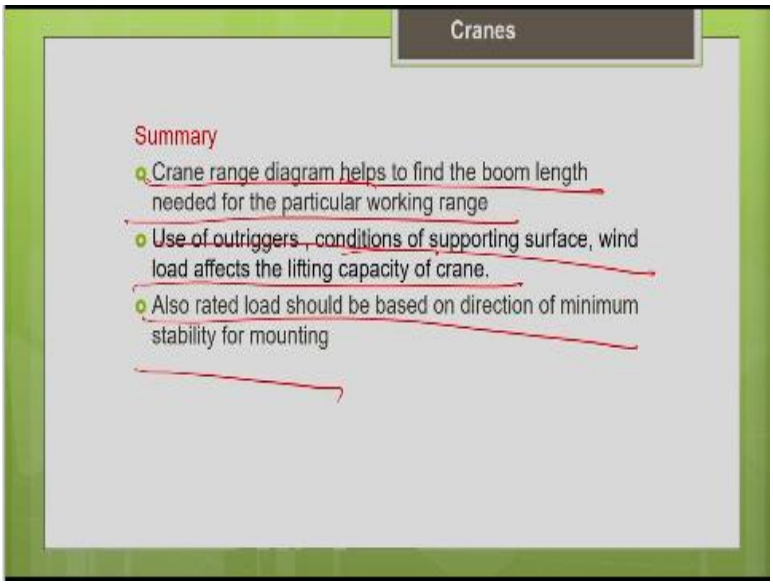

So, we saw the importance of crane range diagram. It will help you to find what is the boom length needed for a particular working range or what a working range boom length can offer. Either way, you can get the data from the crane range diagram. It helps to find the boom length needed for the particular working range. So, you should also always note that the crane rating given by the manufacturer is done.

Assuming that if it is going to be tire mounted crane, it is assumed that you are going to use the outriggers and it is assumed that the crane surface is level. The surface on which the crane is supported is going to be level and it is assumed that the wind speed is not high. So, according to those conditions only, the rating is applicable. If your project conditions are different from the ideal conditions, you have to apply the adjustment and reduce the lifting capacity accordingly.

So, use of outriggers, condition of the supporting surface, then load, everything affects the lifting capacity of the crane. So, and also, the rated load is based on the direction of the minimum stability for mounting that is what we discussed. As a crane boom shift from quadrant to quadrant, you can see that the stability gets affected and the stability is more.

When the crane boom is at the rear end with respect to the carrier, there, the lifting capacity will be more because the stability is more but, the rating of the crane is done based upon the direction of minimum stability for mounting that you have to take it into account.

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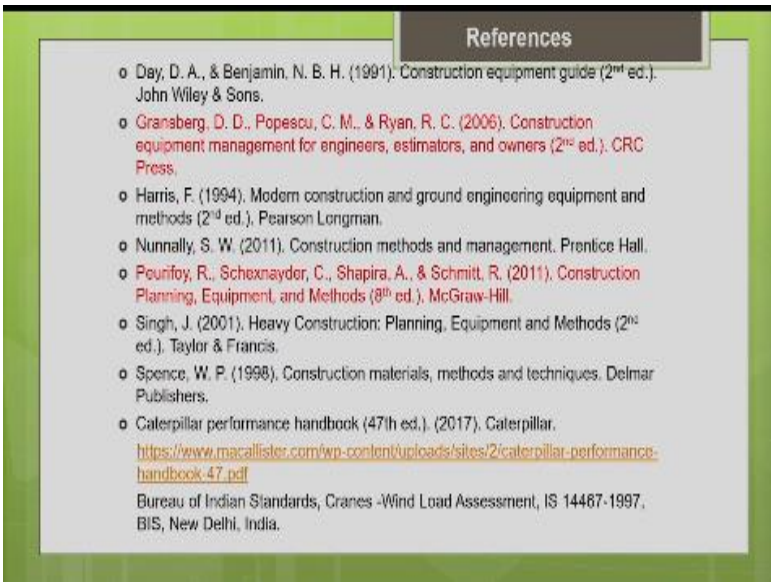

So, these are the references which I have used for this lecture preparation. You can go through the books. So, in the next lecture, we will be discussing about the concrete and the concreting equipment. Thank you.