Port Harbour Structures
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Module 9, Lecture 45
Design of pile

Yesterday we were discussing about this pile design. There are various aspects of the design. The important thing is the design that is to be done during the stage of construction. Normally that design is not done. There is some construction practice which is being followed in certain cases the design is also carried out.

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So this is a reinforcement bar which is transported by a barch. What is the length of (ba) reinforcement that is available in the market? 12 meters hmm? 12 meters, so if you are handling a 12 metre long bar it has some weight it may vary from 3 tons to 6 tons depending on the reinforcement. You are seeing some inner rings here may be in another fear it will biz in. This is to keep the bar in position.

This is the inner ring this is the outer ring. Outer ring is shear reinforcement; inner ring is to keep the shape correctly. You want a circular shape, that means you have to provide a thumb plate is a inner ring which is provided typically it is about 16 MM or 20 MM diameter bars at every 1 to 1 and half meters centre to centre. This is to keep the bar in position that is the main reinforcement as well as to keep the shape alright also.

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There is a person who is holding the bar and is lowering it for, lowering these bars also we need to provide some hooks and other things, it is not shown in this that also is a part of the temporary design. Here you can see the larger diameter this is your inner bar and these are smaller diameter bars which are outside. These are the main reinforcement bars.

Once you are lowering the bars inside the this liner the gap between them should be more than clear gap should be more than 100 millimetres otherwise the concrete will not flow. For land based structure it is different it may be around 40millimetre or more than the diameter of the bar something like that whereas in pile construction we need a clear gap of 100 millimetre. This comes in construction practice.

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So here you can see the inner bar clearly, this is inner bars, this is the outer bars and we have to provide a lap. Lap means when this reinforcement bar is ending and you are putting another reinforcement bar we have to calculate what is known as development length. So that also is to be calculated development depends on what? Many civil engineers are here na diameter of the bar then what else? Bond style hmm bond style, bond style depends on what? Weight of concrete, weight of concrete then what else?

Deformity of steel, do not think too much, what else? Sir plain steel and that uhh, deformity is different you said deformity, no deformity you said. I went for some other thing, it is deformed bars when we T and D (()) (03:30) that is a correct answer plain are deformed bars. What will be the reduction in lap length if it is a deformed bar compared to a plain bar. Fixed I think it is about 25 percent or 40 percent I do not know then what else? The bars whether they are in tension or compression. That is very important that the bars are in tension or compression.

Then another important aspect is you cannot lap the bar at the same level that is another important thing this is what is known as detailing. Most of the structures which are failing they fail either during the construction stage and mainly failure if at all takes place construction or during construction the problem is because of poor detailing not because of poor design. And another thing is the construction methodology are practiced which is not done properly.

So you have to give some if you are lapping one bar from this point onwards the other bar should be lapped with a clear gap of around 300 millimetres. So you have to provide sufficient length of the reinforcement bars for lapping what is a typical development length? It relates to what, development length relates to what? Hmm? I want you to say this much development length is provided. How much you will provide approximately?

Question is not clear? Hmm? You provide 1 metre, 2 metre or in relation to some other dimension you will provide, how much you will provide? Diameter do not go to the bar vendor and tell it depends on deform it is a plain bar deformed bar, grade of concrete he will not understand. If you are going to the site you should tell him clearly how much lap length is to be provided, how will you tell him? Either English or Hindi or whatever it is; you will tell in terms of metres is there any other method to tell? Hmm?

You tell in terms of diameter of bar, terms of diameter, you told earlier did you tell earlier? I did not hear you, how much diameter 40 times of the diameter of the bar it varies from 36 times diameter of the bar to about 60 times diameter of the bar. One of the important things which did not tell is about the strength of steel, ok. Whether it is mild steel or 415 grade or 500 grades that also depends these are the various aspects that is to be considered.

So I said we provide 100 millimetre clear gap in case you are not able to provide 100 millimetre clear gap you can bundle the bars that means you can keep two bars side by side. Then when they are concreting there will be some lean concrete which you have to chip off and you have to throw it off. That is another aspect which you have to do.

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So here what is shown is I do not know whether you are able to see this clearly this is the inner core of the pile and this is the main bars this may be a lap bar or it is a bundled bar what you are seeing is a pile cap which is coming and sitting on the cover of the pile reinforcement. What you are seeing here is a pedestal and these are the hooks which are provided to lift the pile cap. So this is type of construction which they do generally to speed up the construction.

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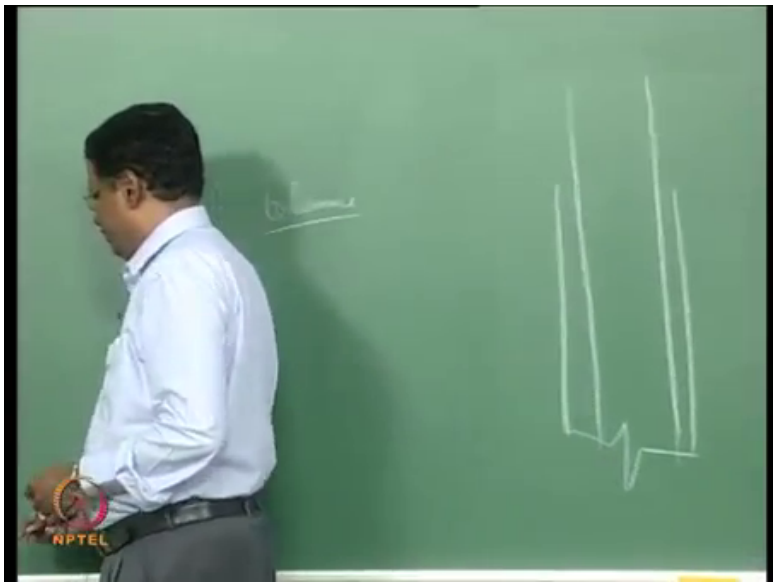

So another important aspect is we do certain aspects to increase the speed of construction. So if this is a pile what is provided, we have to know what is known as tolerance. What is known

as tolerance? Allowance, hmm? What is tolerance? Allowance, what is that allowance what will happen when you are driving a pile what kind of tolerance is required? Suppose you are driving a pile, what kind of problem you may encounter?

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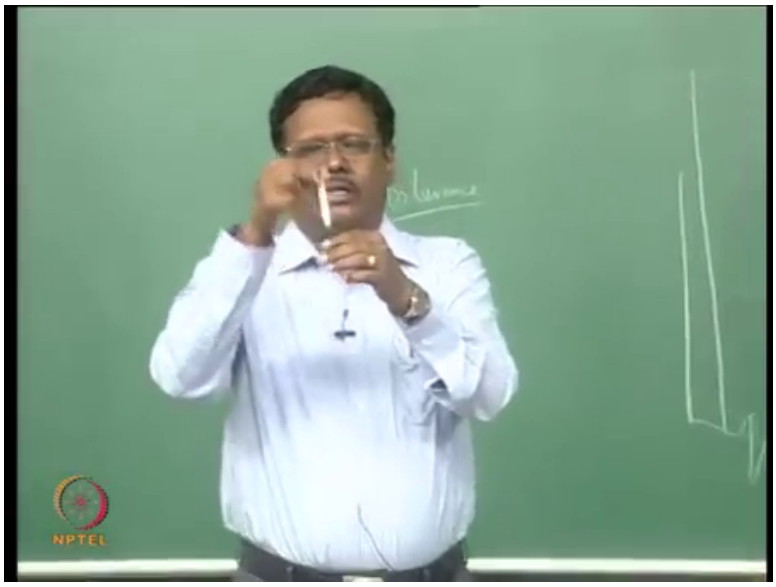

See suppose this is a pile when you are driving it this may not go vertically down, this may go in a inclined manner.

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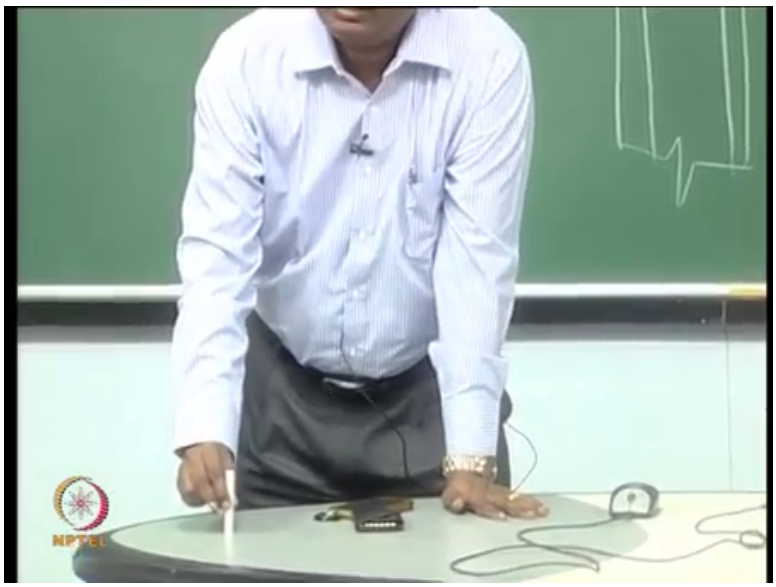

Suppose the pile is to be located here it may be located at a different point it is not possible exactly you can put it, there is a tolerance limit which is given I do not remember exactly generally it is not more than 75 millimetre at the top when you go to the site and if that fellow

is not able to get exactly the location do not blame that fellow it is humanly impossible within plus or minus 75 mm you have to adjust. Then you have to adjust the other things also.

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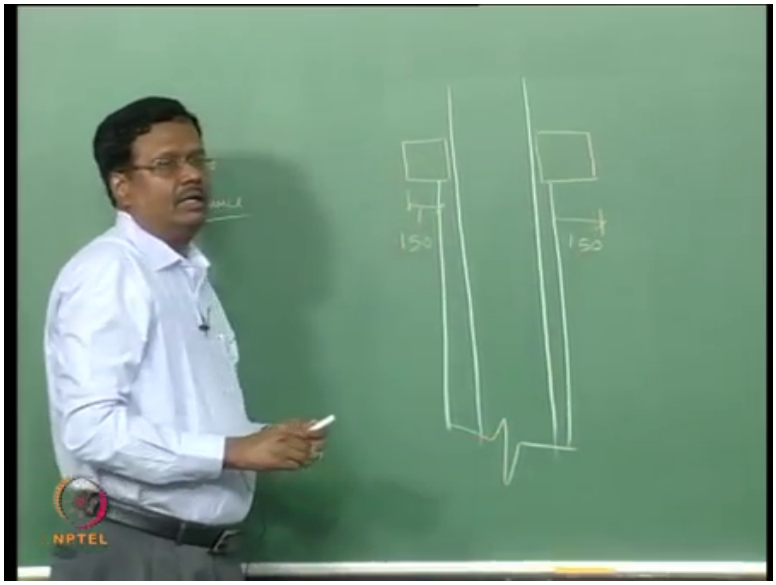

So that is why we provide what is known as the pile cap, what is this pile cap? The pile cap is a precas construction so that the construction can become very fast. There is a slot circular slot what you are seeing the only edges are there is what we make. This pile cap is minimum dimension should be 150 millimetres from the face of the pile. So this will adjust that sound (())(09:14) millimetres, ok; 150 mm more.

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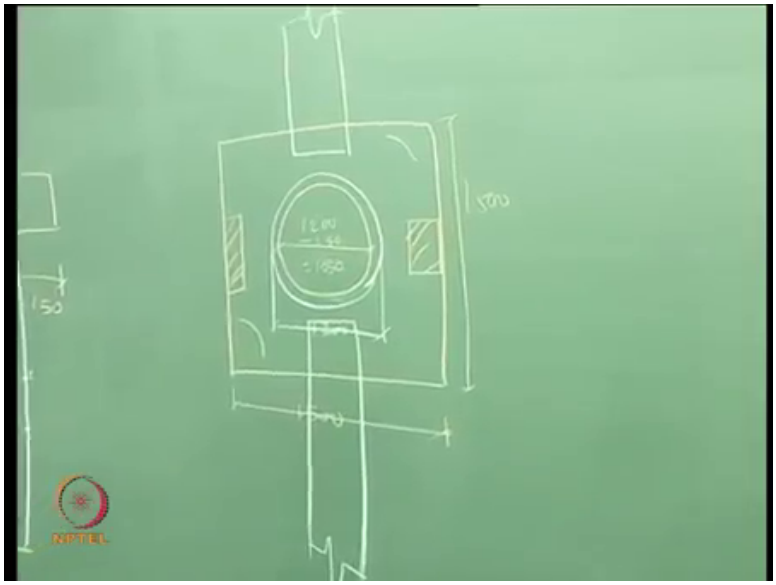

Suppose the pile is 1200 millimetres the pile cap what you are making will be like this, this is a pile which is coming here and this dimension will be 1500, 5500 and this pile cap is made to rest on the cover portion of the pile. So this is your 1200, generally the cover is 75 that

means this will be 1200 minus 150 that is 1050. So what is happening is the pile cap is resting over a barring of 75 millimetres.

Suppose this is a beam or whatever it is I want to place it, how will you place it? You can place like this also very easy. But you will place like this also you cannot place like this it will fall down. There is some barring required for that barring there is a calculation barring pressure you have to calculate. That barring generally is about 75 to 100 millimetres, ok. Then beams what is coming there will be one beam what is coming.

There will be one beam coming here and resting like this. These are the two beams which are placed, these two beams may be deeper compared to the beams in the other side, because stop of the day should be the same, the slap shot should remain the same. But the beams may be different. So for that what they do is they provide some pedestal here.

So that you can place the beam on top of it. That is what you are saying and there are some hooks provided may be you may provide a hook here and then lift it. The hook also should go into the concrete. That is what is shown here for a particular project.

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Now you can see this is a pedestal this is a inner core the pile cap is coming here and resting adjacent to the reinforcement may be 75 mm barring is there. The beam this side will rest on the top of the pile cap and this side it will rest on top of the pedestal. And this is a hook which is used to lift the pile cap, this hook goes inside the pile cap. When they are going to place the precast bin they will cut this reinforcement. Sir what is the bundled?

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Bundled means two bars together they will keep it.Suppose you want to provide a 60 bars (()) (12:05) pile the spacing is 60. If you calculate the spacing it will not be less than, it will not be more than 100 millimetre clear gap, then you put two bars together bundle that means you put only 30 bundled bars. Each bundle containing 2 bars you can have 20 bundles of 3 bars in each bundle that also you can do.

So in order to avoid all these things we prefer to have the reinforcement about between 1 to 2 percent. Earlier you are discussing about 2 percent now a days we want to give only 1 percent for that you have to increase the diameter.

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There will be some congestion of reinforcement and here it is some inch to pile cap is being made is of doing a precast pile cap, here they are doing the inch to pile cap. So this is the pile reinforcement bars the beam bars at the bottom will come so this is the type of congestion that is there in a pile beam junction. This also you have to think carefully and do it. This is about the pile. The next is about the beam, beam design.

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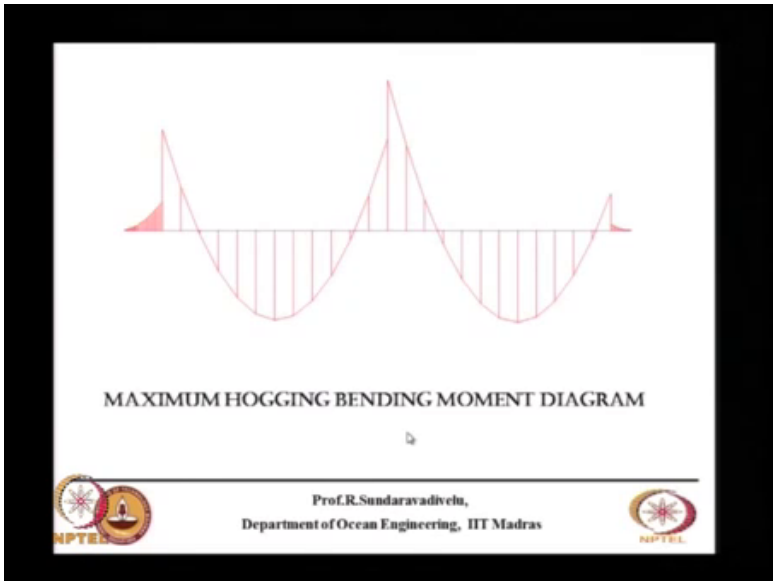

There are two types of bending moment one is called as a hogging bending moment another is called as a sagging bending moment. What is hogging bending moment? What is sagging bending moment? Hmm? Sagging is compression on the top, hmm that is the way to answer you take the compression at the top and tension at the bottom that is called as a sagging moment, hogging means uhh you can say about convex and concave also.

Concave deflection is sagging and convex is hogging. So by depending on the loads coming on the structure you can have a hogging moment that means the negative moment this bending moment diagram is done on the tension side. If you are what is that fellow doing behind you? No, there are two ways of drawing the bending moment diagram. You can draw the bending moment diagram on the tension side or you can draw the bending moment diagram on the compression side.

Even some foreign books they draw the bending moment diagram on the compression side, ok. Generally people draw the bending moment diagram on the tension side. That means if you have a bending moment like this it means you have to provide tension at the top or this

side reinforcement at this side. And here you have to provide the reinforcement. Then there is a curtailment the bending moment here is 0.

So whatever bending moment you are providing here need not have to go continuously. Suppose this is a support generally this is a pile support so you do not have to provide whatever reinforcement we are providing into the pile junction.

But there is a rider that you have to provide 50 percent of the reinforcement into the bottom reinforcement. You cannot curtail it suddenly you can curtail one third of a reinforcement at a particular time. But general recommendation is you do not reduce the reinforcement less than 50 percent in the supports, right? Positive moment especially.

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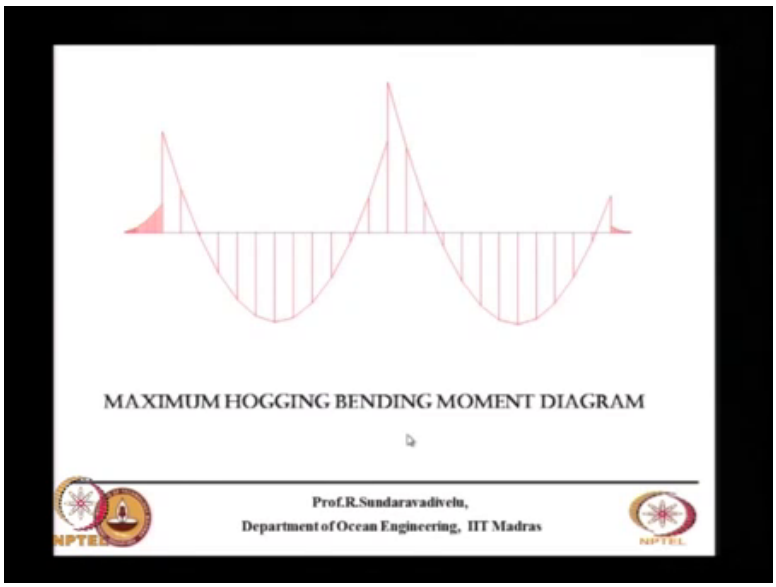

This shows the sagging moment the bending moment is maximum here it depends on the load condition where you are placing the load and this shows the bending moment envelop what you are trying to get. Considering all the load combination what will be the maximum bending moment. If you are able to get this bending moment envelope properly then you can provide the reinforcement accordingly.

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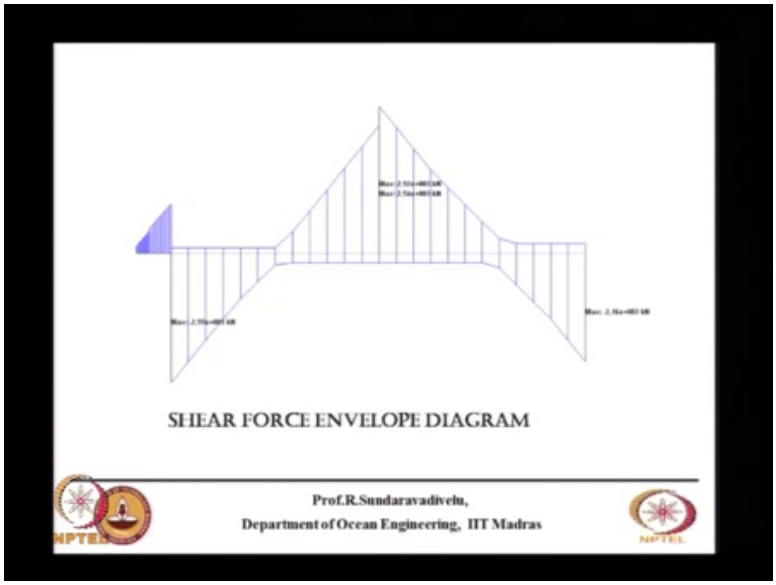

Similarly you can get the shear force also you have to design for uhh both pile, beam and slab for axial force bending moment and shear force. We have to finalize this parameters. There are different grades of concrete M 35 is a grade of concrete. What is a minimum grade of concrete to be used for reinforced concrete structures? 25, M 25, M 20 15 is not there, 20 is used.

For marine structures you have to use minimum of M 30 Grade. How much maximum we can get concrete strength? 90, 70, M 200, 200 is not possible who told 200 (())(16:52). My be it may be some special type of concrete generally for common purpose they use upto M 80. But for getting higher grade of concrete it is not super place that is required what is required to get the higher grade of concrete? Iron, fibres.

That is another better method you do not know about silica fume, you have to add silica fume about 5 percent silica fume if you add your strength will increase. Generally if you want to increase the strength you have cement sand course aggregate water what is to be done to increase the strength of the concrete. Only one answer you have to tell, do not tell all answers in the (())(17:50). Water cement ratio, water cement ratio that is the correct answer.

What is to be done with water cement ratio? Hmm? Decrease how much it can be decreased, 0.35, hmm decreased I am asking lowest value I am asking 0.35, generally upto 0.55 you can do. But for marine structures you should not use more than 0.45, why? You can get two water cement ratios, one is 0.35 another is 0.5 same strength you can get. I am saying 0.35 is

preferred why? Strength is the same 0.35 and 0.5 is the water cement ratio strength is the same.

But I am saying use 0.35 instead of 0.5 what is the reason? Segregation, more segregation, segregation is construction, hydration, hmm? Hydration is chemistry problem. You do curing properly, hmm you avoid segregation do curing everything you do it properly but still I would like to have 0.35 ratio compared to 0.5 ratio. Durability is a right answer, permeability because of lesser permeability you have higher durability.

So what you have to talk about concrete structure is strength and durability. Lower water cement ratio ensures better durability, ok. Another thing is the cover so then second level of answer we will see to increase the durability you have to reduce the water cement ratio. Then what else you can do? Use silica fumes, silica fume is to increase the strength so it will block the pores also, it will block but silica fume is expensive.

See you are going in a Mercedes benz go in a highway for all kinds of roads do not go for Mercedes Benz. Silica fume use it for higher grade of concrete, no questions but increasing durability across all grades of concrete silica fume is not the answer. Have you understood? Increasing durability for a M 35 or M 40 grade of concrete silica fume is not the answer. Fly ash increases it why it increases?

It is finer than cement, so yeah finer than cement it fills up the gap fights up cement so it increases, how much a fly ash can be added? See you have generally 8 to 9 bags of cement I am sorry yeah 8 to 9 bags of cements that is used for cubic metre of concrete what is the weight of 1 cubic metre of concrete. 2.4 tons, 2400 kg 8 bags of cement what is the weight? hmm? 8 bags of cement what is the weight? 8 bags what is the weight? 400 kg.

Sorry 2400 kg you are putting 400 kg of cement instead of putting 400 kg of cement you can put 300 kg of cement and 100 kg of fly ash so it reduces the cost. Other than fly ash what else can be used? Hmm? Gypsum, not gypsum, you do not know. Fly ash (())(21:42) material only what is it? Slag, slag blast furnace slag cement can be used that is much better than fly ash. But if you use a slag cement you can put 300 kg of slag and 100 kg of cement.

Do you know that? It is being done ennore port is built like that 300 kg of slag and 100 kg of cement ulta it gives better performance. Then grade of steel 415 and 500 you can use.

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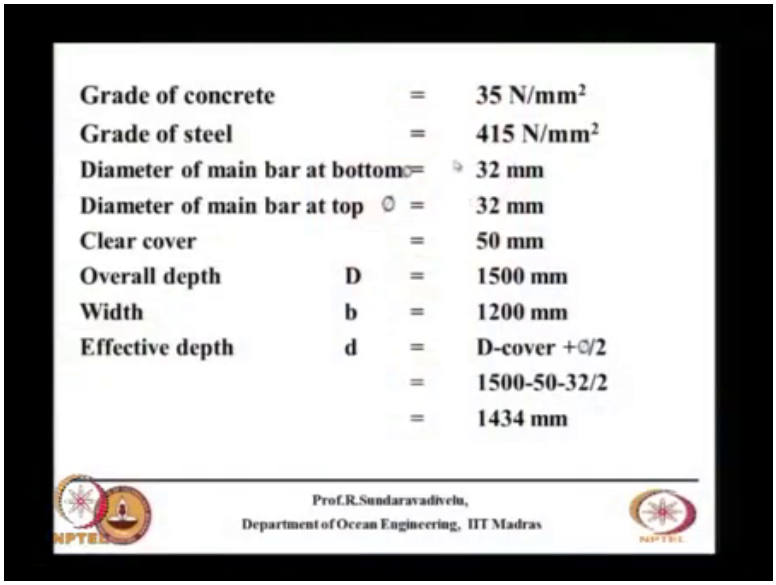

What is the maximum diameter of bar available? 32, I think 36 also available then you provide clear cover 50, the depth of the beam is 1500 width is 1200. Generally the width of the beam in harbour constructions are much much wider compared to any other thing.

Increasing the depth is better for design, but increasing the width is better for construction, we have come across some designs by Australian company for one of the port Jawaharlal Nehru its width is more than the depth. I was thinking why this he has done like that it is only for reducing the congestion at the junction. Provided more width than the depth. Structural designers prefer to have more depth because they say there is cost saving.

Actually increasing the width is better. We prefer to go for a beam width which is generally more than the diameter of the pile. I have given 1500 mm is a diameter of the pile. I would prefer to go 1500 mm for the width of the beam. So that you can provide the reinforcement at the sides.

It may look uneconomical it is not always uneconomical then you have to calculate the effective depth this only come into the design equations.

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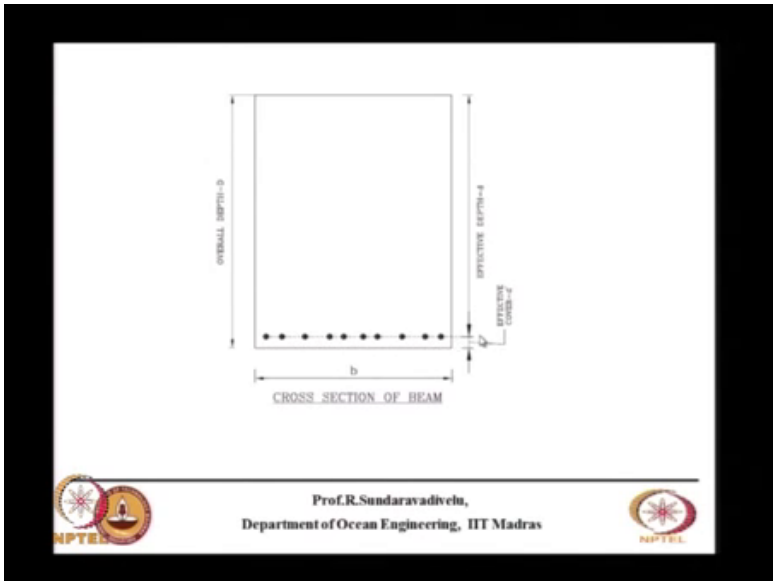

So this is the definition this is the overall depth from the centre line of the main reinforcement to the extreme phase is effective cover. And from the top surface to the centre line of the reinforcement is called as the effective depth.

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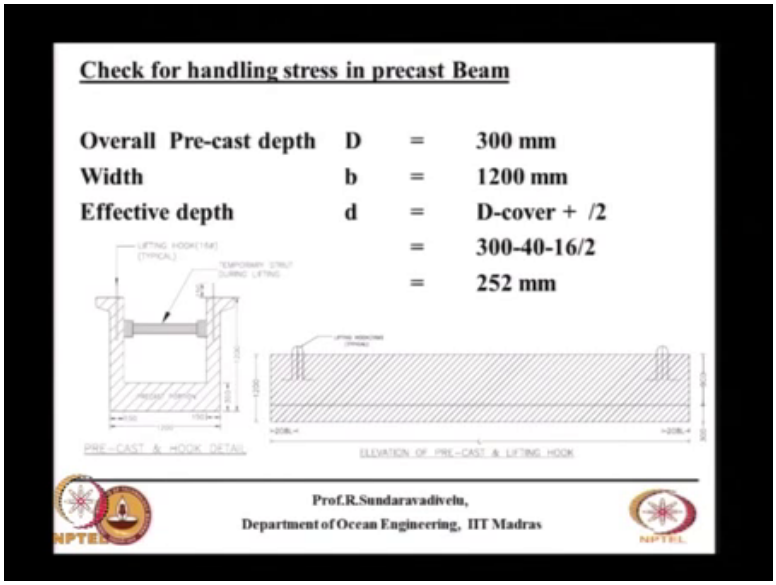

The construction is done for marine structures using a composite construction consisting precast and cast sensitive beam. Why are you doing this precasting and casting like this box section? Why are you concreting only a smaller area for precast? The other alternative is you can concrete 50 percent of the beam precast 50 percent as (())(24:22).

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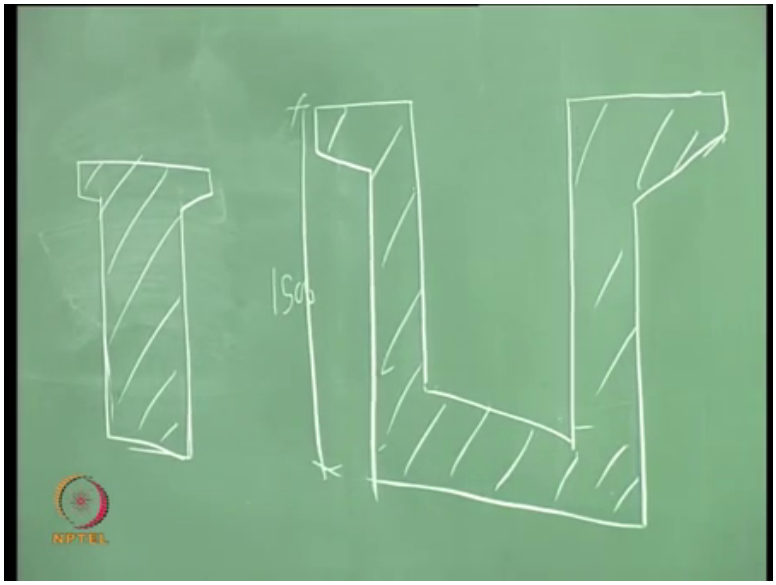

See there are two methods by which you can do the precast and composite construction one is you have only the skin for the, the other method is you cast 50 percent. Suppose this is 1500 so the whole thing can be precast like this here we are precasting only this much portion. What do we do a smaller portion which we are doing a full what is the reason? Generally this is preferred, why we do like this? Mainly to reduce the weight of handling when you want to handle the precast section.

If you do the total uhh 90 percent or 60 percent of the beam as the precast the weight will be very high. Generally they will be able to handle about 6 to 8 tons weight only. So to reduce the weight we are putting, I am giving a temporary strut otherwise it is a lift these are the hooks which are provided to lift. This location of the hooks is also important. There is a classical problem in structural engineering where to locate these hooks.

These hooks are located at the ends but generally it is located at the distance of 0.216 times length to get the hogging and bending sagging moment equal its a classical problem.

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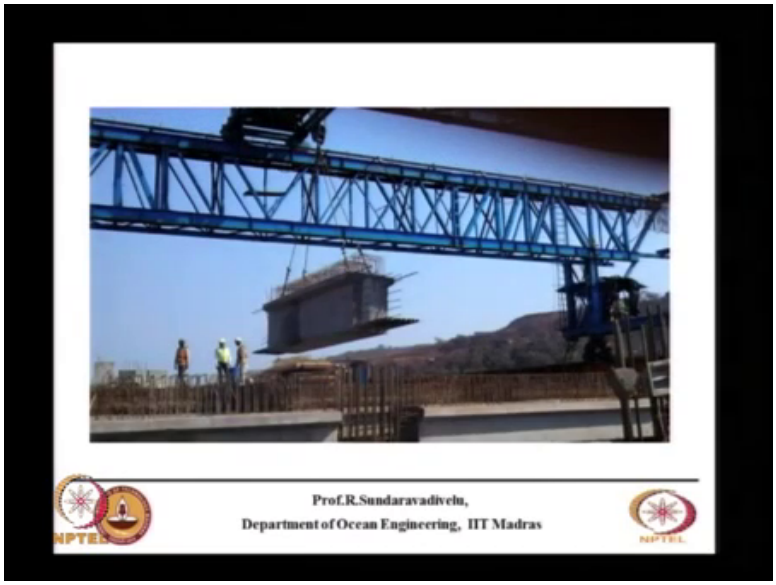

So this shows how they are doing the installation this is how they are lifting you have the hooks here then you are lifting it. So there are two stages of design one is for lifting what is the reinforcement required actually it is not done like that what they do is they do for the final stage of loading find out what are the reinforcement provided at the bottom and check whether that reinforcements are sufficient during lifting.

As you have seen in the initial slides the sagging moment is very high we have provided adequate reinforcement. So you can lift it from the end itself. And there are some reinforcement which are coming from the bottom itself. So these are the shear connectors

between the precast and inch to construction. These are the reinforcement which will go into the pile gap, pile reinforcement gap to get integrity. And your top reinforcement where the hogging moment has come that will be placed here and it will be continuous.

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So now they have placed. So whatever I explained earlier you can see the pile cap here, this is the pedestal which is placed. Here the depth of the beam is smaller here it is the precast beam which is placed and they have tied the reinforcement inside also. And the inside is hollow only here but they have completed the reinforcement to reduce the time required to tie the reinforcement, this is the other beam that is placed.

If this gap is not the same as maintained since we are providing 150 mm uhh pile cap you have a barring of atleast minimum 100 millimetre. One side may be higher 100 become 125 other side may become smaller 100 will become 75, minimum 75 may have to be provided. But this dimension is fixed we do not change it for different tolerances. But we adjust by providing adequate pile cap width.

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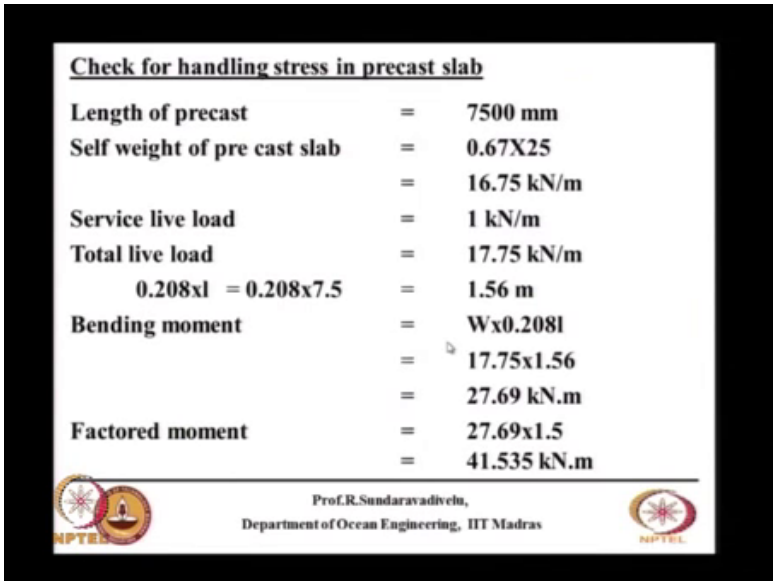

So this is a calculation that is done for handling stresses. You calculate basically the bending moment. Normally for limit stress design you multiply by the node factor to get the factored moment.

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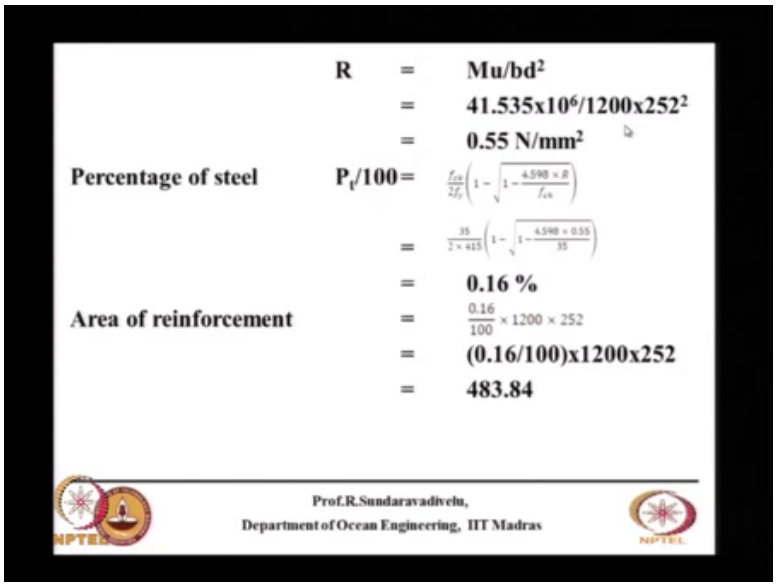

You calculate what is known as RU R that is Mu by bd square M is the bending moment b is the width of the beam and d is the precast uhh thickness effective depth. Then you get the percentage of the steel using this formula and provided accordingly.

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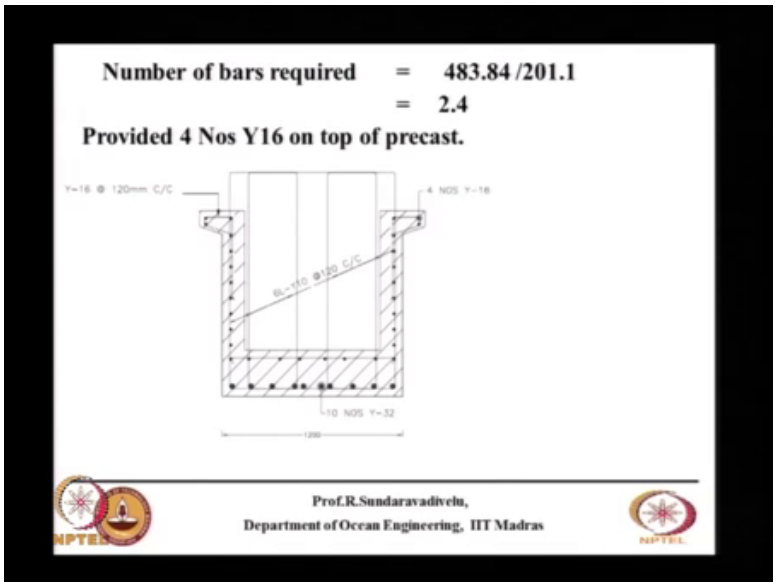

You calculate the number of berths and provide adequate berths like this. if you want to take the full width of the beam 1200 you need this shear reinforcement coming from the precast portion also into the incetive portion, you have to tie it together. You cannot assume the bond the interface bond between the precast and incutive construction. You need reinforcement and carriage into the precast and incetive that is done by this shear stirrups.

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This shows another view how they are placing these bars specially the bars you can see here. This is for the sagging moment same calculate you calculate or use this formula to calculate the percentage of steel then provide the percentage. You have to provide some minimum

percentage. What is a minimum percentage required for column? Column is 0.4 percent pile is 0.8 beam is 0.2 percent this is minimum reinforcement which you have to provide for the main bars.

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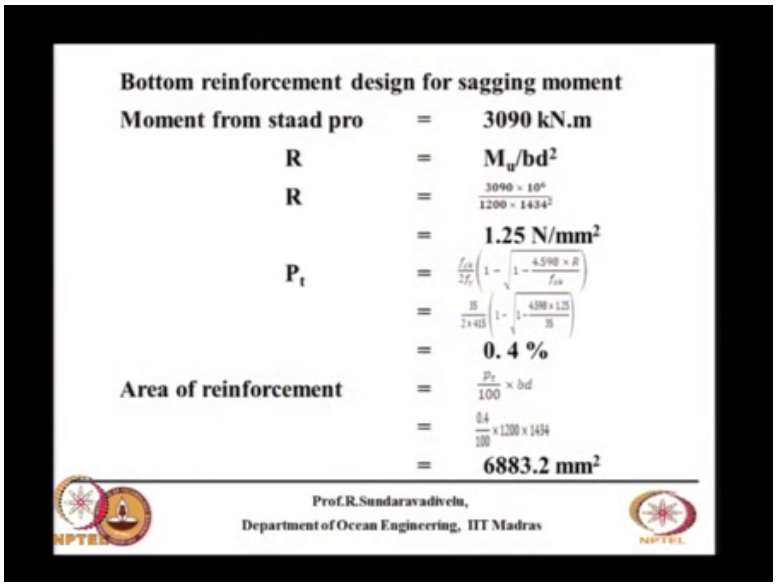

Whatever your calculation shows. You get 8.56 bars means you can either provide 9 bars or 10 bars depending on what you want to decide. Do not provide 8.56 means 12 bars and all. Provide very close to that. So there are two calculations one is 2 stages I said precast and the incetive uhh temporary stage of construction and final operation. Another thing is you design the reinforcement by this then you have to check for crack width.

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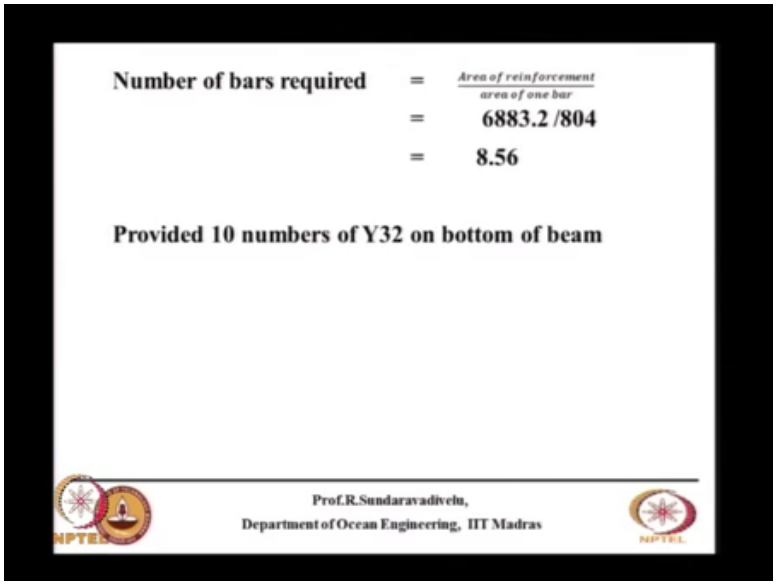

That is other type of design, so normally whatever reinforcement that is coming for stress level check you have to increase at least 30 to 60 percent to check for crack width, I will explain the crack width later.

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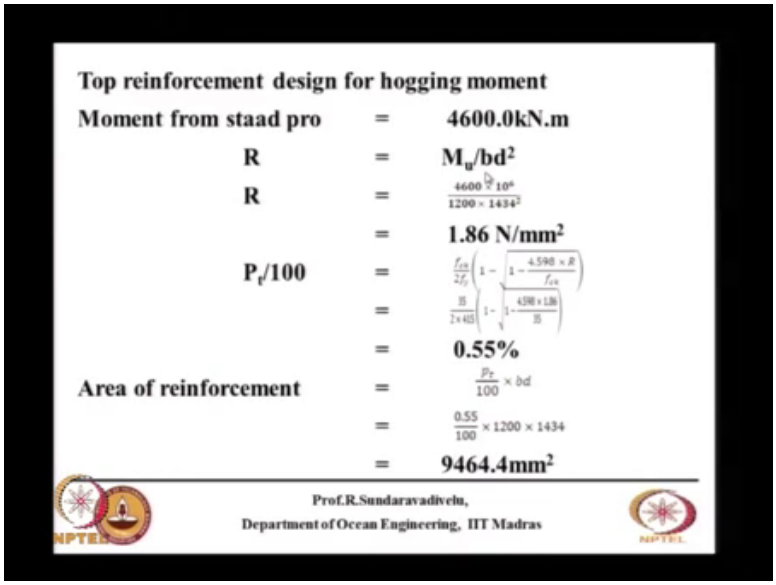

This is the top reinforcement for hogging moment, top reinforcement is coming for case 0.55 percent bottom is 0.4. So this R value typically it is better to restrict about 3 or 3.5 do not keep anything more than that value that is generally better. Do not increase the steel reinforcement more than 1 percent.

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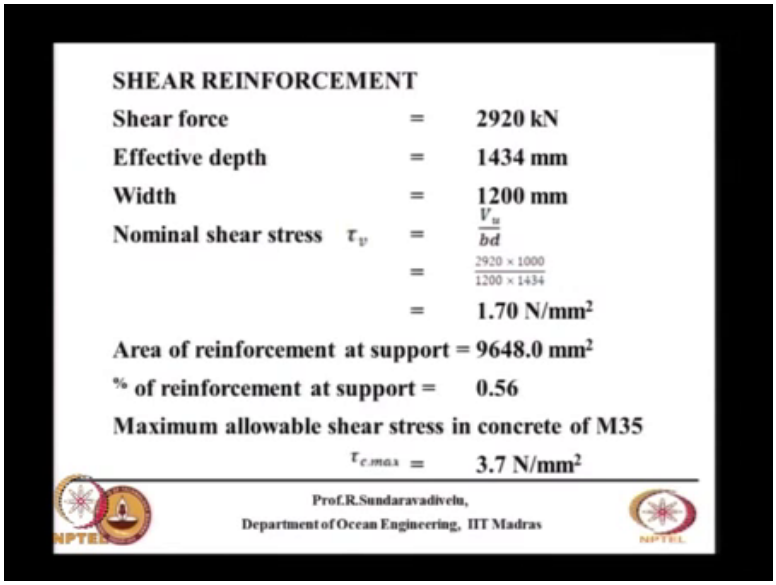

Then you have to design for shear there are uhh certain things to be calculate, one is you calculate the nominal shear stress that is a shear force divided by the width of the beam and depth of the beam you get the shear stress. This is the shear stress what is coming here.

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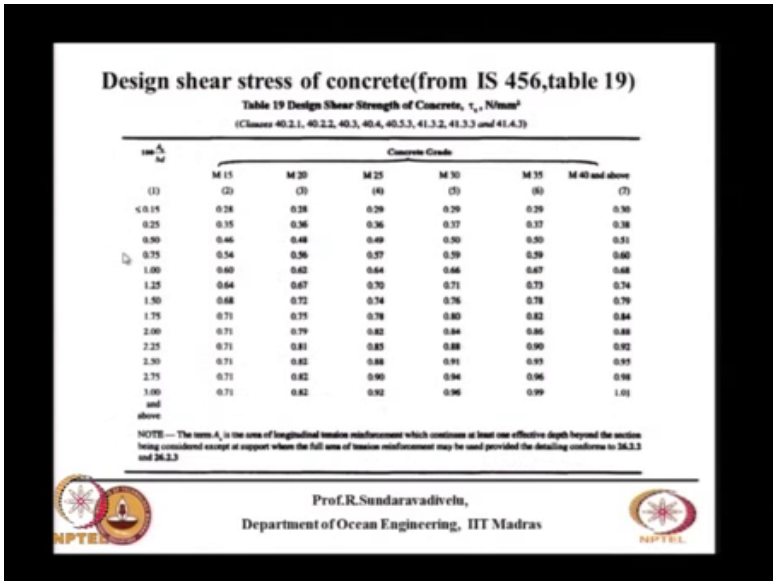

Then you have to go to this table this is an IS456 table 19 what it shows is what is the percentage of steel provided what is a grade of concrete and what is a allowable shear stress. So allowable shear stress depends on not only the grade of concrete but also the percentage of steel. Do not say percentage of steel percentage of tension steel, clear? Do not calculate the hogging moment percentage or sagging moment percentage and calculate.

Calculate what is the percentage of tension steel that is what is to be calculated suppose it is one percent grade of concrete is M 35 allowable shear stress is 0.67. So that you have to calculate then based on that for this particular case as a percentage of steel is 0.56 for tau c max is 3.7, I am sorry this is different that for any grade of concrete M 35 the maximum shear stress that can be allowed is 3.7 Newton per millimetre square.

The spacing provided should be less than the minimum shear spacing what you are getting. So you have to do this check. So to summarize again you have to check for shear you have to calculate the nominal shear stress. This should be less than the maximum available shear stress. Then you have to calculate what is the shear to be taken by the stirrups. Then you find out the spacing.

The spacing should be less than the spacing required for minimum shear reinforcement that depends on the grade of steel and diameter of shear stirrup what you are providing. The spacing would be calculated using this formula.

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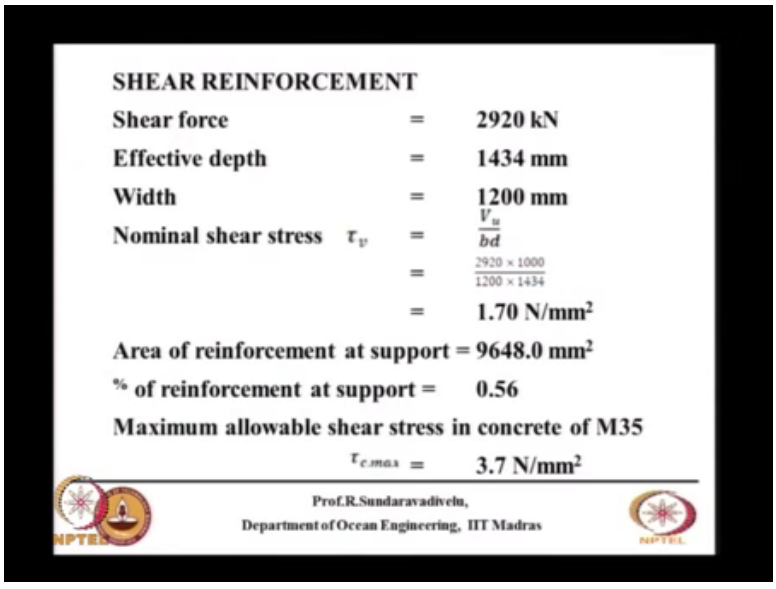

Suppose this shear stress what you are calculating is more than 3.7, you have to redesign the section, there are two stress we are talking one is the nominal shear stress another is the maximum allowed shear stress for a particular grade of concrete. If the nominal shear stress is more than the maximum allowable shear you have to either increase the grade of concrete or you have to revise the section.

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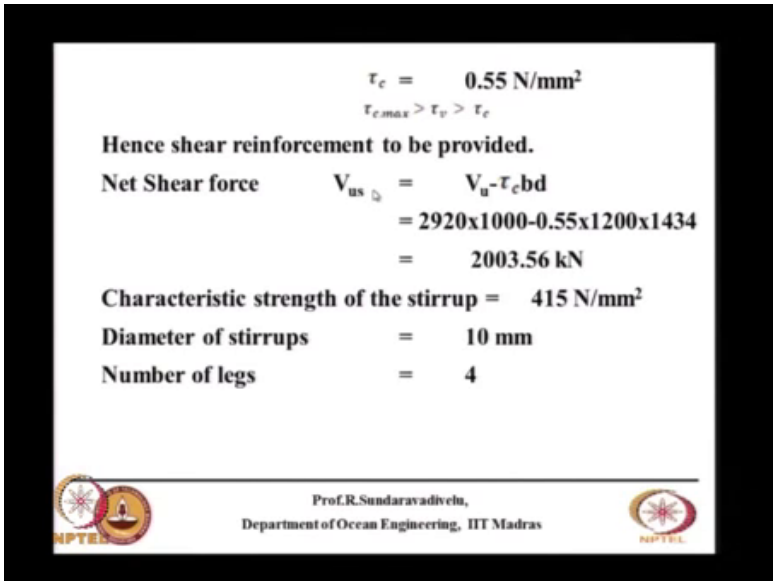

This is the permissible shear stress, so what you have to calculate is this V us that is a shear force to be taken by the reinforcement is a shear force minus tau c, tau c is coming from this table , tau c into b into d and for this there is a formula to calculate the spacing for the provided diameter of the stirrup and accordingly you can provide we are providing a 10 mm bars 6 legs, there are 6 legs of reinforcement we are providing.

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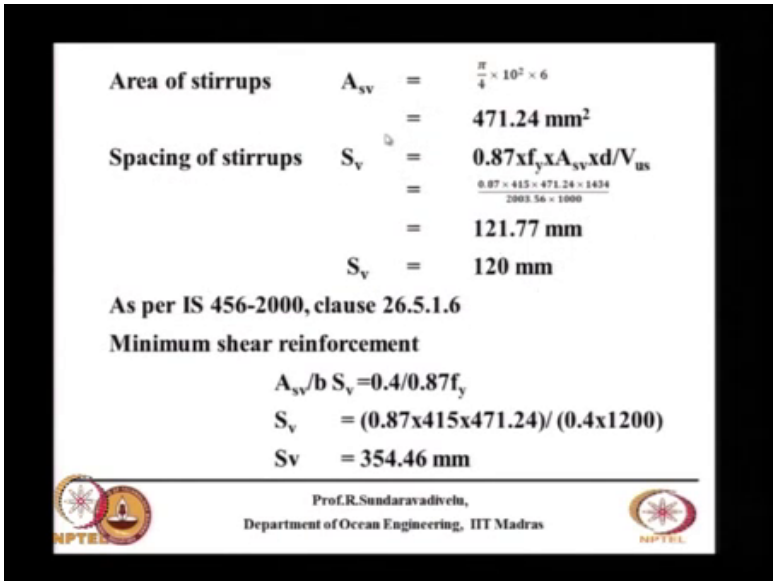

You calculate the area of stirrups and then what you do is, you calculate the spacing it is coming 121.77 you provide a spacing less than this 120 millimetre centre to centre. This also should not become very close, generally the shear stirrup spacing is about 100 millimetres not

less than that. Then there is a class for minimum shear reinforcement, you check what is the minimum shear reinforcement what is the spacing required.

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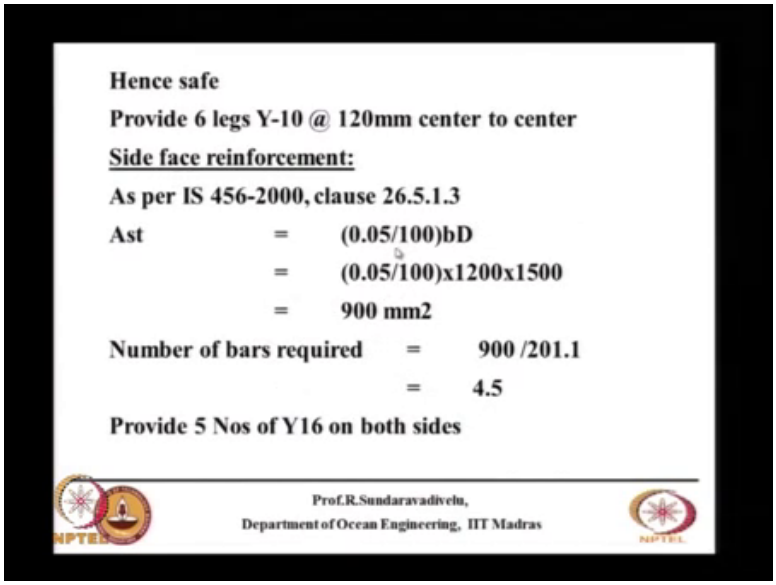

Then you have to provide side face reinforcement, side force reinforcement is what is provided at these sides what you are showing.

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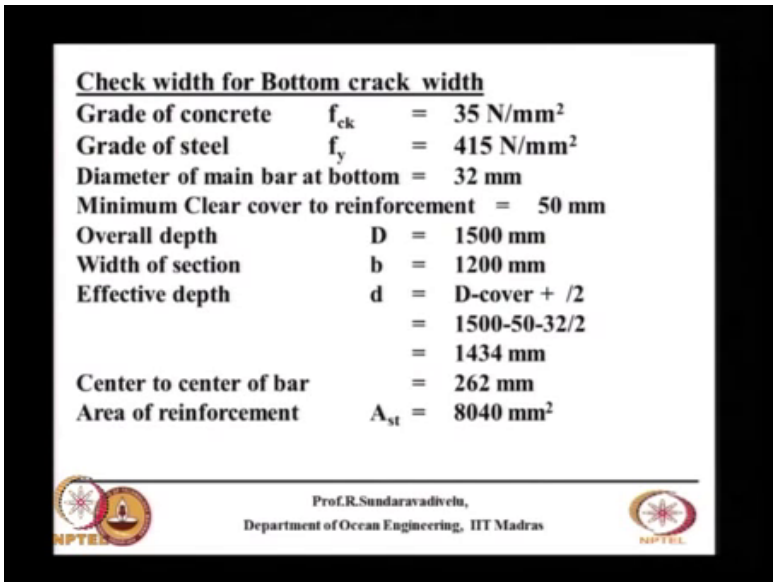

You cannot leave the skin like this. This is called as the side face reinforcement. The side face reinforcement also about some minimum percentage is there that is 0.05 times sectional area that you calculate

So this is 0.05 percent of b into d, you find out how many box are required and provide the side face reinforcement. Then we have to check for crack width, check for crack width is

basically you are calculating what is the stress in steel and accordingly you will be providing the reinforcements. I will go from the reverse side.

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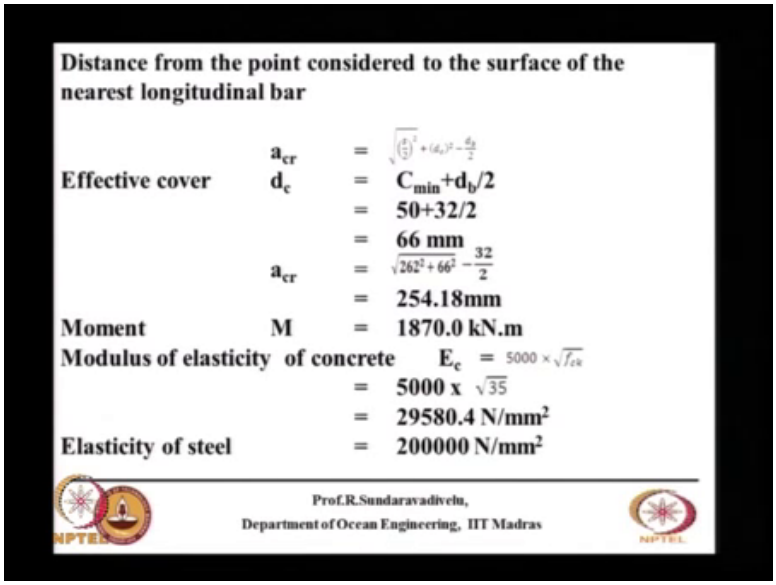

So this is the formula for crack width WCR is the crack width. There is a permissible crack width it depends on the environmental condition.

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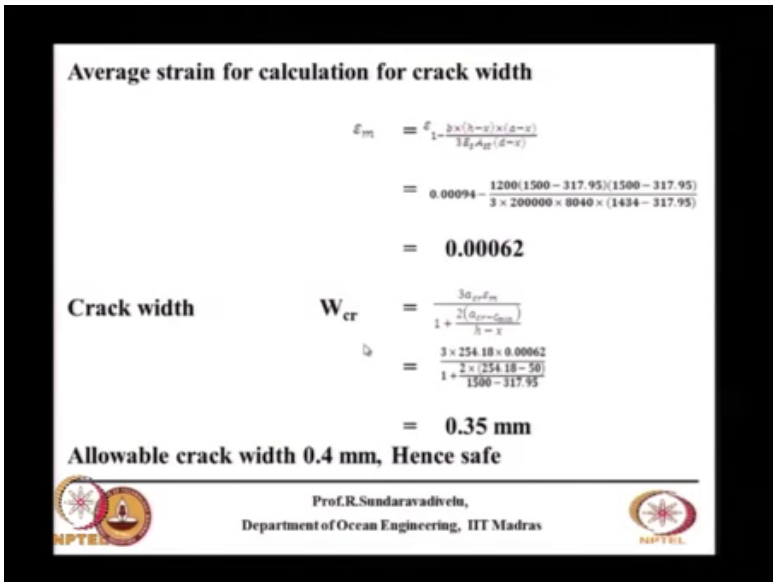

Generally the crack width is 0.1 millimetre, 0.2 millimetre and 0.3 millimetre, this is in the splash zone this is in the submerged zone this is in the mud zone. So suppose there is a pile here this is your water level, this is your mud level. So this is your mud zone this is your submerged zone so the water goes up and down here during tidal, this is your and above this

is called as the beam. This you can call it as atmospheric zone. This also you may provide about 0.3 mm.

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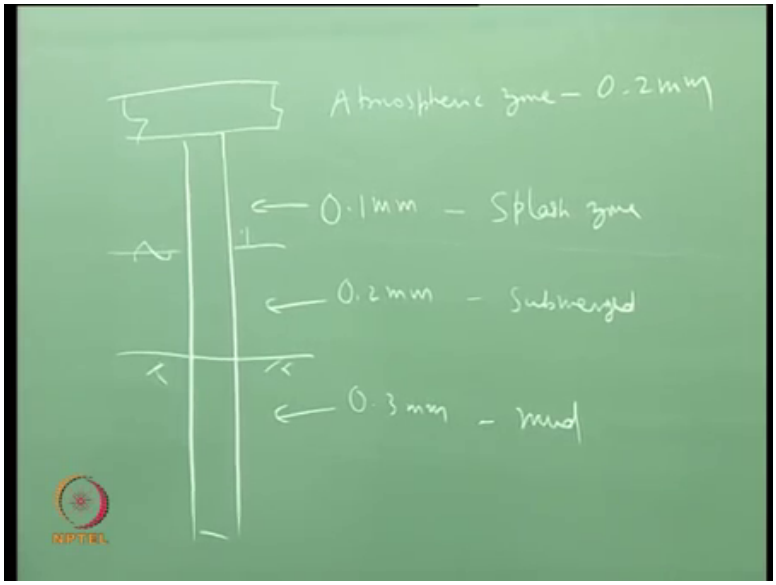

So you have to calculate the crack width, this is a formula which I calculate the crack width but generally the crack width depends on the stress in steel by young's modulus, this gives the epsilon, epsilon is the strain in steel.

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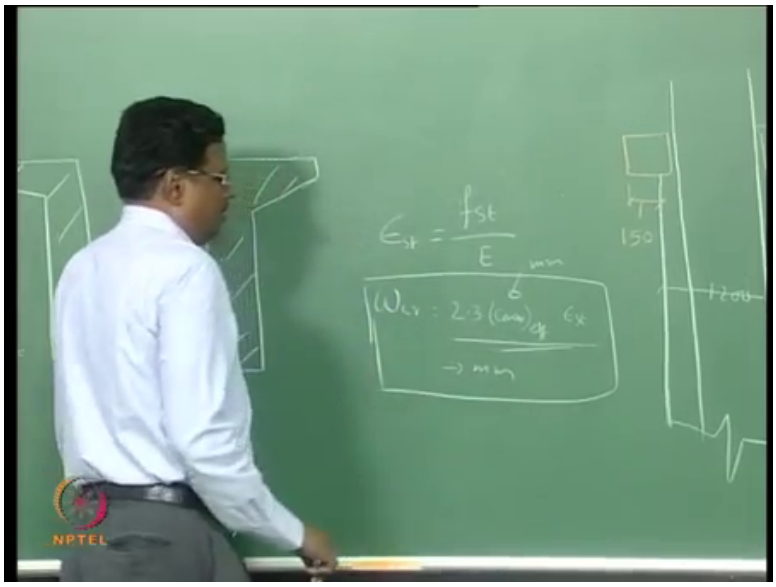

So approximate formula for crack width is the old formula designing 2.3 uhh cover effective replied by epsilon xt. So if you substitute cover in millimetre the crack width will come in limit. This is an approximate formula 2.3 is a coefficient cover is the effective cover suppose

it is a 75 millimetre is clear cover effective may be 90 millimetres or 100 millimetres epsilon s t is the stress in steel. So if you want to reduce the crack width you have to reduce the stress in steel. You cannot reduce the young's modulus it is the same.

But you want to reduce the crack width do not reduce the cover,ok do not reduce the cover if you want to reduce the crack width cover is for durability that is a different aspect. This is a coefficient but here in this particular case this formula is a little bit exhaust you, here also they calculate this epsilon 1that is f s by e s into h minus x into d minus x.

So this epsilon 1 is similar to epsilon s t that is f s by e s into h minus x into d minus x. So uhh in epsilon s t what I have written is the stress the stress in steel at this centre of the reinforcement epsilon 1 is uhh I think at the bottom surface. It is weighted h minus x and d minus x is coming.

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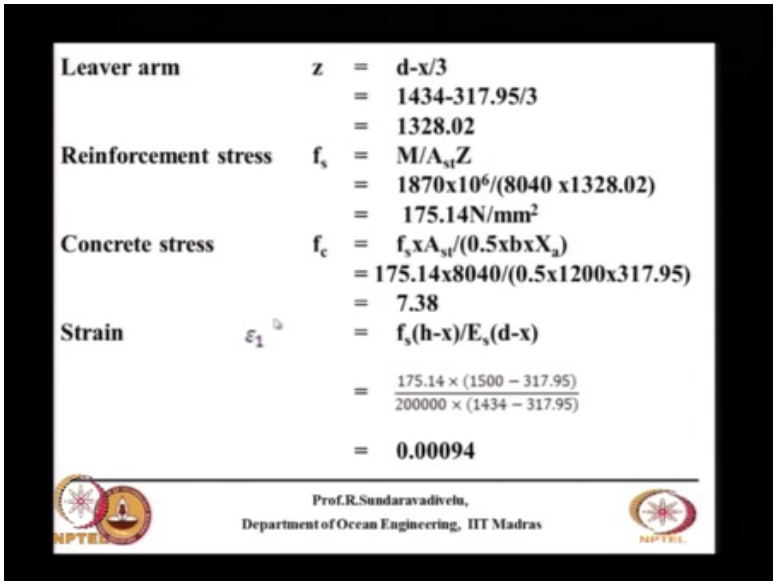

Then there is tensioning effect and for that this percentage is reduced from the strain that is called as a epsilon m and this formula ACR is distance between so it is using I was using this one effective cover what they are using is this distance is called as ACR. The maximum distance to reinforcement bar from there surface

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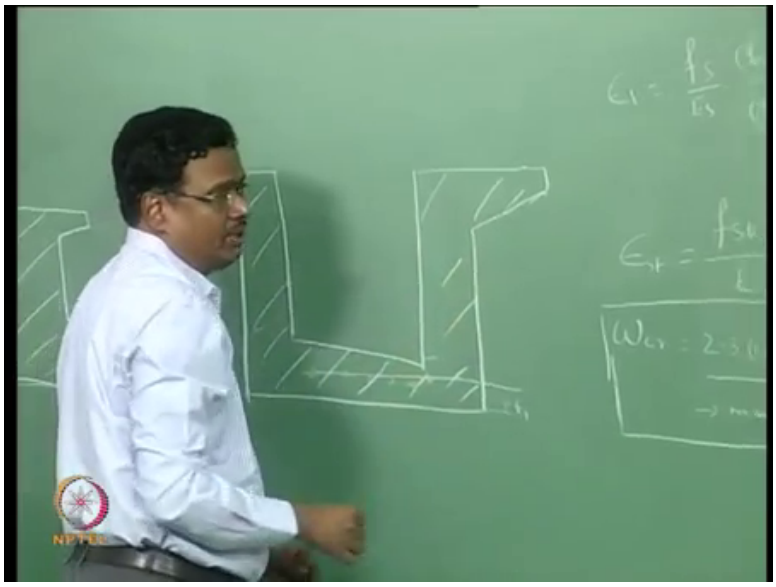

These are some modifications which is done, this is wrong I simply has made my students 0.4, 0.4 is never allowed we got this (())(40:17) putting. It is never allowed do not go by this it should not be more than 0.3.

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You cannot leave the skin like this. This is called as the side face reinforcement. The side face reinforcement also about some minimum percentage is there that is 0.05 times sectional area that you calculate

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So once you place the beams precast then you put some top reinforcements when they put these precast slabs so we will discuss in the next class about the design of slab.