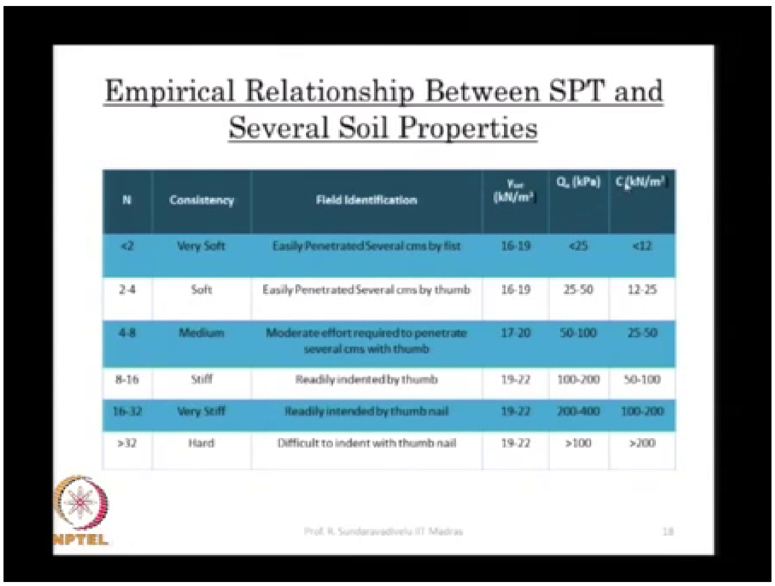
Port and Harbour Structures
By Professor R. Sundaravadivelu
Department Of Ocean Engineering,
Indian Institute of Technology Madras
Module 11 Lecture 47
Empirical Relationship between Spt
And Several Soil Properties

In this class we will see the empirical relationship between spt, spt means standard penetration test and several soil properties, several soil properties means Gama saturated that is density of the soil saturated density.

(Refer Slide Time: 00:31)

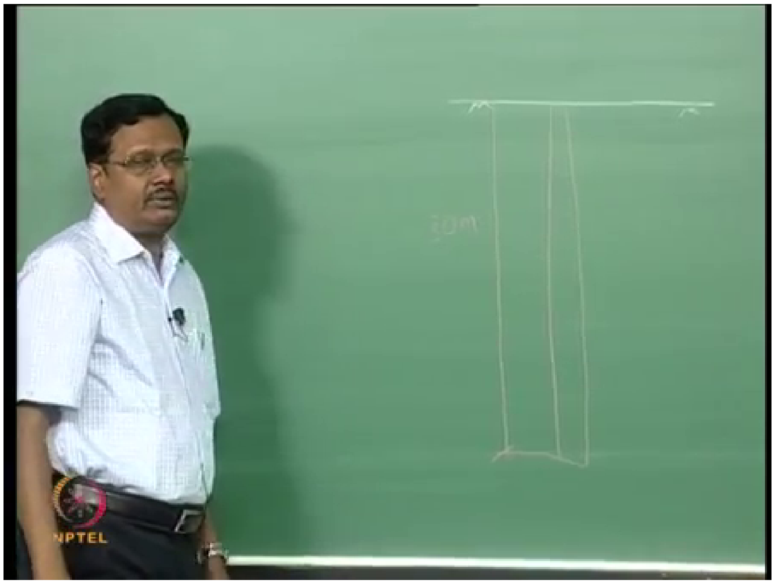


N	Consistency	Field Identification	γ_{sat} (kN/m³)	Q_u (kPa)	C_u (kN/m²)
<2	Very Soft	Easily Penetrated Several cms by fist	16-19	<25	<12
2-4	Soft	Easily Penetrated Several cms by thumb	16-19	25-50	12-25
4-8	Medium	Moderate effort required to penetrate several cms with thumb	17-20	50-100	25-50
8-16	Stiff	Readily indented by thumb	19-22	100-200	50-100
16-32	Very Stiff	Readily intended by thumb nail	19-22	200-400	100-200
>32	Hard	Difficult to indent with thumb nail	19-22	>100	>200

Q is the compressive strength of the soil c is called as a cohesion or shear strength of the soil, the consistency of the soil can be define in three terms one is soft another is stiff the third one is hot. I will be giving different types of classification from different text books, there are certain field identification that is possible one is easily penetrated several centimeters by thumb.

There is very soft clay is also there that is easily penetrated that is less than 2 this is a type of soil in which we are going to design the diaphragm wall n value is less than 2 that means the sp2 spoon will go on its own weight without any blows. Then it may explain what do they do what kind of test they do to get the standard penetration test

(Refer Slide Time: 01:36)



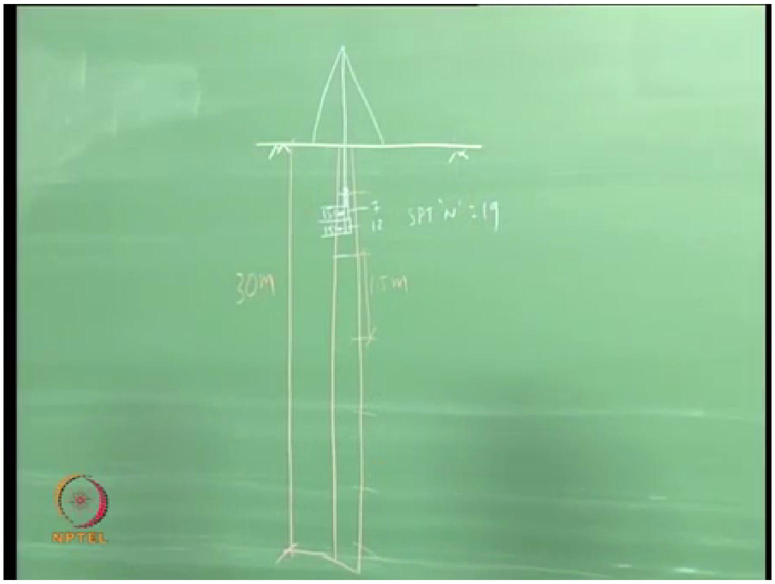
See suppose this is your bed this can be done below also below sea bed also but on land how they do I will tell they will go very deep generally they go about 30 meter deep or off shore structures generally for about 30 meter they do the test they do the test at different intervals the spt test typically the interval is about 1.5 meters.

But this varies suppose there is a layer changing the layer is only 1 meter thick then they do at that particular layer what they do is there is a tie pod through which there is a spoon it comes here there is a spoon here they raise the spoon and drop it whereas some standard weight of the spoon is there standard height where they are lifting is there they lower it that is one blow then again another blow third blow, fourth blow like that it goes for about 15 centimeters.

Before coming to this level they will remove the soil here so they bore it and remove the soil that means the soil here will be disturbed so they neglect the first 15 centimeter reading then they go to the next 15 centimeter then they go to the next 15 centimeter, 15 centimeter they write let us say about 7 this as 12 then spt n value is 90 this is for 15 centimeter and 15 centimeter then they bore up to this then they conduct at the next point like that they continue to do it.

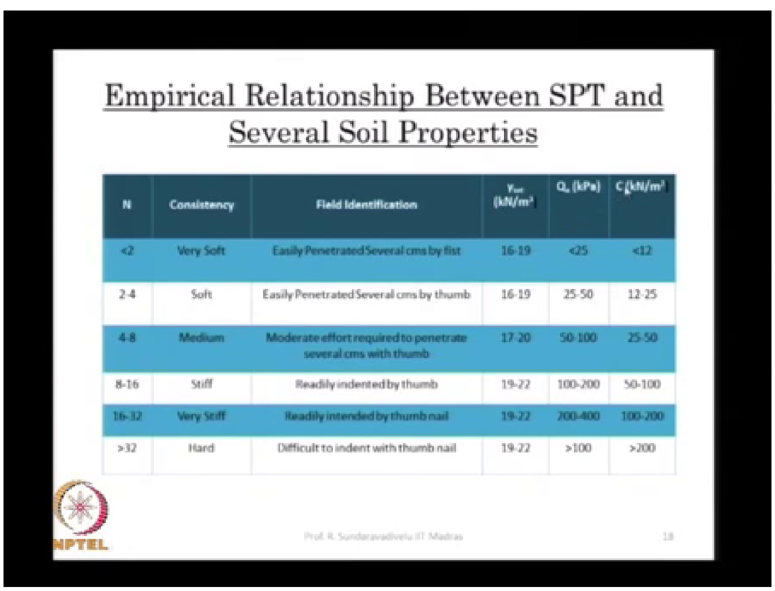
They do other tests also they take the sample they do a track silt strength

(Refer Slide Time: 03:40)



So many other studies they do it but mainly we rely on this sptn test any doubts in sptn test, standard penetration test standard means there is a standard, standard means weight of the spoon is standard, procedure is standard, penetration means how much it penetrates 15 centimeter suppose you go on hitting 100 blows and there is no penetration don't continue to do it, you stop it.

(Refer Slide Time: 04:20)



Empirical Relationship Between SPT and Several Soil Properties

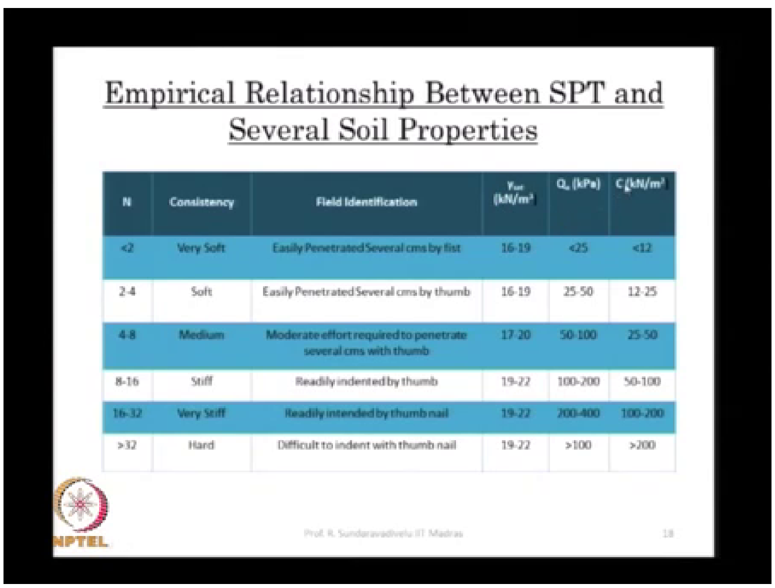
N	Consistency	Field Identification	γ_{sat} (kN/m³)	Q_u (kPa)	C_u (kN/m²)
<2	Very Soft	Easily Penetrated Several cms by fist	16-19	<25	<12
2-4	Soft	Easily Penetrated Several cms by thumb	16-19	25-50	12-25
4-8	Medium	Moderate effort required to penetrate several cms with thumb	17-20	50-100	25-50
8-16	Stiff	Readily indented by thumb	19-22	100-200	50-100
16-32	Very Stiff	Readily intended by thumb nail	19-22	200-400	100-200
>32	Hard	Difficult to indent with thumb nail	19-22	>100	>200

Prof. R. Sundaravadivelu IIT Madras 18

Maximum they do for 100 blows, 100 blows 10 centimeters penetration for 30 centimeter sptn value will be 300 if it is less than 2 generally the saturated density will be lesser, c value is taken as 6 times n in kilo Newton per meter square, 6 times n value is taken as c value 6 into 2 is 12, this is 2 to 4 that is 12 to 24, 4 to 8 24 to 48 so 6 times n be taken as c, q will be 2c (04:52 labeling) by this 2 as the consistency of the soil increases the density of the soil also will be increase.

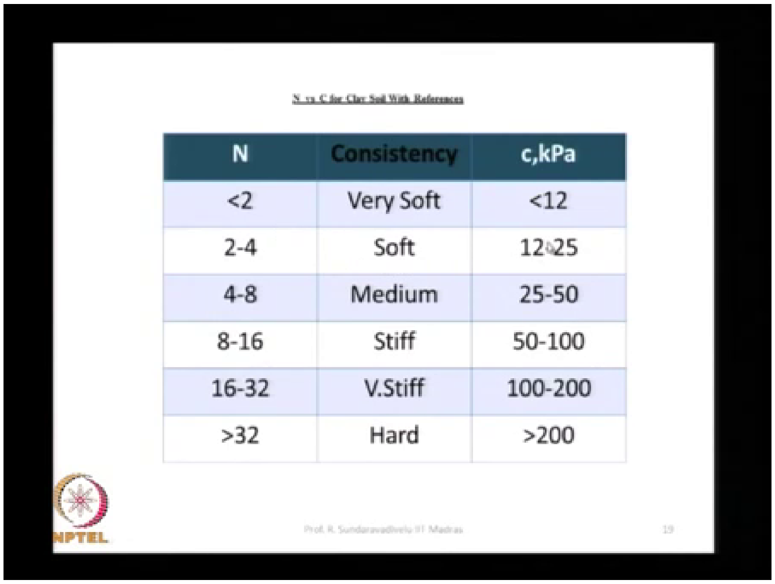
Saturated density means you take the sample the sand it can be easily explained you pour water it will take tin saturation certain quantity of water then take the density that is soil is a three phase medium you will have soil particles water and air, if the air waves are completely filled with water then it is a saturated density.

(Refer Slide Time: 05:29)



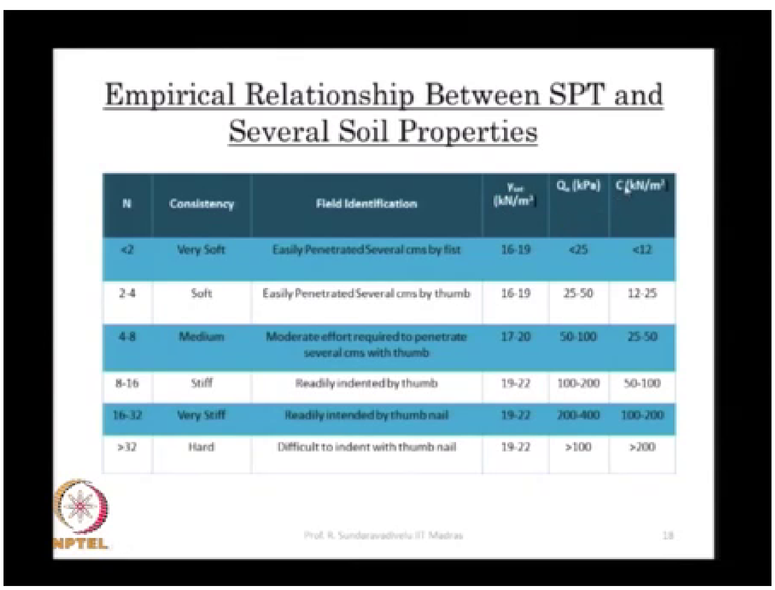
Rock is similar to clay soil only the n value can go more than hundred it may go to 400 500 like that.

(Refer Slide Time: 05:40)



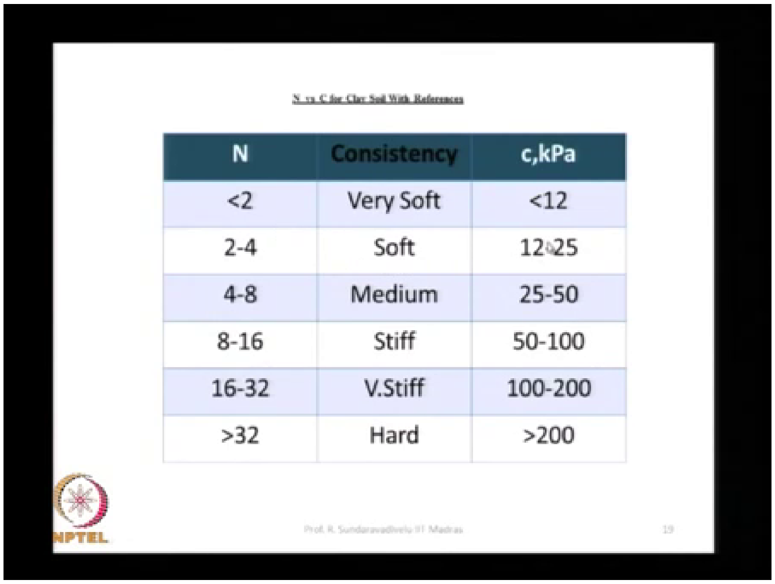
So here also the same thing only is given In a different format.

(Refer Slide Time: 05:47)



So here very soft soft medium stiff very stiff and hard.

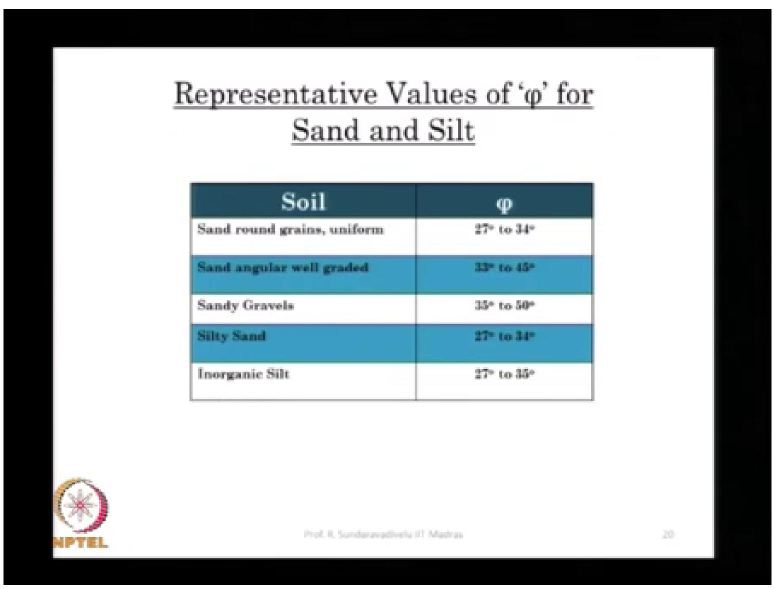
(Refer Slide Time: 05:50)



N	Consistency	c,kPa
<2	Very Soft	<12
2-4	Soft	12-25
4-8	Medium	25-50
8-16	Stiff	50-100
16-32	V.Stiff	100-200
>32	Hard	>200

That is what is written here so we can very easily understand this generally c greater than 200 kilo Pascal is some kind of weak rock

(Refer Slide Time: 06:02)

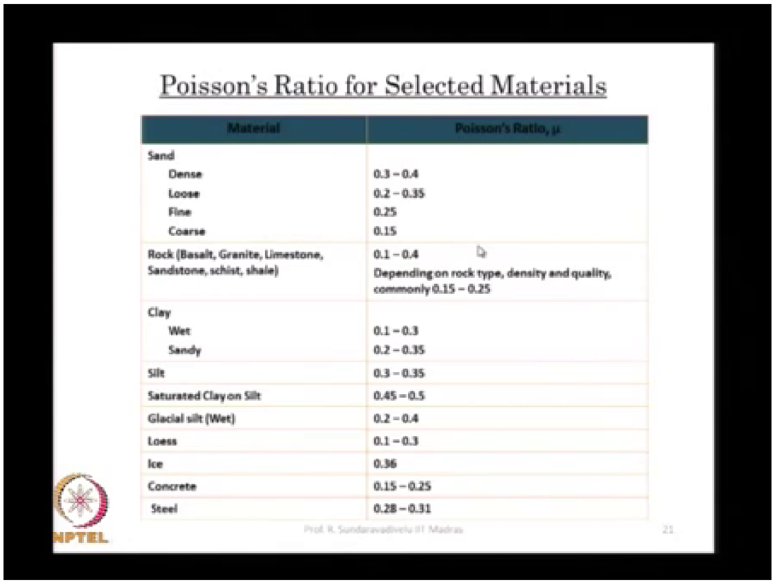


Soil	φ
Sand round grains, uniform	27° to 34°
Sand angular well graded	33° to 45°
Sandy Gravels	35° to 50°
Silty Sand	27° to 34°
Inorganic Silt	27° to 35°

then we have other type of soil that is a sand, sand will have 5 values that is given here different type of sand, sand and silt are same in the sense silt will have particle size smaller than the sand.

We may have clay silt in which it will have cohesion. If you have a sandy silt it will have not have any cohesion the 5 values are given varying from 27 degrees to 50 degrees the gravel is 50 degree I don't think this is correct it may not be so high.

(Refer Slide Time: 06:40)



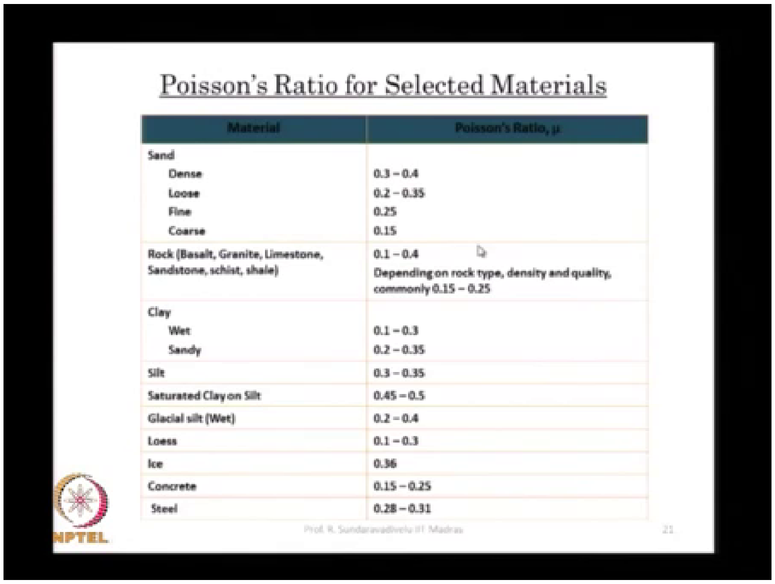
Poisson's Ratio for Selected Materials

Material	Poisson's Ratio, μ
Sand	
Dense	0.3 – 0.4
Loose	0.2 – 0.35
Fine	0.25
Coarse	0.15
Rock (Basalt, Granite, Limestone, Sandstone, schist, shale)	0.1 – 0.4 Depending on rock type, density and quality, commonly 0.15 – 0.25
Clay	
Wet	0.1 – 0.3
Sandy	0.2 – 0.35
Silt	0.3 – 0.35
Saturated Clay on Silt	0.45 – 0.5
Glacial silt (Wet)	0.2 – 0.4
Loess	0.1 – 0.3
Ice	0.36
Concrete	0.15 – 0.25
Steel	0.28 – 0.31

Maximum is 35, 38 only then we have poison's ratio you know what is poison's ratio, what is poison's ratio? Lateral change to longitudinal strain, generally it is about 0.3 this is required because when you do the analysis the earth pressure is a lateral earth pressure. And this lateral earth pressure when you are trying to find out this has some influence of poison's ratio.

Another thing is when you do some analysis we estimate the spring constant that is reaction by the soil passive force we cannot estimate we have to find out a reaction for which we idealize that by a spring element or calculating that also we need the poison's ratio.

(Refer Slide Time: 07:35)

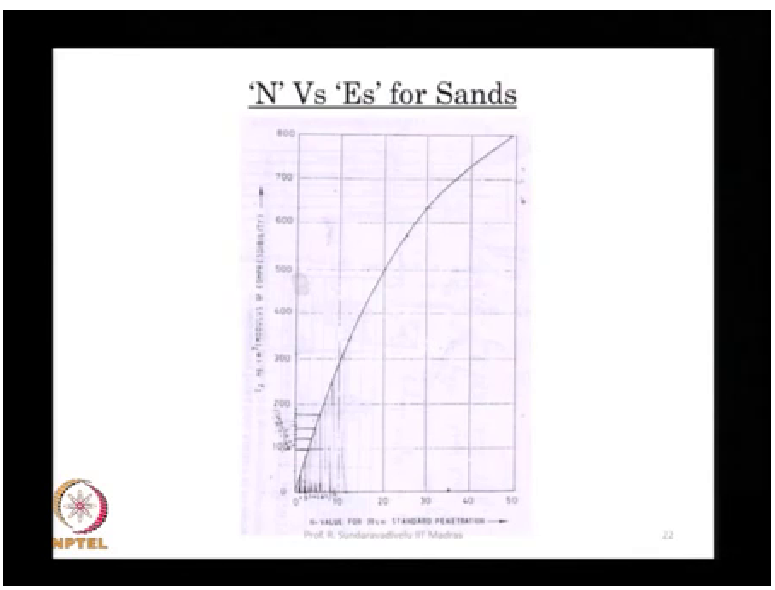


Poisson's Ratio for Selected Materials

Material	Poisson's Ratio, μ
Sand	
Dense	0.3 – 0.4
Loose	0.2 – 0.35
Fine	0.25
Coarse	0.15
Rock (Basalt, Granite, Limestone, Sandstone, schist, shale)	0.1 – 0.4 Depending on rock type, density and quality, commonly 0.15 – 0.25
Clay	
Wet	0.1 – 0.3
Sandy	0.2 – 0.35
Silt	0.3 – 0.35
Saturated Clay on Silt	0.45 – 0.5
Glacial silt (Wet)	0.2 – 0.4
Loess	0.1 – 0.3
Ice	0.36
Concrete	0.15 – 0.25
Steel	0.28 – 0.31

generally poison's ratio is less than 0.3 for soil and for clay it is in between 0.1 to 0.3. Sand it is between 0.15 to 0.4, rock is similar to concrete it can vary from 0.1 to 0.4, 0.1 is a very weak rock, concrete is between 0.15 to 0.25 steel is between 0.28 to 0.31

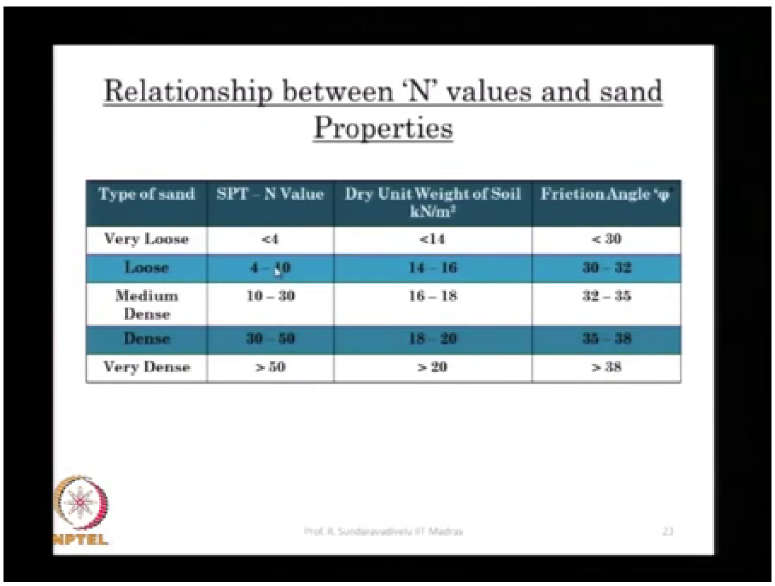
(Refer Slide Time: 08:04)



When you want to calculate the spring constant we also need the young's modulus. What is young's modulus? Stress by strength so when you want to find out the reaction by the soil we need the spring force, spring force is related to stress, stress is related to young's modulus.

So we have sptn value as this young's modulus n value is given in this axis up to 50 and this is the young's modulus in kg per centimeter square can take this value what is the young's modulus of concrete related to the grade of concrete 5000 into root of fck that is the young's modulus of concrete and steel that is a constant value, whatever be the grade of steel.

(Refer Slide Time: 09:17)

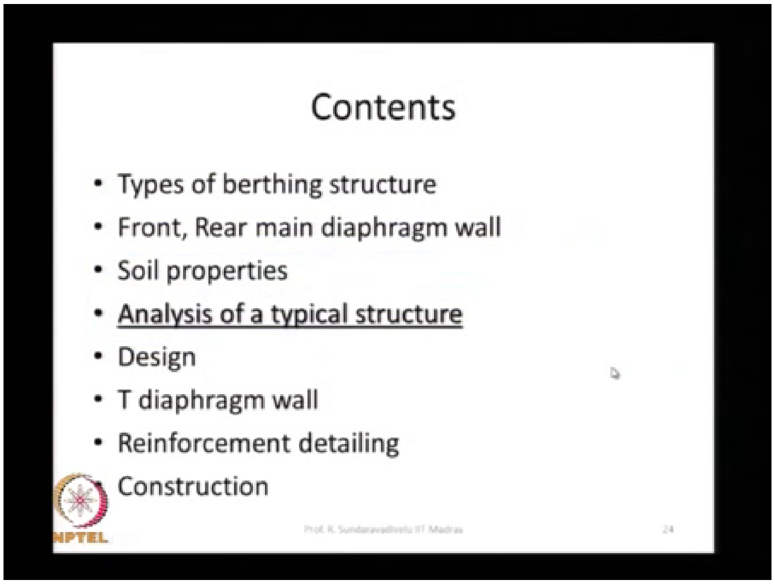


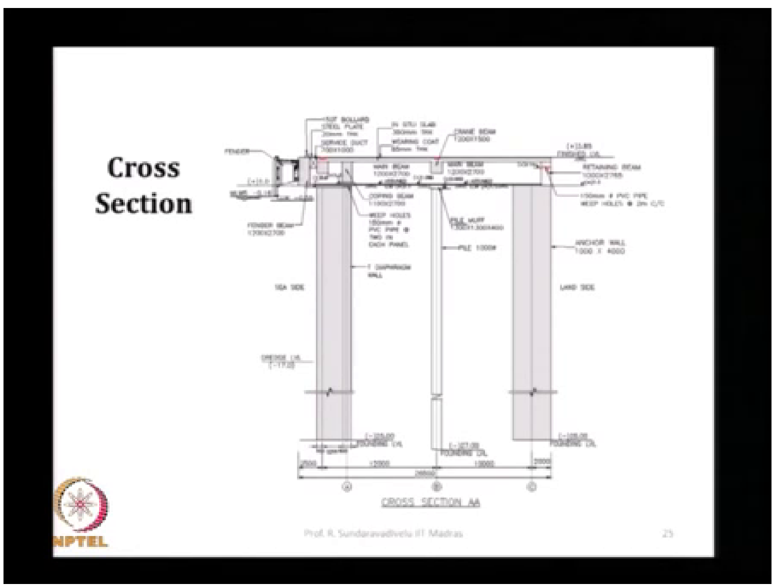
Type of sand	SPT – N Value	Dry Unit Weight of Soil kN/m²	Friction Angle 'φ
Very Loose	<4	<14	< 30
Loose	4 – 10	14 – 16	30 – 32
Medium Dense	10 – 30	16 – 18	32 – 35
Dense	30 – 50	18 – 20	35 – 38
Very Dense	> 50	> 20	> 38

So just like clay were we are given different properties here also we are giving different properties of sand. We classify the sand as very loose medium dense and very dense, I explained about this sptn value as you see here a very small n value less than 4 we have very loose 10 to 30 is medium dense greater than 50 is very dense, sand liquefies when you have a earthquake then the sand liquefies sptn value less than 10 then it is a very loose sand then it liquefies then you have to do ground improvement for that here we are giving the dry unit of soil.

That means you take the sand sample and dry it in the oven you don't have any water three phase medium we have only sand particle and voids then you calculate the weight that is your dry unit weight it is less than 14 16 to 18 and this is greater than 20, friction angle this is less than 30 this is greater than 38 the limit is around 38 only

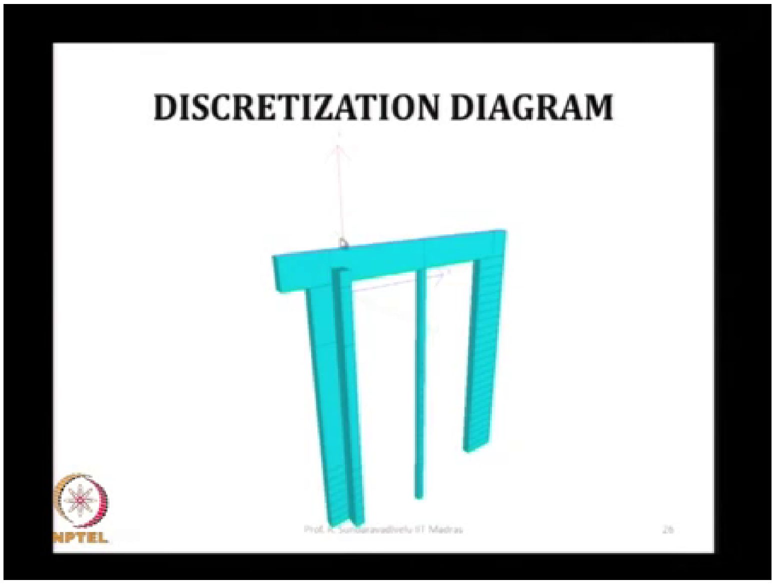
(Refer Slide Time: 10:33)





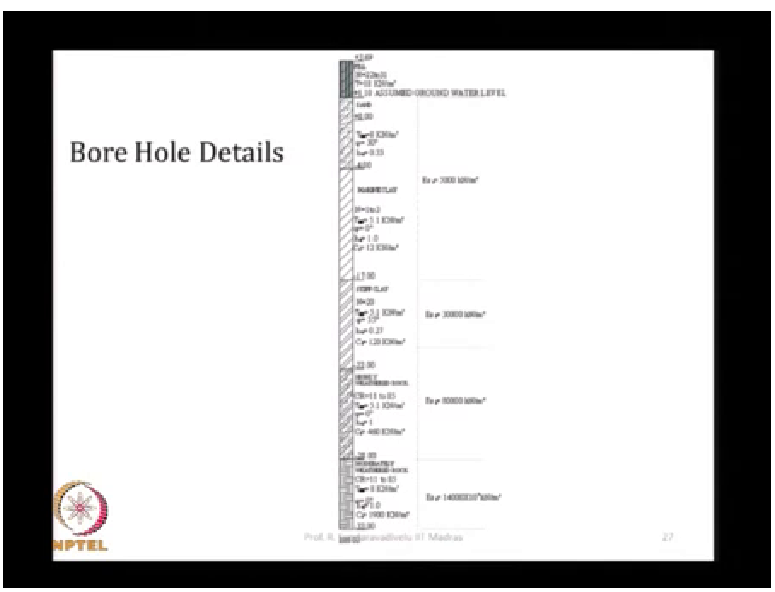
Then we will go to the analysis of the structure what has failed Nearby there was another structure that was coming up. For which we have designed the structure, this is the diaphragm wall, this is an anchor wall this is a pile and we have a cross beam connecting them there are some beams here placed and another beam here retaining beam there are two beams which are crane beams there is a fascia beam which is used to fix the fender.

(Refer Slide Time: 11:15)



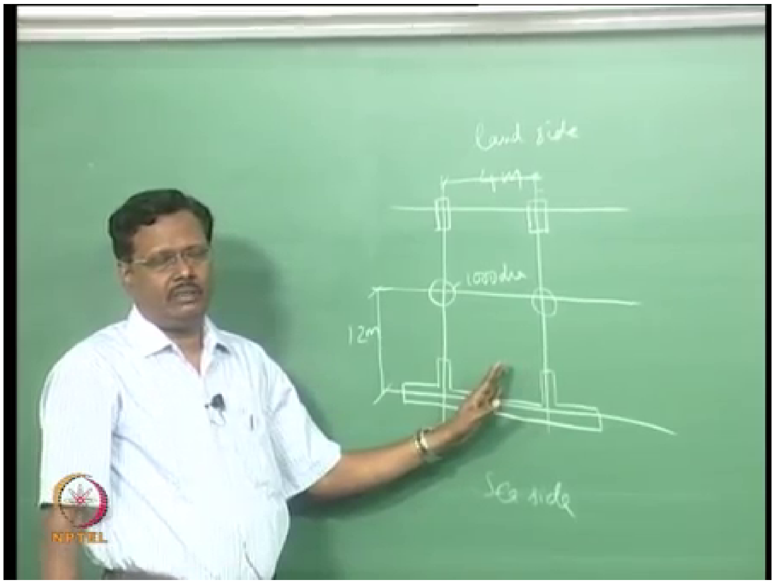
This shows the 3d idealization of the structure using Stad pro it's a standard software used for structural analysis and design. We will be seeing this in a next class how to generate the data for this, this is a T diaphragm wall this is a circular pile it's a rectangular anchor wall there is a beam which is connecting we have taken it a typical 2d structure for the analysis.

(Refer Slide Time: 11:52)



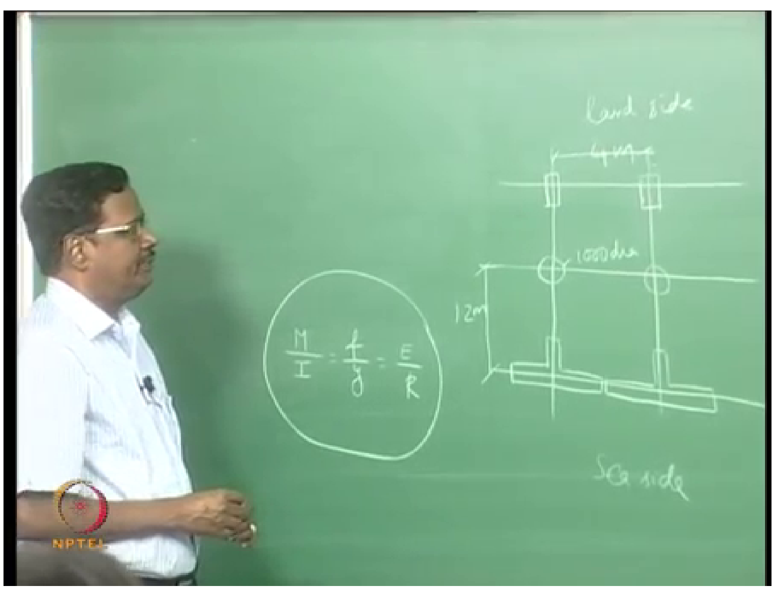
This shows the bore hole details.

(Refer Slide Time: 12:00)



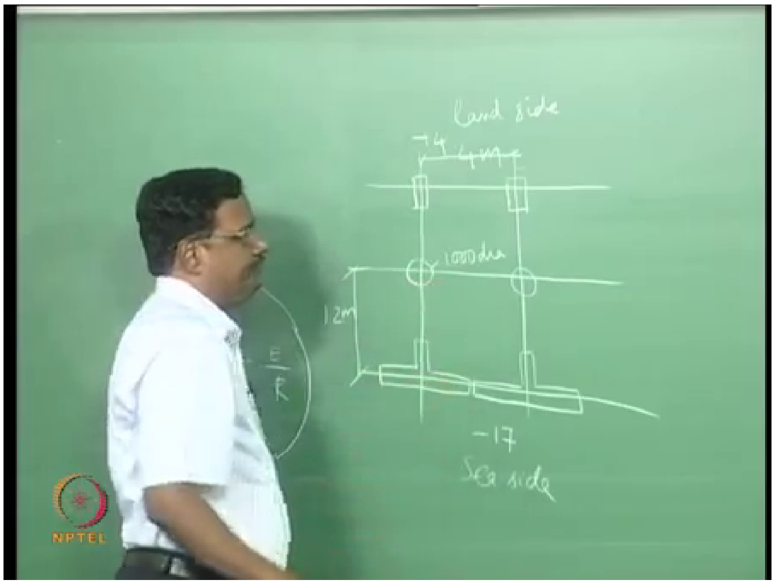
The sea side this side is a land side so you have T diaphragm wall I will tell you why we are using T diaphragm wall because it needs more moment of inertia.

(Refer Slide Time: 13:32)



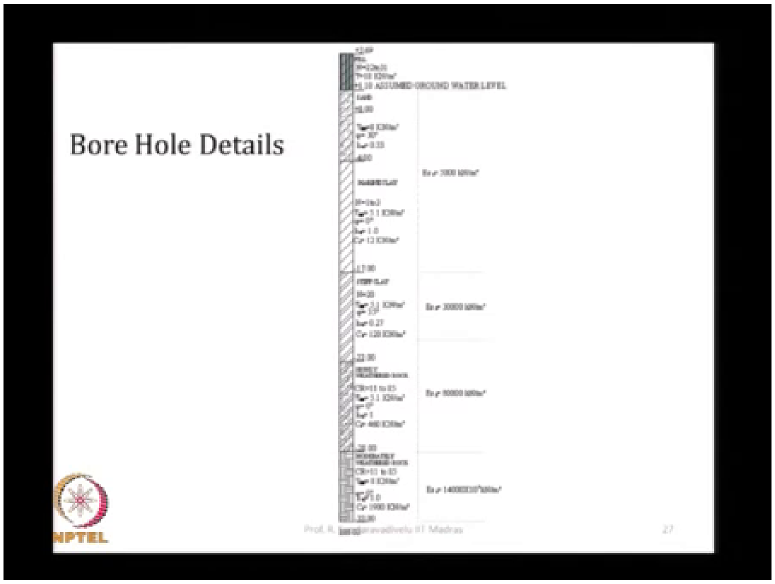
So this formula you remember this is the you try to understand how the derivation is what are the limitations what are the assumptions for this formula whenever you want to do structural analysis we will be using all this parameters one is the bending moment another is moment of inertia, stress, y is the distance to the extreme fiber e is the young's modulus r is the radius of the gyration, all these things are important mainly you have to check for deflection.

(Refer Slide Time: 14:14)



As well as stresses in the number if you do side by side like this, this goes as a continuous structure to retain the soil here you will be dredging up to minus 17 here the top level may be plus 4 approximately so here it is minus 17 it is plus 4 that means inside this portion there is some soil which will be retain by this structure.

(Refer Slide Time: 14:25)



So when you started doing this analysis we have taken the soil profile exactly and the location of the berth.

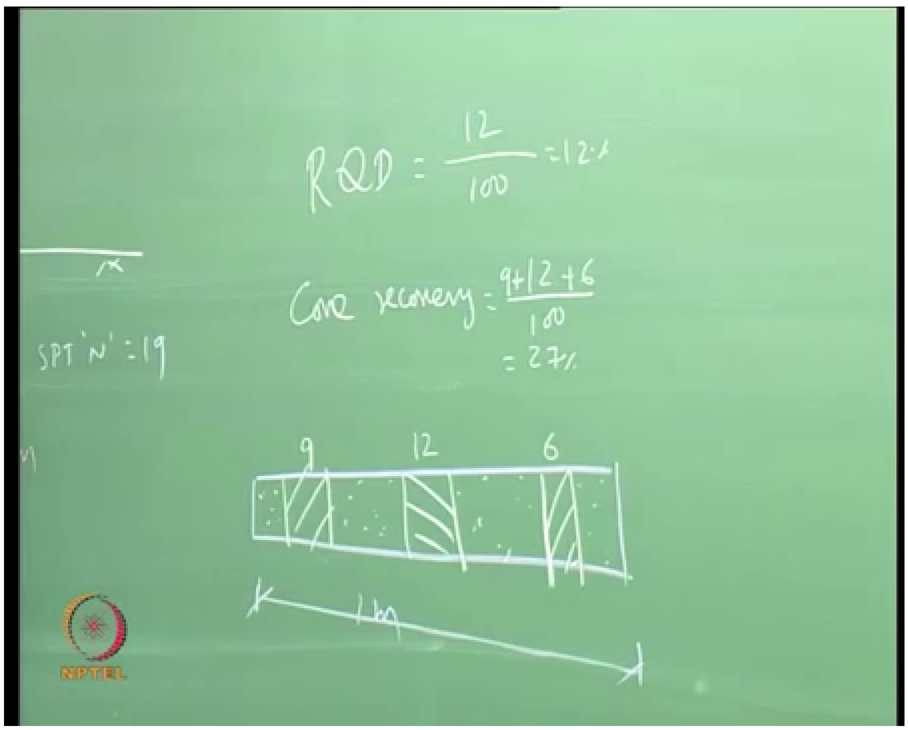
When you did the soil investigation top level was 3.69 there was a original ground level which was at plus 1.1 above that they use some filling here the filled soil the Gama is 18, n value is from 22 to 31 so here it is about 2 end of meters they read two three test here each point you will have different results the range is 22 to 31 we assume the groundwater level at this plus 1.1 need not have to coincide with this but sometimes we may have to it may coincide.

Then we have sand up to minus 4 plus 00 is given only for some just to mark the level only whereas the soil from 1.1 to minus 4 is a sandy soil it has submerged density of 8 kilo Newton per meter cube above the water level we give the dry density or natural density below that we give the submerged density, phi value is given as 30 degrees we have calculated the quay 1 minus sin phi by 1 plus sin phi that is 0.33 minus 4 to minus 17.

We have marine clay n value is 1 to 3 the density is also very less 5.1 saturated density, I am sorry submerged density phi value is zero, k is equal to 1, c is equal to 12 kilo Newton per meter square young's modulus for this soil is 5000 kilo Newton per meter square then we have a stiff clay n is equal to 20 the density is the same it has some component some sandy clay only it is, it has some phi value also, (quay) it's not a clay alone it is a sandy clay.

And we have the cohesion value given as 120 kilo Newton per meter square young's modulus is 30,000 kilo Newton per meter square then we have highly weathered rock young's modulus is 80,000 here we have written Cr Gama is 5.1, phi is zero degree k is 1, c is 460 kilo Newton per meter square what is Cr? What is rqd Cr means it is core recovery.

(Refer Slide Time: 17:45)

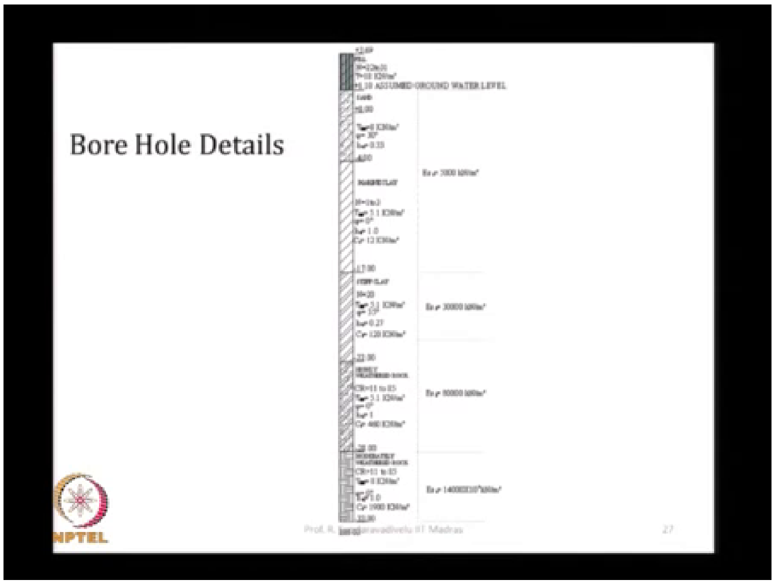


Suppose if you are using this spt test suppose you have encountered some rock here you cannot do spt test. What you do is you go here and take a rock core, take a core of rock and what happens is suppose you take a core of about 1 meter what happens is there will be some pieces of rock here, some pieces of rock here, some pieces of rock here.

Let us say it is 12 centimeter it is 6 centimeter it is 9 centimeter core recovery is 12 plus 6 9 plus divided by 100 that is 27 percent, RQD means rock quality designation that is any piece more than 10 centimeter alone you take. Divided by 100 that is 12 percent here you have some powders, rock breaks here you don't get a piece is it clear.

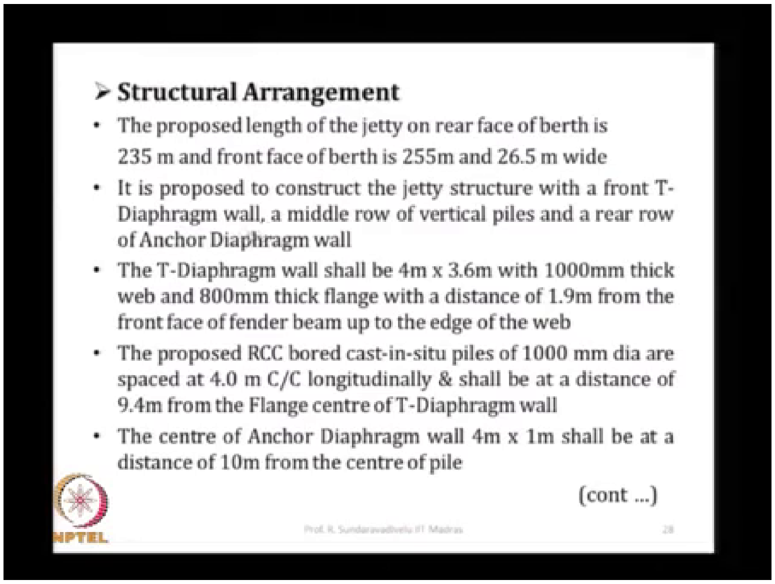
You core through the rock you may not get rock as a single mass you are getting only 3 pieces sometimes 4 pieces sometime you will get a single piece of 1 meter then core recovery and RQD is equal to 1 100 percent that is a very good quality rock, so this gives some idea what is a type of rock.

(Refer Slide Time: 19:16)



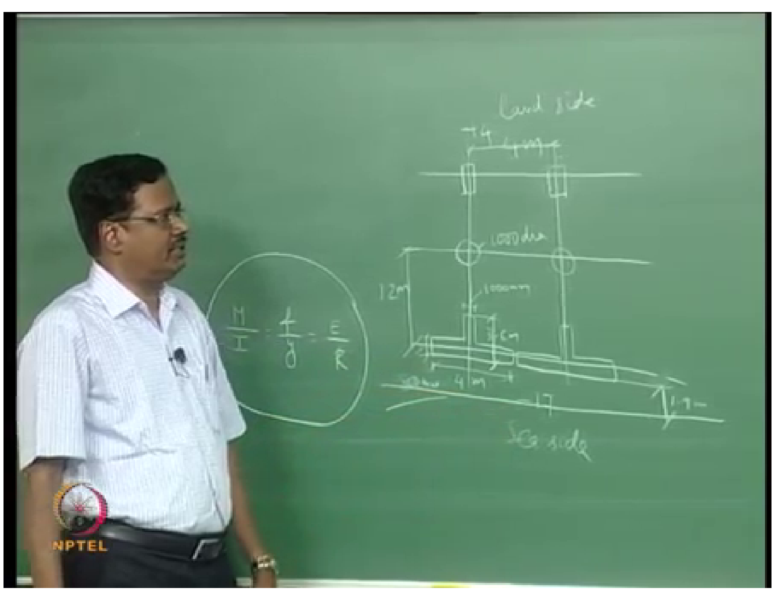
RQD is zero for this particular thing. Otherwise they would have given here RQD, similarly it is moderately weathered rock which is a better rock moderately weathered or highly weathered which is a better rock? Highly weathered rock or moderately weathered rock, moderately weathered rock is a better rock don't say highly means it is not good, highly weathered means the weathering action is so much the quality of the rock deteriorates.

(Refer Slide Time: 19:43)



The proposed length of the jetty is about 235 meter on the back side. And the front side it is 255 it is some kind of a trapezium we have a T diaphragm wall in the front middle row vertical piles and rear row anchor diaphragm wall this is a sometimes we call it as a dead man diaphragm wall also the T diaphragm wall is 4 meter by 3.6 meter with 1000mm thick web and 800mm thick flange.

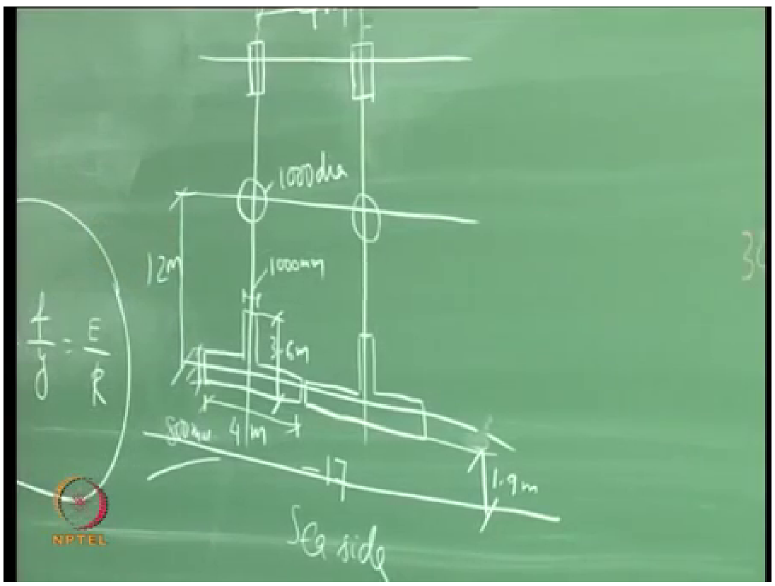
(Refer Slide Time: 20:13)



This is a 4 meter this is 3.6 meter this is called as a web this is 1000mm this flange is 800mm we have the fender beam in front.

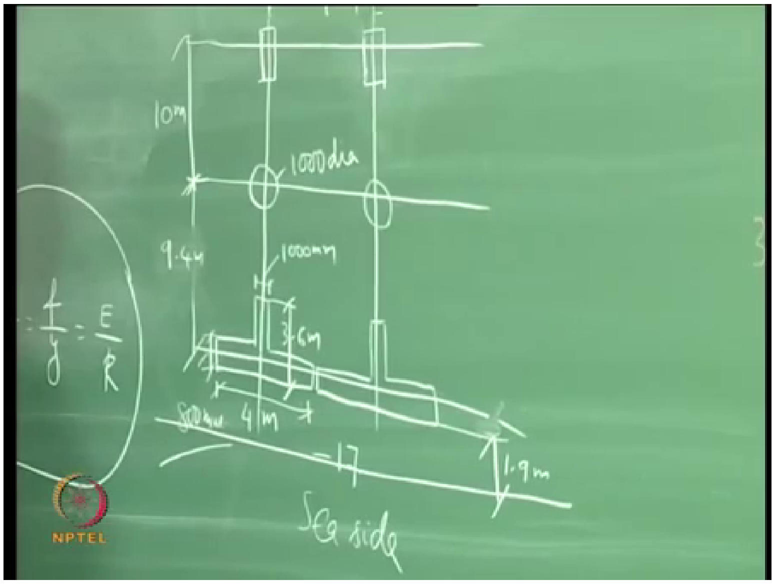
They say that there is a fender beam in the front the distance from this central line is not here it is about 1.9 meter, so (we have a) we don’t want the diaphragm wall on the face of the berth because when the ship comes by some tempting issue not go on hit so there is a fender beam here then there is a fender afterwards the easier.

(Refer Slide Time: 21:24)



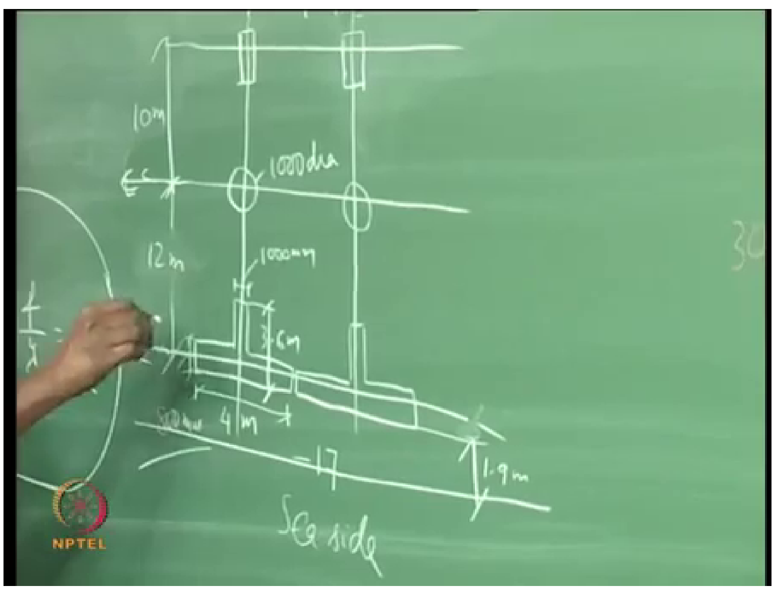
This diameter is 1000 dia is placed at 4 meter center to center, flange center it is given as 9.4 meter.

(Refer Slide Time: 21:55)



This distance is 10 metre but this 9.4 meter I don’t know whether it is correct or not.

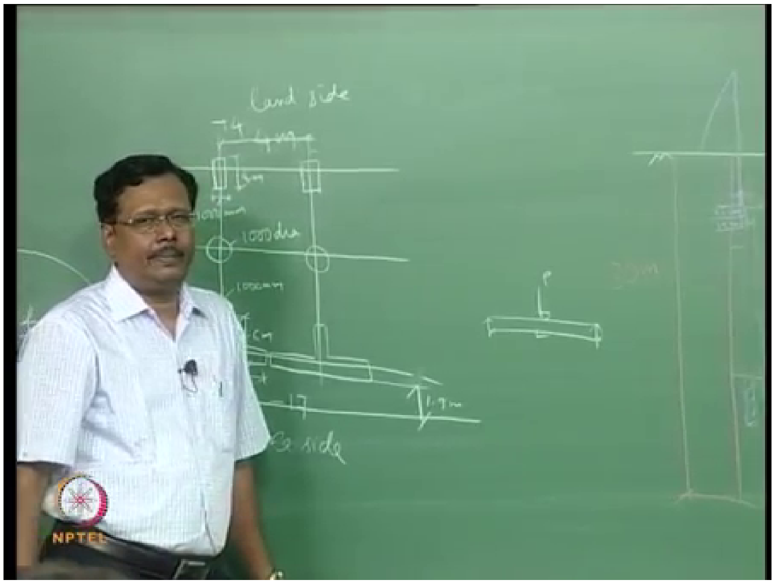
(Refer Slide Time: 22:00)



There may be some mistake in that it must be 12 meter only because we have a crane track here central line of crane that is another crane is there because of that it may be like that but anyhow it doesn't matter center to center distance between the crane track is 12 meter this distance is 4 meter and this thickness is 1000 millimeter I want to show here.

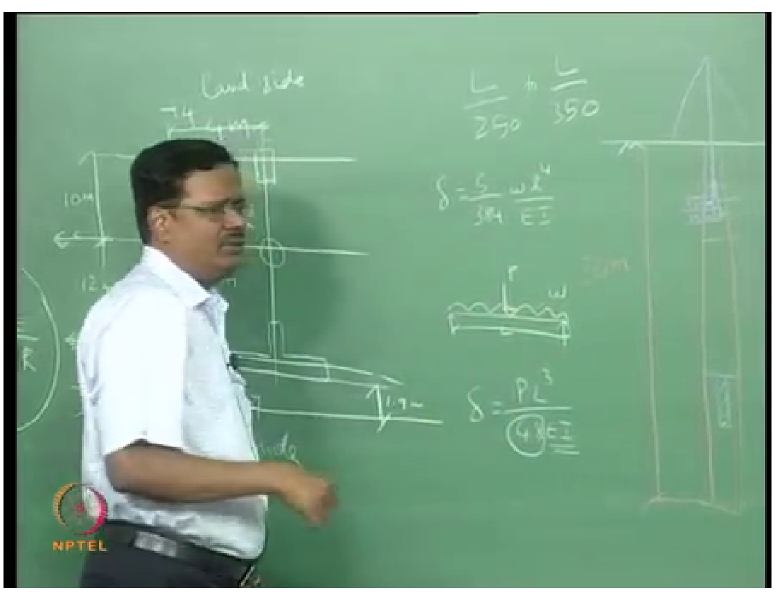
This main diaphragm wall is subjected to lot of earth pressure and the deflection is to be reduced.

(Refer Slide Time: 22:44)



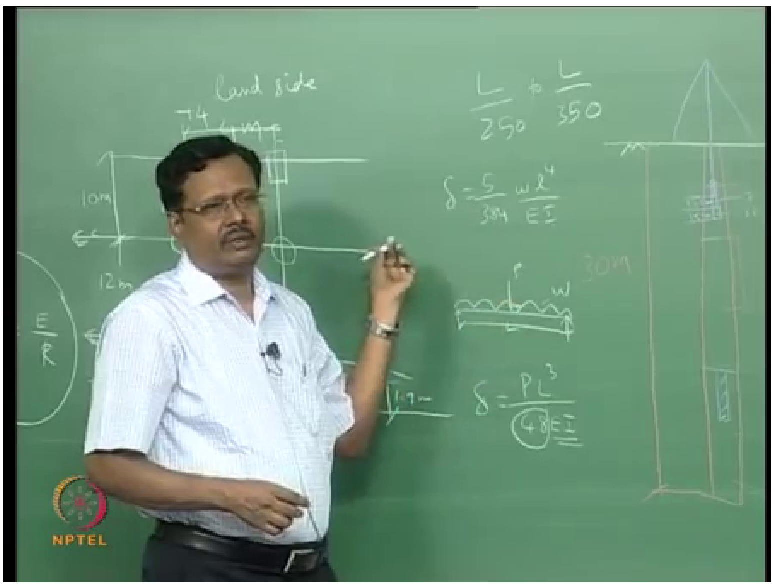
What is the deflection for a simply supported beam subjected to point load p, this coefficient we will check I think it is correct only but doesn't matter what is the unit of this delbeen millimeters it depends on young's modulus and moment of inertia and L is the span p is the load then you have a udl means, udl means what is a load what is the deflection 5 by 384 wl power 4 by a.

(Refer Slide Time: 23:35)



So now the load acting on the diaphragm wall will be pcm not this, the boundary conditions are not like this, boundary conditions are different so you have to do analysis and find out what is a limit of deflection how much you have to limit the deflection somebody was telling something what is the limit for deflection L by that is depth you are telling span by depth ratio it is between L by 252 L by 350 different cases during a construction stage (during all) considering.

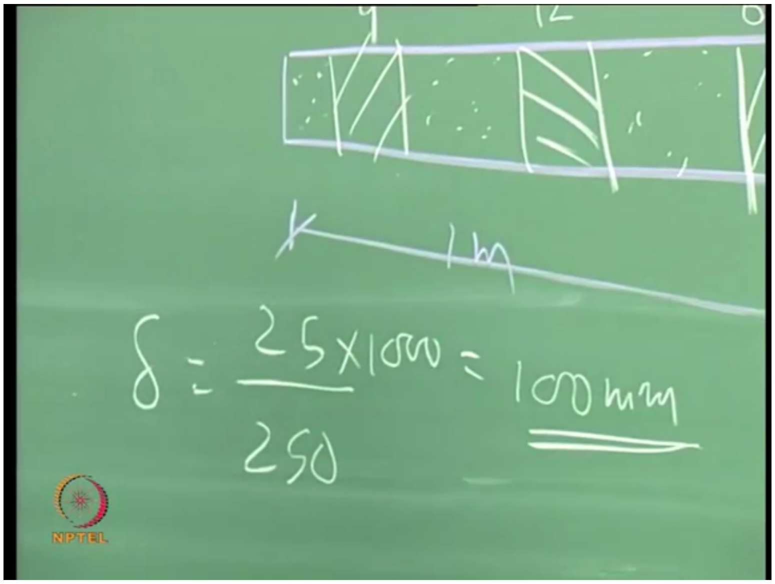
(Refer Slide Time: 25:28)



All the live loads and things like that so this is 17 that is 21 ok but we don’t know what is the span here, here it is going down below the sea bed so we don’t know this span suppose let us say that the span is about 25 meters permissible deflection is for a 25 meters span 25 by 250 into thousand is equal to 100 millimeters, 100 millimeter is how much this will be 100 millimeter I think somewhere here like this, this will be about 100 may be the cell phone size length.

May be 100 millimeters the diaphragm wall permissible deflection can be 100 millimeter how to control this deflection?

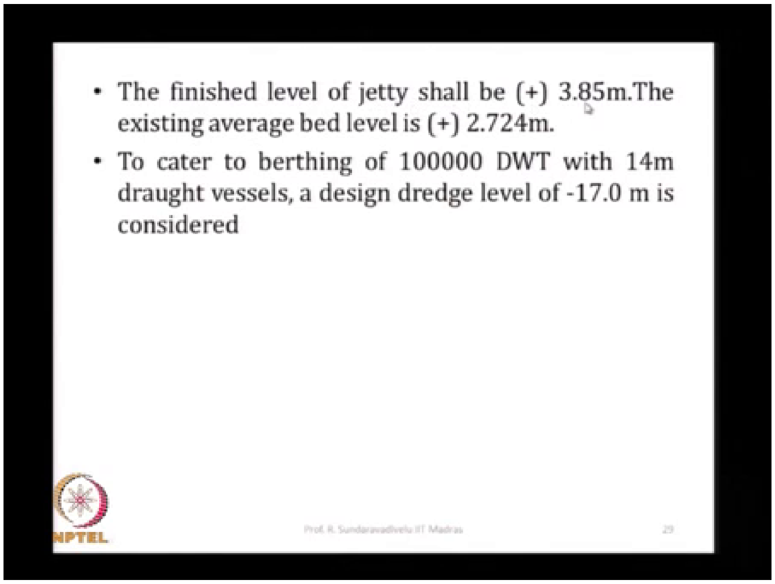
(Refer Slide Time: 25:16)



The control of deflection is all the places high if you increase the moment of inertia your deflection will be reduce one of the reason we put a T diaphragm wall is to increase the moment of inertia then another is young's modulus cannot increase the young's modulus very much but if you go for a better grade of concrete you can increase.

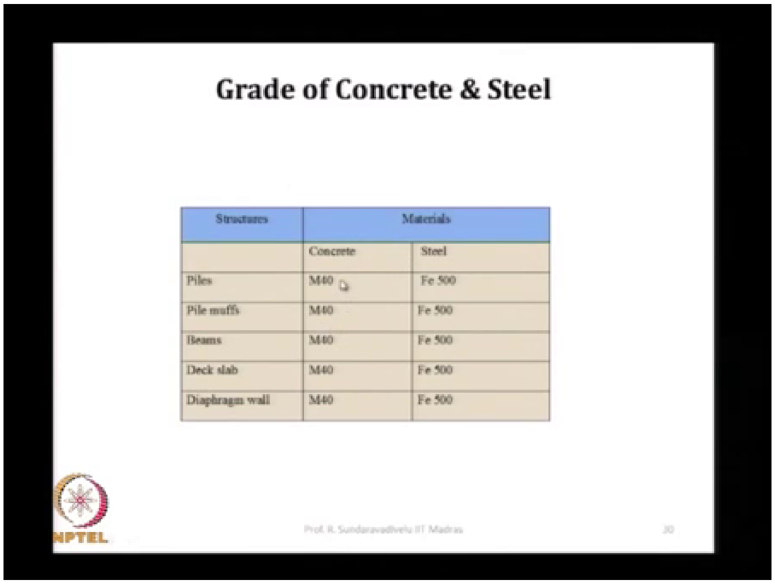
So we have gone in for m35 grade very difficult in the field to do more than m40 grade so we gone for m35 grade then load can be reduced suppose the span between this is 4 meter because you reduce it to 3 meter the earth pressure acting will be only for about distance of 3 meters the load will be reduced so we have to see all these things and correspondingly carryout the analysis.

(Refer Slide Time: 26:17)



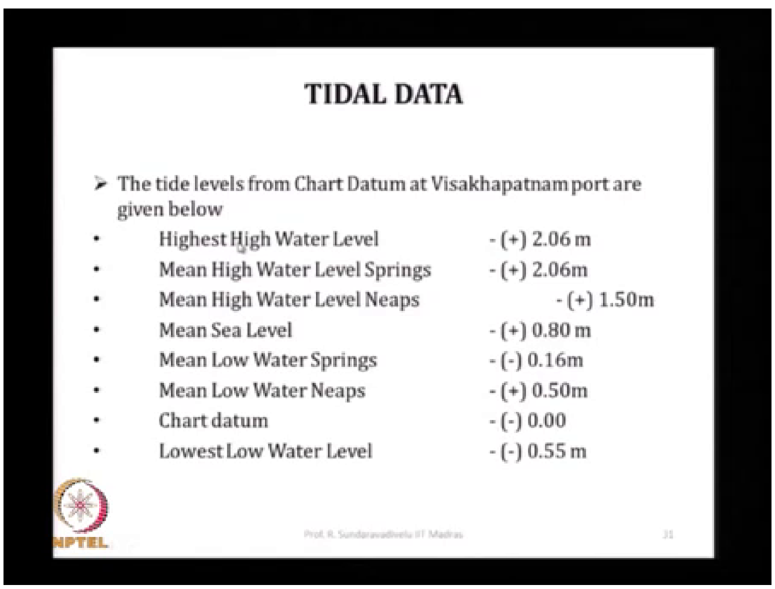
A top level is 3.85 average bed level is existing 2.724. We have to design it for 1, 00,000 dwt vessel with a draft of 14 meter and design dredge level of minus 17 meters.

(Refer Slide Time: 26:36)



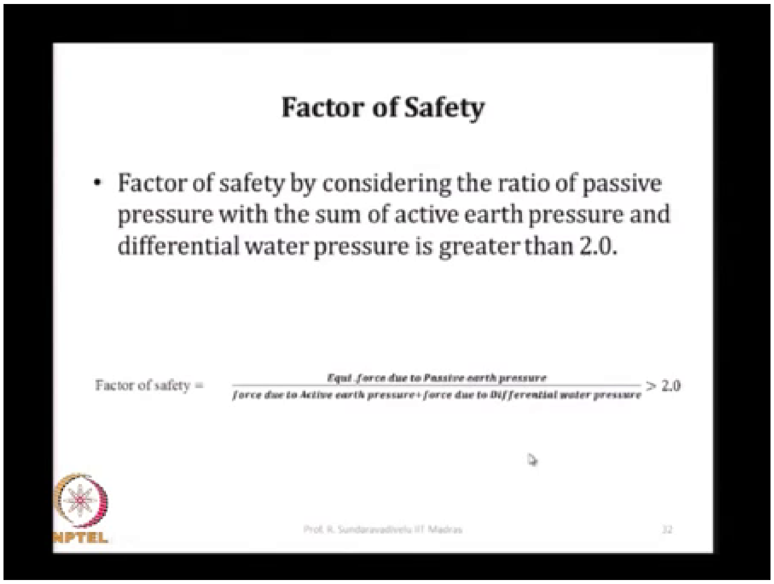
I think they have used m40 grade not m35, Steel grade is Fe 500.

(Refer Slide Time: 26:46)



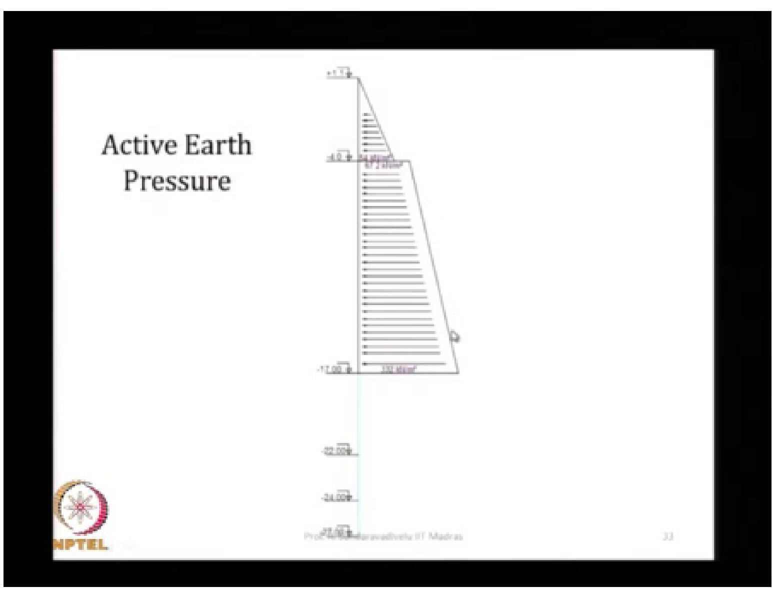
We should get all these water levels highest high water level, mean high water level spring, neap water level, mean sea level, mean low water spring, mean low water neap, chart datum, lowest water level.

(Refer Slide Time: 27:08)



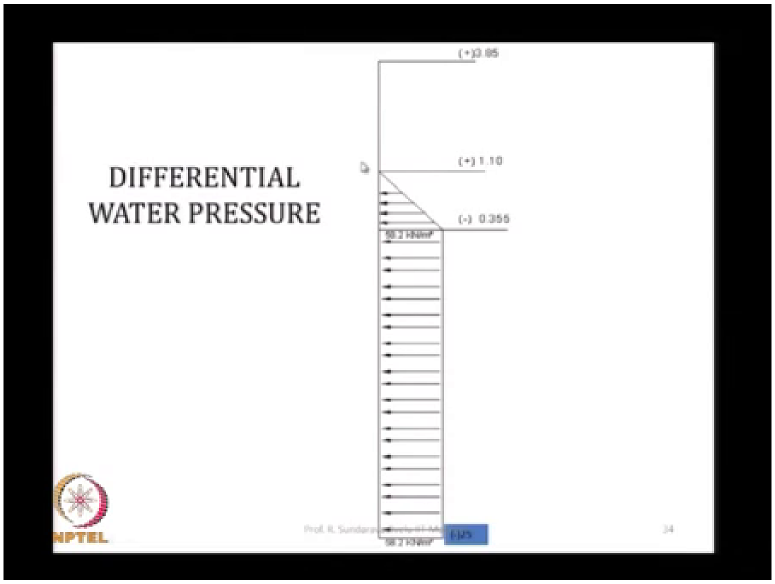
Somebody was asking how to fix the founding level of the diaphragm wall. We have to calculate the factor of safety this is by considering the ratio of passive pressure; I have to say passive force with the sum of active earth pressure force and differential water pressure it should be greater than 2 this is the force due to passive earth pressure, this is force due to active earth pressure and due to differential water pressure this is the earth pressure

(Refer Slide Time: 27:39)



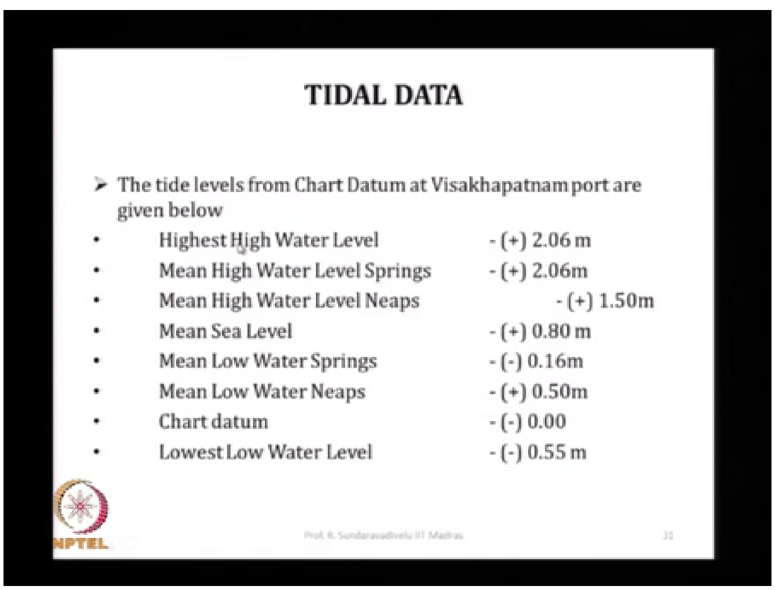
Active earth pressure depending on the soil parameters.

(Refer Slide Time: 27:46)



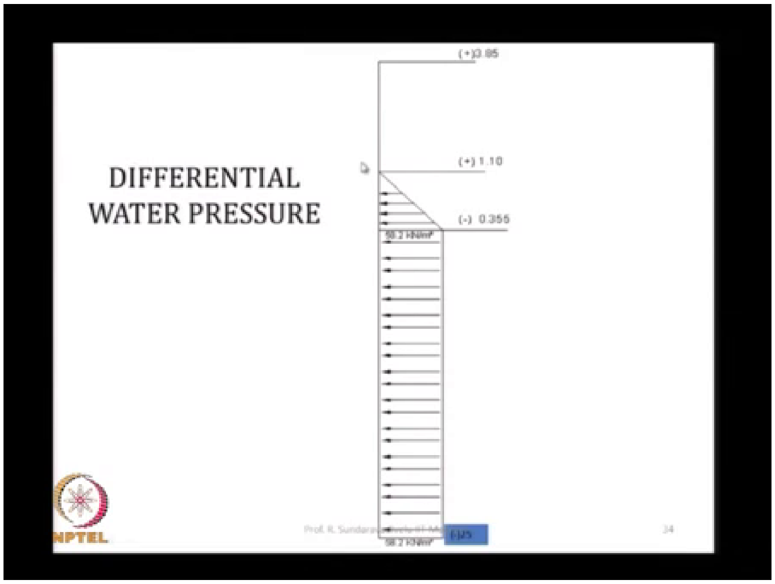
This is the differential water pressure.

(Refer Slide Time: 27:49)



So you've given the water level here we assumed 0.3 meter there is a procedure to calculate the water level on the sea side depending on the drainage condition.

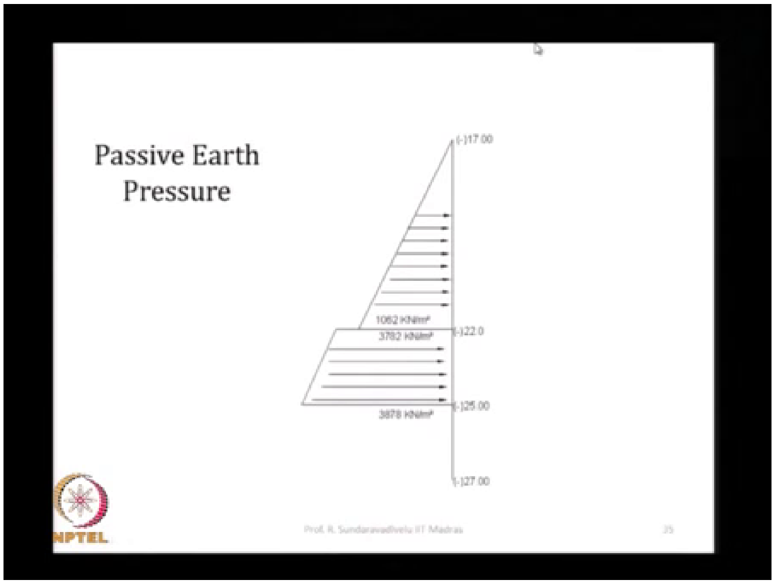
(Refer Slide Time: 28:02



So using that you have calculated the differential water level is about 1.455 meters using that you can calculate the differential water pressure, 58.2 is given here because 1.455 will give 14.55 kilo Newton per meter square but you have to multiply by 4 meters is it clear.

Why 4 meters, why do you have to multiply by 4 meters? That is spacing between the piles we do a typical section which is 4 meter wide center to center distance between the pile it governs the typical section that’s why we multiplied by 4 that is 14.55 into 4 is 58.2 but this differential water pressure goes right down at the bottom.

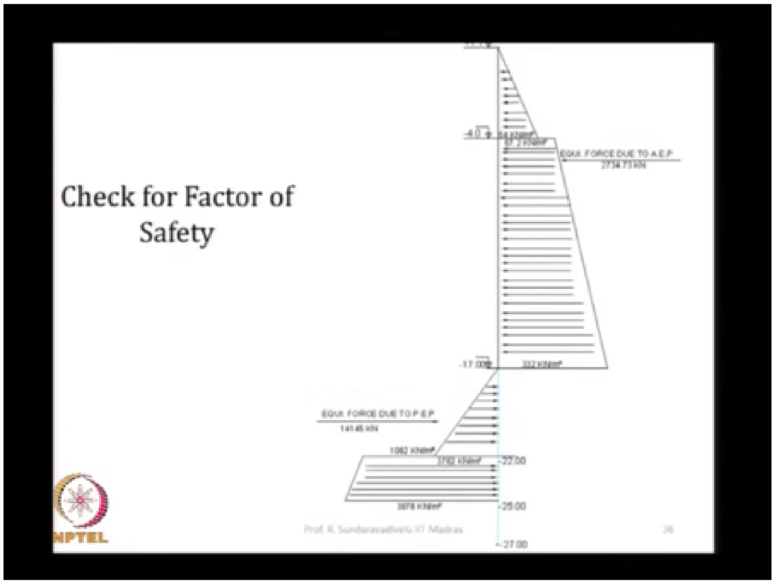
(Refer Slide Time: 29:05)



This is the passive earth pressure from minus 17 up to minus 25 Though we have given the founding level at minus 27.

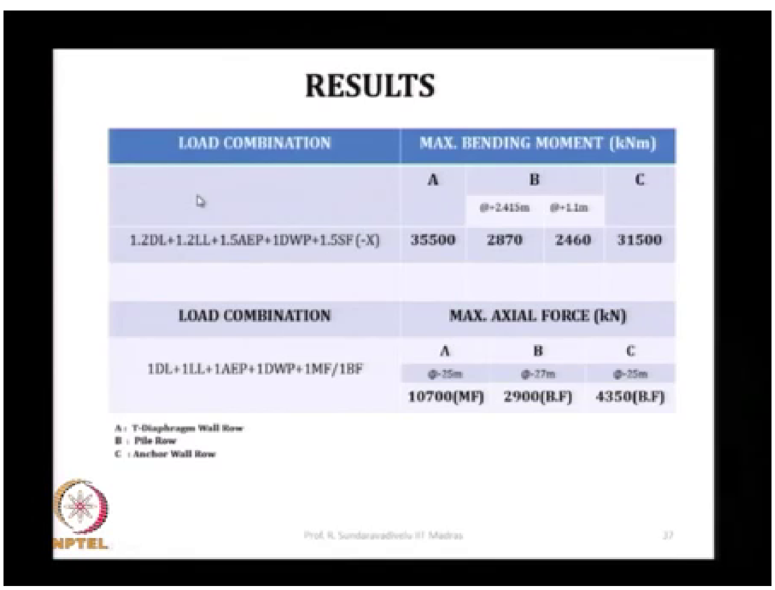
We calculated originally you want to do at minus 25 we want to found it also at minus 25, this project IIT Madras is the design consultant there is a independent engineer who is engaged by the developer and the Vishakhapatnam port trust developer is Abg group, this Abg group and Vishakhapatnam port they were engaging a independent engineering who will check the design of IIT Madras and he wanted minus 27. So we have provided minus 27.

(Refer Slide Time: 29:47)



So with this the factor of safety comes to about this is a passive earth pressure is 14 145 this is 27 34 so more than 5 I think.

(Refer Slide Time: 30:18)



Then when you do the analysis you have to do the analysis for different load combinations 1.2 times dead load, 1.2 times live load, 1.5 times active earth pressure generally is 465 code says

4651 only one times active earth pressure whereas Vishakhapatnam port in the tender document said.

Because another structure has failed due to active earth pressure they said you increase the factor load factor to 1.5 one time the differential water pressure.1 5 times the seismic force on the x direction, abc a is the main diaphragm wall b is your piles c is your anchor wall this bending moments are in kilo Newton meters 35500 kilo Newton meters, pile we are calculating at two different levels because the beam bottom is coming up to 1.1.

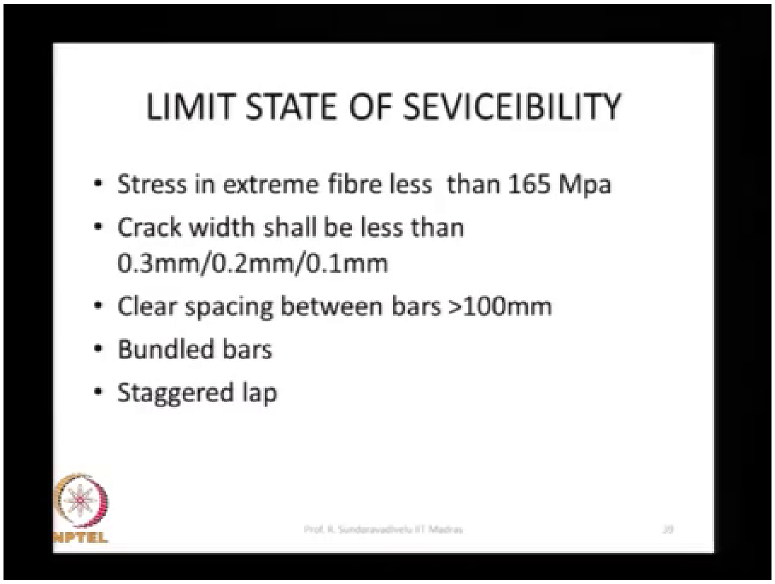
It take the central line for idealization so (we are we ca) we can design only at the bottom level of the beam for the pile anchor wall is 31500 then (for) this is for maximum bending moment one of the load combination for maximum axial force there is another load combination this is to find out the founding level of pile, this is limit state of collapse this is limit state of serviceability, limit state of collapse increase the load by a load factor.

And this design is also different for the concrete in limit state of serviceability you don't increase the load by any load factor do the analysis for the actual load similar to working stress design find out the maximum force coming on to the structure for the pile if the maximum force coming on the structure is 2900 kilo Newton the load is transferred by skin friction and unbarring calculate the ultimate load that it can take and give you a factor of safety.

That should be more than this 2900 so when you put a mooring force combination the maximum axial force comes for the main diaphragm wall we put the berthing force combination you get the maximum force for the pile as well as for the anchor wall that is why it is listed here, any doubt in this you have different forces acting dead load, live load, berthing force, mooring force seismic force, active earth pressure, differential water pressure.

And you have to consider different load combinations how many combinations will analyze do you think, how many combinations you will analyze? Guess the number, how many combinations you have to do? No no you just guess the number how many load combinations will, you will do 120 combinations because we have the crane load, position of the crane load, different front tires, finally it comes likes this.

(Refer Slide Time: 33:43



See for limit state of serviceability. There are two cases that are given one is the crack width, another is the deflection, deflection should be less than L by 250 or L by 350 depending on various conditions. The crack width means whenever there is a concrete the concrete will crack you cannot see that the concrete will not crack it will crack because there is a lot of stress that the steel will take, steel will take up to 165 mega Pascal.

This is a allow build stress whereas actual size will be 500 mega Pascal, how much will be the tensile strength of the concrete, 0.7 times what he is telling is write 0.7 times root of fck, 10 percent may be some approximate value exact value is modulus of rupture that is equal to the tensile strength only modulus of rupture is a tensile strength only that only used to calculate the gross moment of inertia, this 0.7 times root of fck.

Will be 3.5 suppose if it is 25 m25 grade it will be 3.5 mega Pascal where is 3.5 mega Pascal where is 165 mega Pascal, this permissible tensile strength of concrete that is given in is code for different grades also that also we can check that may be somewhere in the range of this modulus of rupture only and that value you compare with this so the tensile strength of concrete is much less than the tensile stress in steel so the concrete will crack in tension.

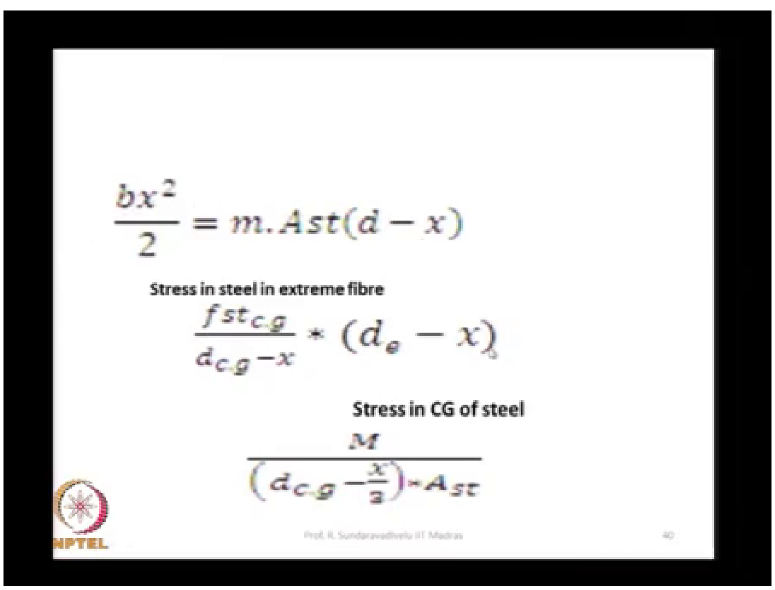
So you have to neglect that concrete but when it cracks there is some crack width so there are 3 zones one is splash, intermediate, and submerged zone. Splash zone means where the water level goes up and down where we (35:50 received the racket to 0.1mm) then concrete has to flow between the reinforcement bars for that the spacing between the bar should be greater than 100 millimeter what will be the size of the coarse aggregate?

Concrete consists of three parts one is coarse aggregate, fine aggregate, cement then you add water, what is the size of a coarse what is the size of a coarse aggregate? 20 mm generally sometimes they use 40mm for main concrete for foundations 20mm means the aggregate has to go that distance should be more than 20 millimeter since we are doing it under water as well as below the sea bed minus 25 handle (you have to) the concrete has to go from the top.

So we need a spacing of greater than 100 mm, to achieve this we can use the bundle bars then what is a length of the reinforcement bar? Reinforcement bar is coming and you are tying it and it lowering it what will be the length of the reinforcement bar? How much it is transported, question is not clear, bar is coming from the factory from the shop you are bringing it to the site what will be the length standard length? 12 meter is a standard length.

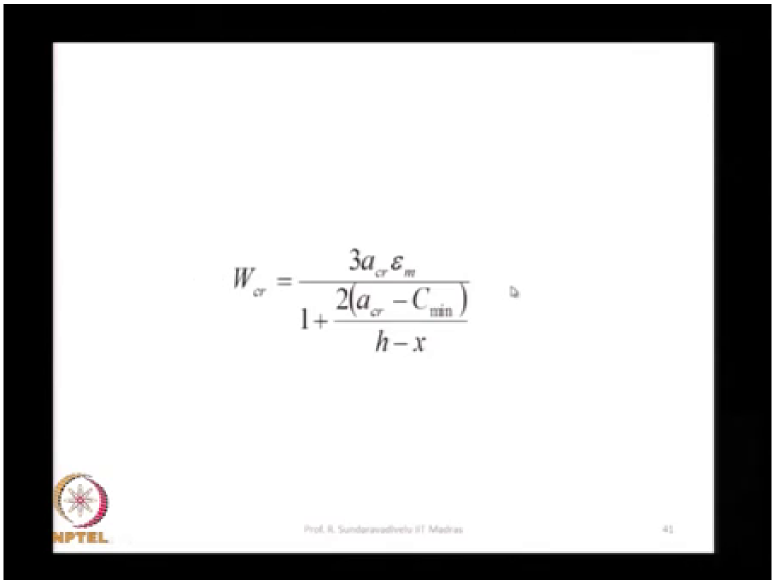
15 meter I don't know so they sometimes use only 6 meter length that means if that diaphragm wall is from minus 27 to plus 128 meter there should be some lap the lap should not be at the same place you have to stagger the lap these are the things which you have to do.

(Refer Slide Time: 37:43)



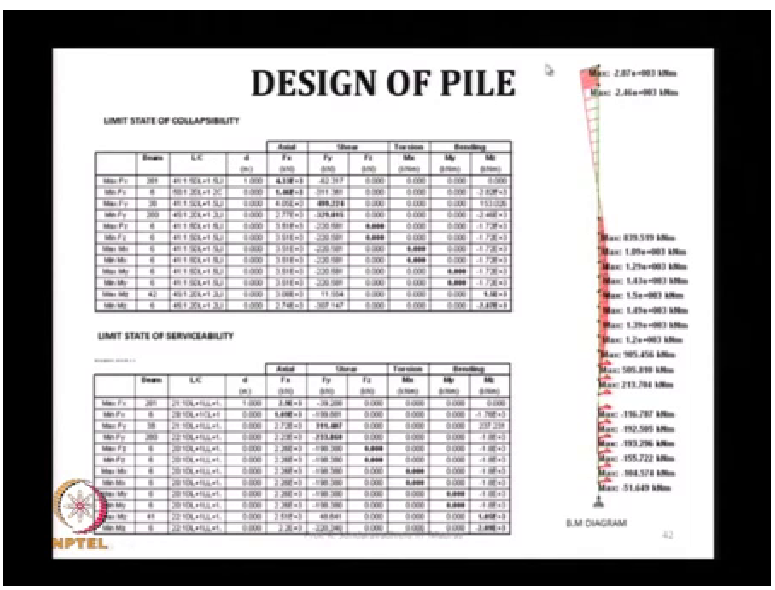
This calculation I will discuss separately.

(Refer Slide Time: 37:58)



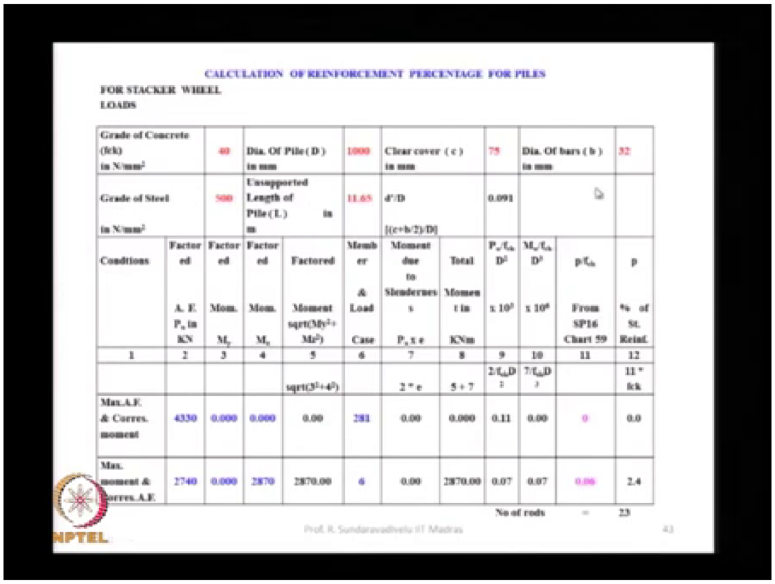
This is the calculation to get the crack width.

(Refer Slide Time: 37:53



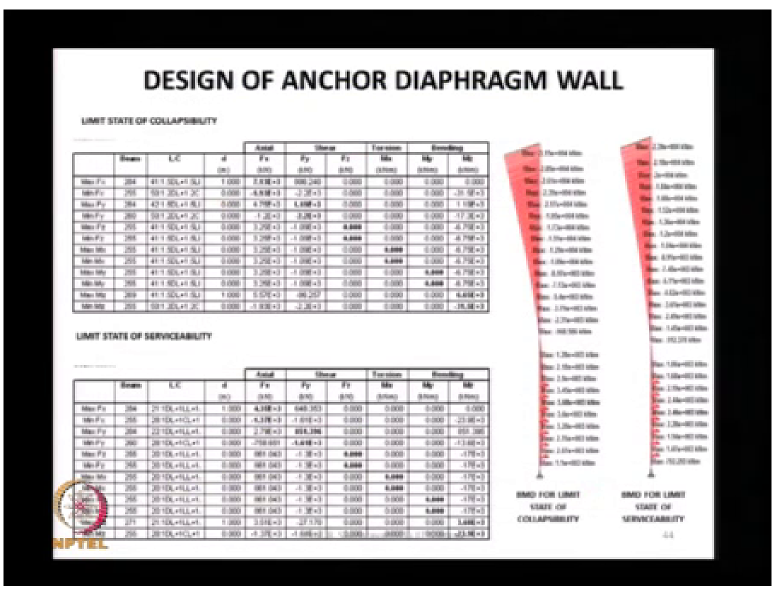
This is the result what you will be getting; this is the bending moment diaphragm and the pile. So this bending moment diagram is dawn on the tension side that means on this side there will be tension here it will be on the other side suppose this is the water side this is the land side reinforcement should be provided more on this side and this side so it should not be at the same phase but the circular pile we put uniform reinforcement.

(Refer Slide Time: 38:24)



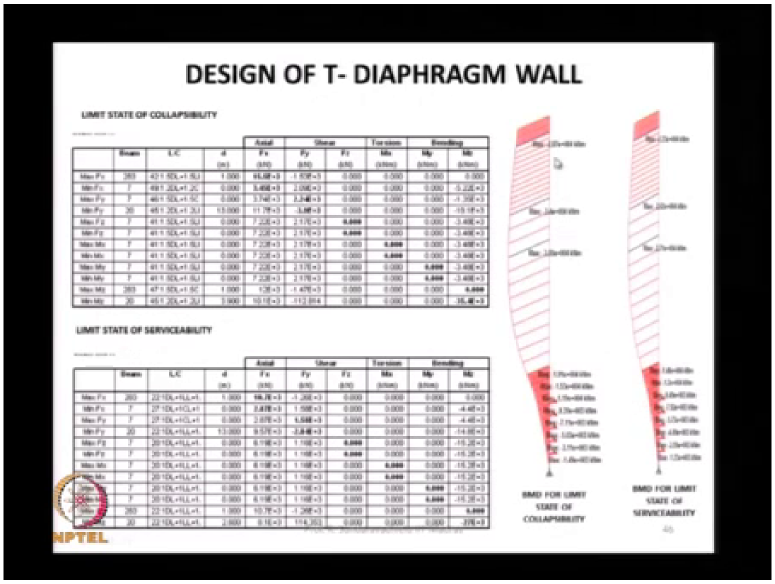
This is the typical spread sheet which we prepare to calculate the reinforcement for piles. This also I will discuss later.

(Refer Slide Time: 38:30)



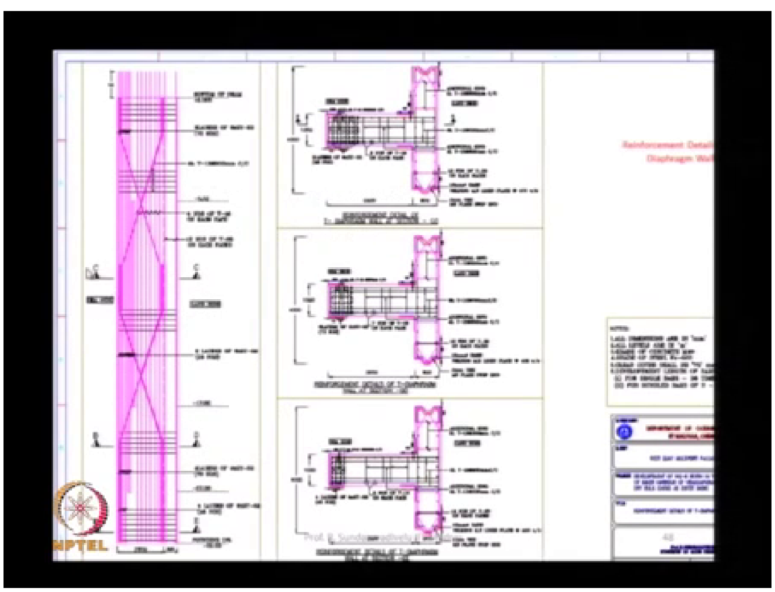
This is the bending moment and the anchor wall. So this shows that the reinforcement should be more on the sea side and less on the land side.

(Refer Slide Time: 38:42)



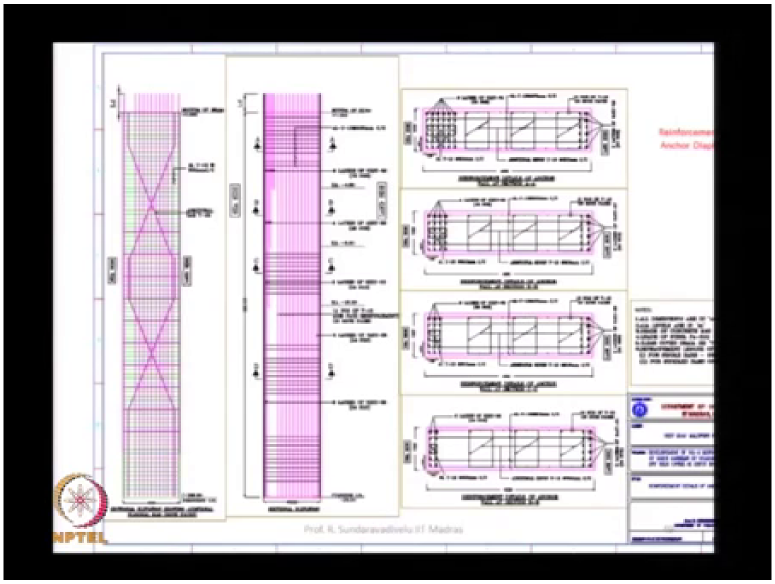
This is for the T diaphragm wall reinforcement is only on one side. It is not on both the sides, there are two reinforcement given one is for limit state of collapse another is for limit state of serviceability.

(Refer Slide Time: 38:58)



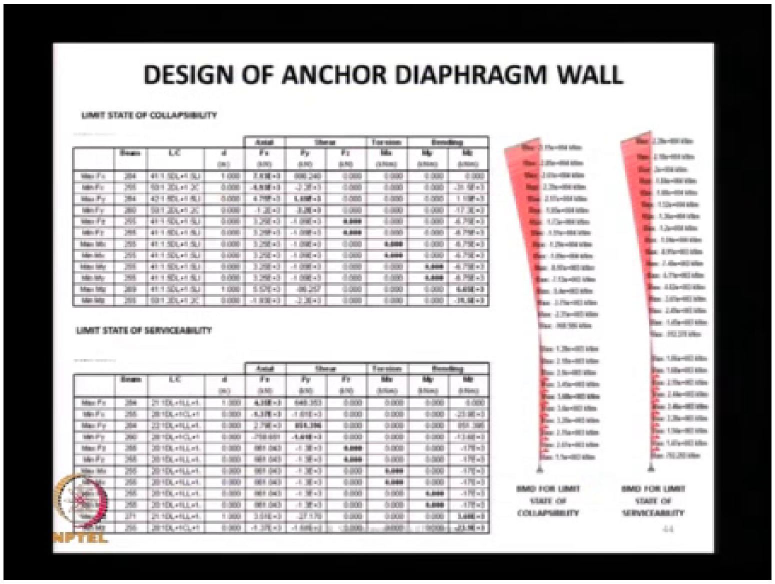
The detailing is very important so this reinforcements are given. Actually (this reinforcement) this diaphragm wall is not same

(Refer Slide Time: 39:15)



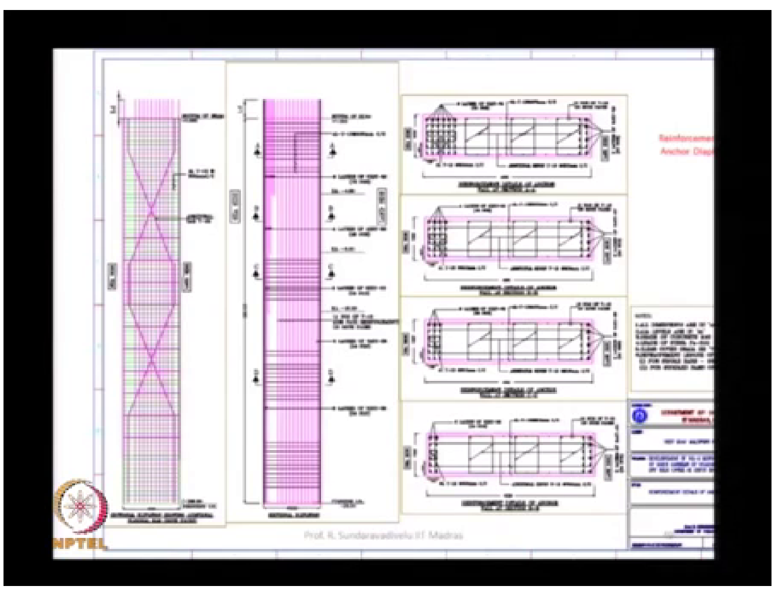
As what we have given here I will skip this it is slightly changed so this is alright this is on the sea side we put so much of reinforcement here. The spacing between the bars and this side as well as this side should be more than 100 millimeter we have to provide some compressive bars also to tie this shear stirrups whenever you are designing you have to design for both for bending and shear. And you have to provide some more shear stirrups also so what is called as a detailing the reinforcement.

(Refer Slide Time: 9:47)



If you see the anchor wall is more here as you go down it is reduced and afterwards it goes to the other side.

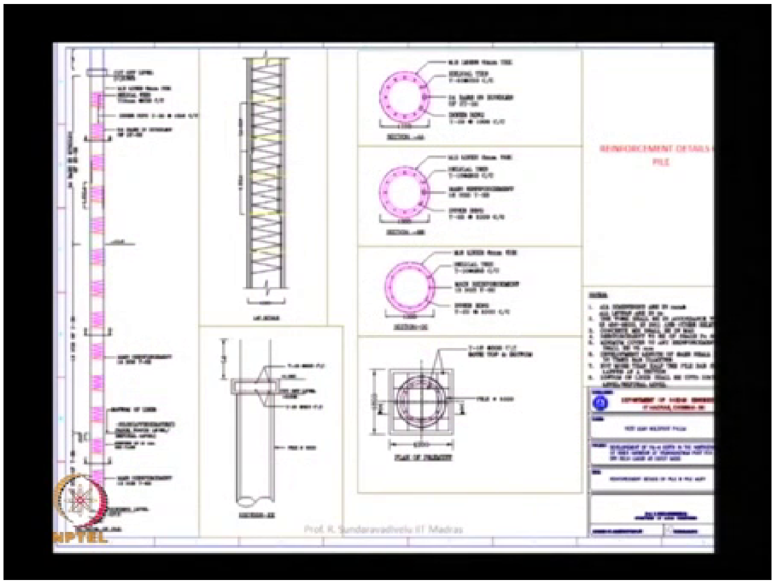
(Refer Slide Time: 39:56)



So we have 4 sections here so as you are going down this is the top section this one section below two sections below and the bottom of section as we are going down we are reducing the number of reinforcement bars.

When you go here your bending is on this side only so reinforcement is given where the tension is there because concrete is within tension.

(Refer Slide Time: 40:22)



This is for a pile, pile also as you go down the reinforcement is reduced.

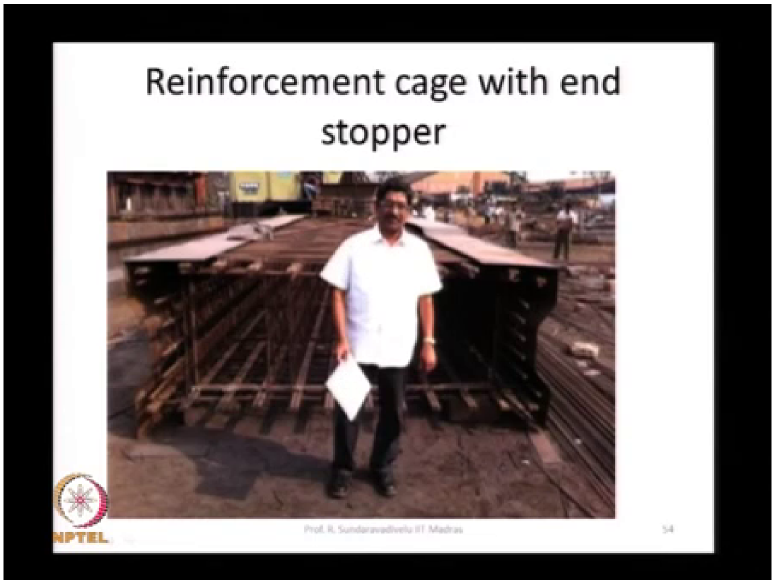
(Refer Slide Time: 40:29)

This is a tool which is used to cut the pile to bore the pile.

(Refer Slide Time: 40:39)

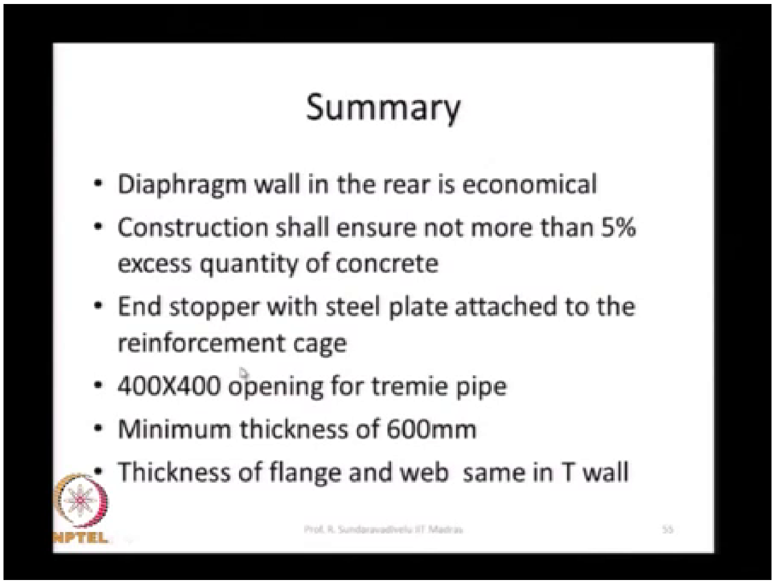
There is one moving trolley here this is used with the tool along this direction to cut for diaphragm wall.

(Refer Slide Time: 40:53)



This is the engineer who is standing just to show how the reinforcement is? So this is your reinforcement in the anchor wall this is the shape which we are giving for the anchor wall not a rectangular thing we have given some plates here because the soil was collapsing to avoid the collapsing they have put some steel plates as a shuttering built along with the reinforcement bars.

(Refer Slide Time: 41:10)



A diaphragm wall in the rear is economical which are putting in the main portion because the surcharge load if we take it will be difficult. When you do the boring of concrete it should not be more than 5 percent the end stopper with steel plate attached to the reinforcement cage what I shown in the slide is required.

We need a opening of 400 by 400 for lowering a tremie pipe for concreting the minimum thickness of the diaphragm wall should be 600mm and thickness of flange and web if it is same it is better for a T wall here your soil state different thickness subsequently we are revised. So if it is same then boring will become easy ok.