Port and Harbour Structures.
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Module-2.
Lecture-8B.
Wave Rose Diagram.

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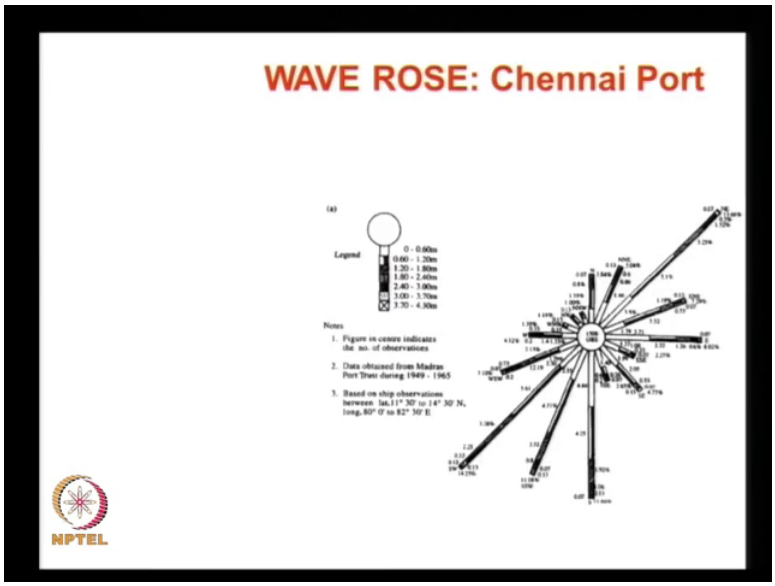

We will discuss about Wave Rose diagram, it is called as Wave Rose diagram, we have Wind Rose diagram also. The Wave Rose diagram gives certain information, the informations are the wave height, the direction of the wave and the percentage of occurrence. Which direction you have more number of waves? North-east. Next?

Southwest.

So this is your north-east direction, so north-east direction, the percentage of occurrence is higher. There is a symbol given here, if it is white patch without any symbol, it is 0 to 0.6 metres, that is the wave heights here, this much percentage of occurrence will be less than 0.6 metres. The highest is about 3.7 to 4.3, that will be occurring somewhere towards the tip of this.

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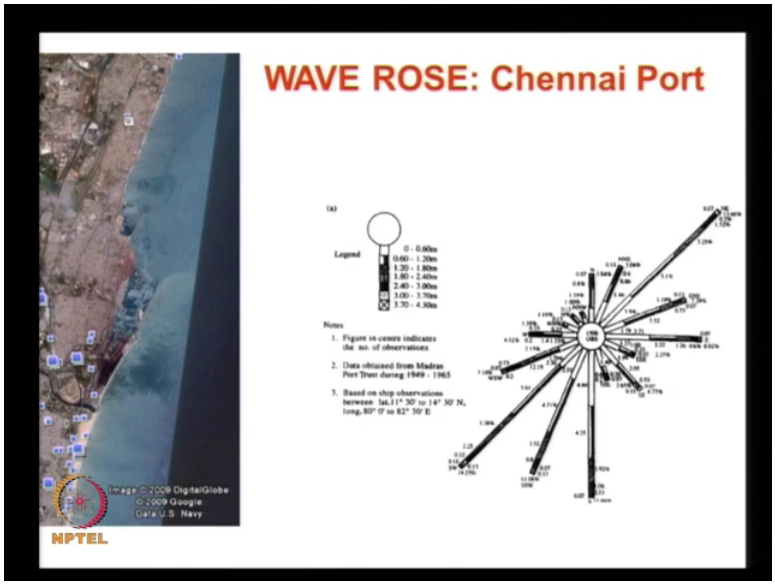

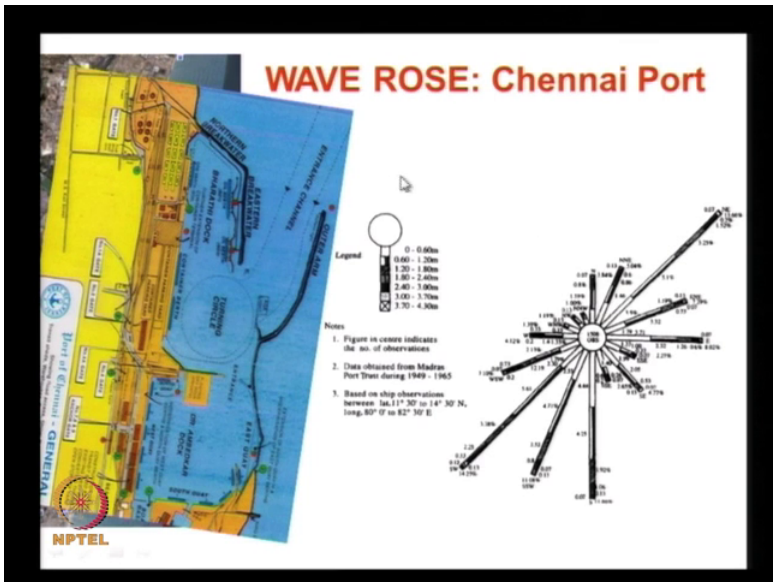

Now we will see the Chennai port, satellite imagery. So the satellite imagery shows the orientation of breakwaters and to be more understanding, I am showing the layout picture. The North is like this, I have oriented this also in the north. Yesterday we were discussing about the entrance channel turning circle and all. So the entrance channel is not north-east, it may be between North, Northeast and north-east, that is the direction of entrance channel.

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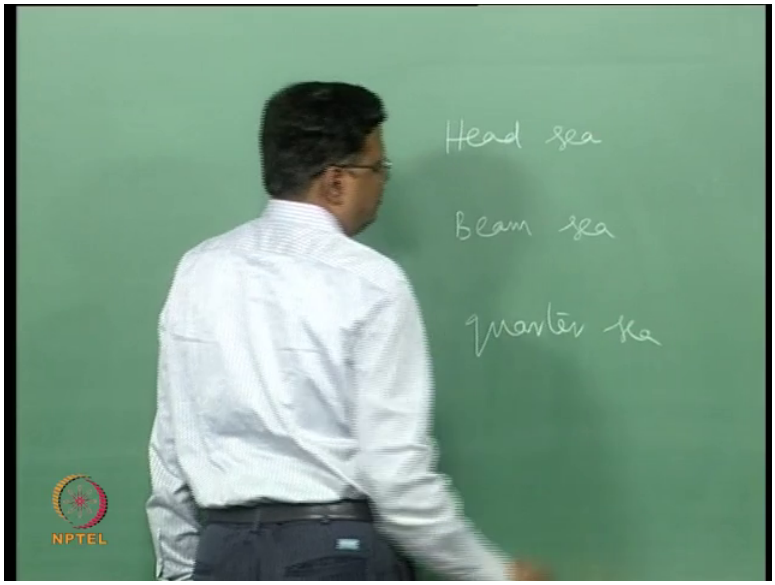

We have 3 conditions for the ship in relation to the wave direction. One is called as the head sea, other is called as the beam sea, another is called as the quarter sea. So I am growing the plan of the ship, you please draw, do not simply look at the board, otherwise you will get sleep. Try to draw the ship the way in which have drawn or better than what I have drawn. The ship should look like a ship, 2nd point is the dimension should be proportionate. The dimension what I have drawn is approximately proportionate. This is the length of the ship, this is called as the beam of the ship. From this figure can you tell me approximately what will be the ratio of length to be, what I have drawn? 1 is to? It should be 1 is to 7. Does not look 1 is to 7?

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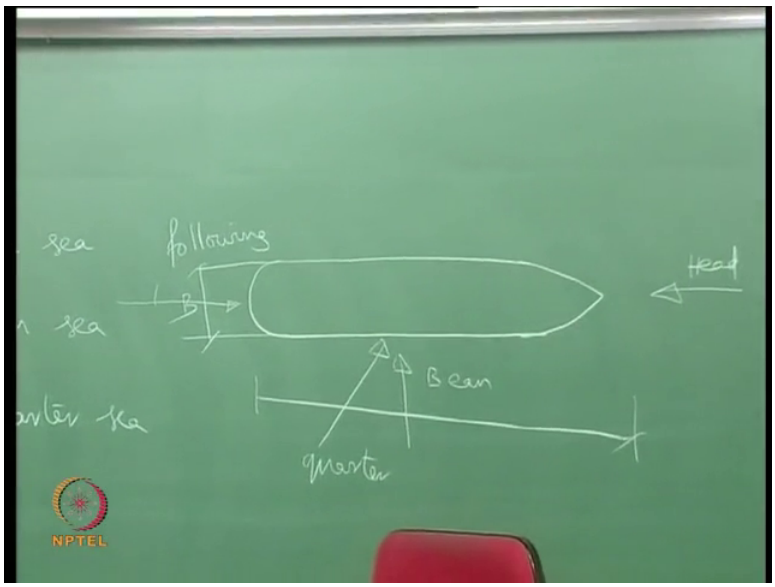

This is the beam, okay, 1, 2, 3, 4, 5, I think you are exact. So I should have drawn it longer. Ocean engineering students, which direction should be the wave for head sea condition? From left to right, right to left, top to bottom, bottom to top? .

Right to left.

Right to left. Beam sea? Beam sea? Bottom to top or top to bottom, anything is okay? Both the directions? Quarter sea is like this, any direction and the wave is like this, this is called as the following sea. When you want to bring the vessel through the entrance channel, which direction you want? Head sea, Beam sea or quarter sea or following sea? Because the wave is coming in this direction, following sea, you are telling it may push the vessel but the wave, the head sea condition is also okay, no problem.

But generally it will be in the following sea only. If we see the entrance channel orientation and the wave direction, so it is better that it is in the following sea or head sea. Yesterday we discussed or in one of the class we discussed about the heave, pitch, roll, surge, sway and yaw motion. So if the ship is in the head sea or following sea, you will have the pitch motion. In the pitch motion you have more moment of inertia, so the motion response will be less, that is why you want to give the head sea or following sea.

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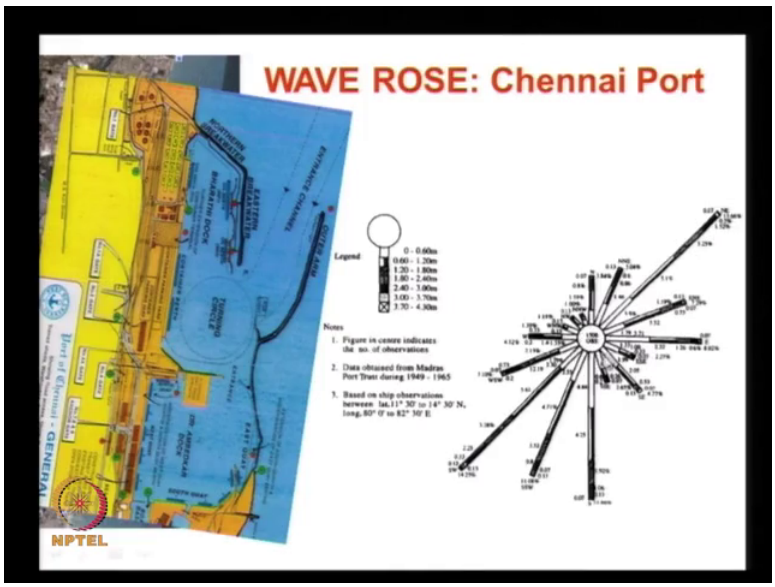

There are certain more information given here. This figure in the Centre indicates the number of observations, I think it is around 1900 observations. This data is obtained, the Port trust during 1949 to 1965. The basis for the data is ship observations between latitude 11 degree 30 minutes to 14 degree 30 minutes north and longitude 80 degrees to 82 degrees 30 minutes

east. This is a very large area, not a small area. The ships which are plying, they are told what is the typical wave height and direction, based on that they have given this information.

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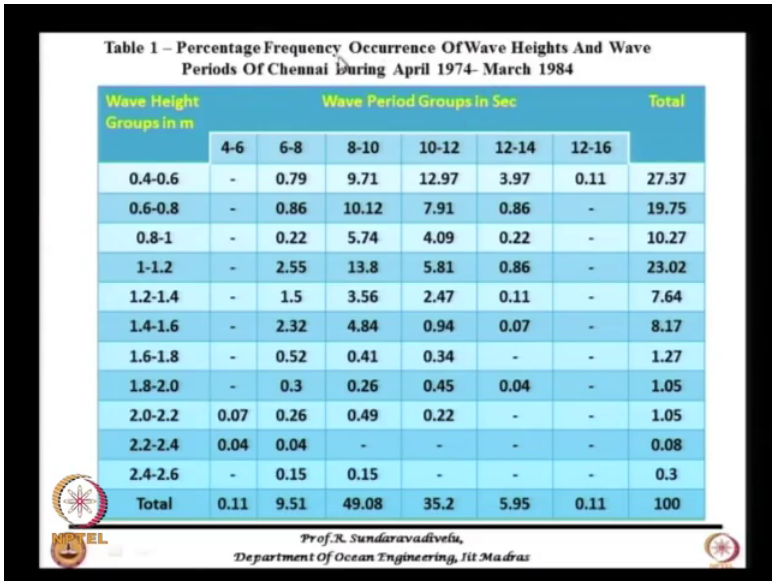

But statistically if you want to use, it is very difficult to interpret but pictorially for engineering it gives all the information. But we want to quantify, you can get this information, percentage frequency of occurrence of wave heights and wave periods of Chennai during April 1974 to March 1984. There are 2 information given, one is wave height groups in metre, another is wave period groups in seconds. So if it is 0.79 percent, the wave height is in the range of 0.4 to 0.6 metres and the wave period is in the range of 6 to 8 seconds.

The maximum is somewhere here, 13.8 percent, 13.8 percent times over this period of about 11 years, the wave height is in between 1 to 1.2 metres and the wave period is between 8 to 10 seconds. If we see the total here, you can see that up to this point, that is less than 1.6 metre waves are 15, 38, 48, 68, 75, 95, 95 percent of the waves are less than 1.6 metres. And the wave period, maximum is between 8 to 10 seconds, 49 percent. This percentage is given but per year if you want, approximately it is 5 million cycles, approximately it is coming.

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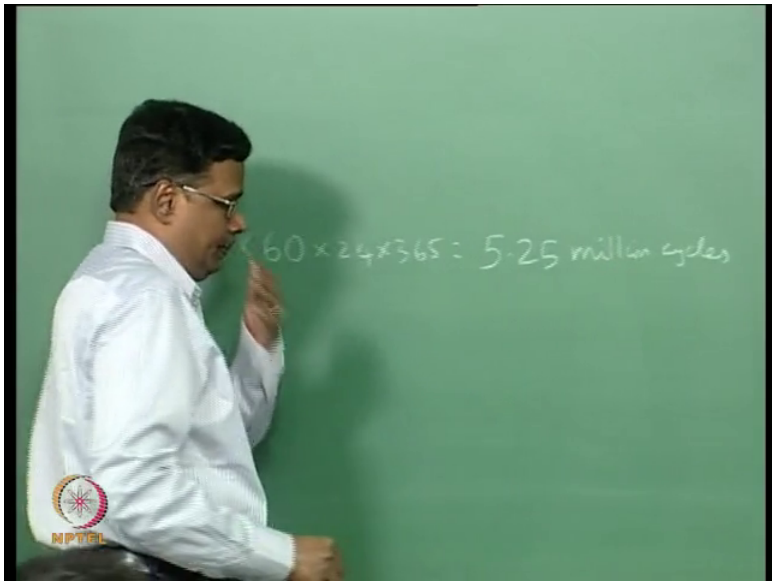

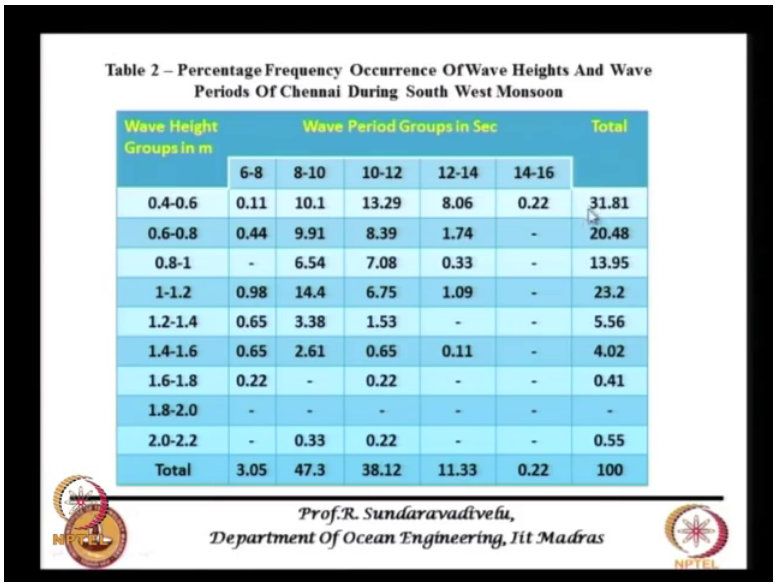

Table 2 – Percentage Frequency Occurrence Of Wave Heights And Wave Periods Of Chennai During South West Monsoon

Wave Height Groups in m	Wave Period Groups in Sec					Total
	6-8	8-10	10-12	12-14	14-16	
0.4-0.6	0.11	10.1	13.29	8.06	0.22	31.81
0.6-0.8	0.44	9.91	8.39	1.74	-	20.48
0.8-1	-	6.54	7.08	0.33	-	13.95
1-1.2	0.98	14.4	6.75	1.09	-	23.2
1.2-1.4	0.65	3.38	1.53	-	-	5.56
1.4-1.6	0.65	2.61	0.65	0.11	-	4.02
1.6-1.8	0.22	-	0.22	-	-	0.41
1.8-2.0	-	-	-	-	-	-
2.0-2.2	-	0.33	0.22	-	-	0.55
Total	3.05	47.3	38.12	11.33	0.22	100

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If we assume 6 second waves, there will be 10 waves in a minute, 60 minutes in an hour, 24 hours in a day and 365 days. So if you multiply this, you will be getting, 10 into 60 into 24 into 365 is 5.25 million cycles. If it is a 10 seconds wave, this will be much less, 12 seconds wave it will be half of this. But there will be combination between 4 to 6 seconds to 12 to 16 seconds. So it will be somewhere, typically about 4 million cycles are considered per year. These number of cycles are required for fatigue calculation.

The failure of the structure member can be to do axial tension, compression, bending, shear and it can also be due to fatigue. Then we have 3 monsoon seasons, one is north-east, another is Southwest, the 3rd one is the non-monsoon season. So if we take Southwest monsoon, which is for a very long duration, maybe 6 to 7 months, they have given the wave height

groups, 0.4 to 0.6 metres, the percentage of occurrence is very high, 31 percent, here it is 27 percent or stop it is 20, 13, 23, generally in south-west monsoon, less than 1.6 you will have nearly 99 percent of the waves.

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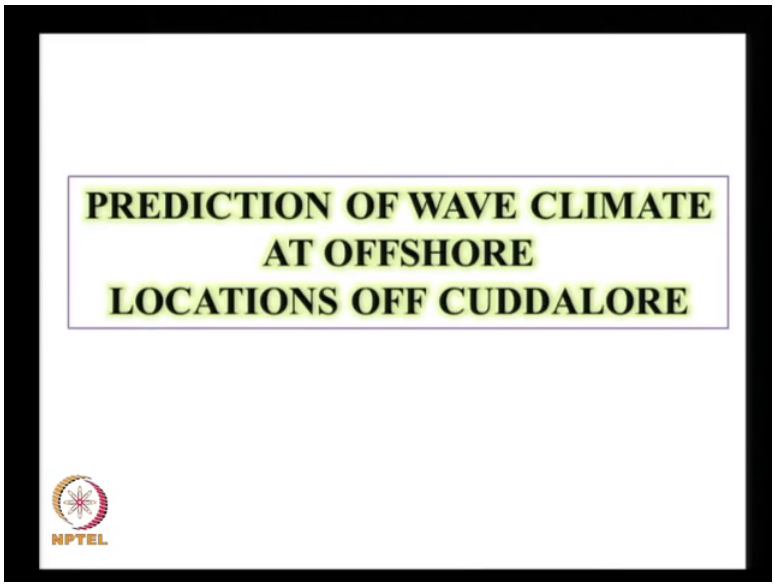

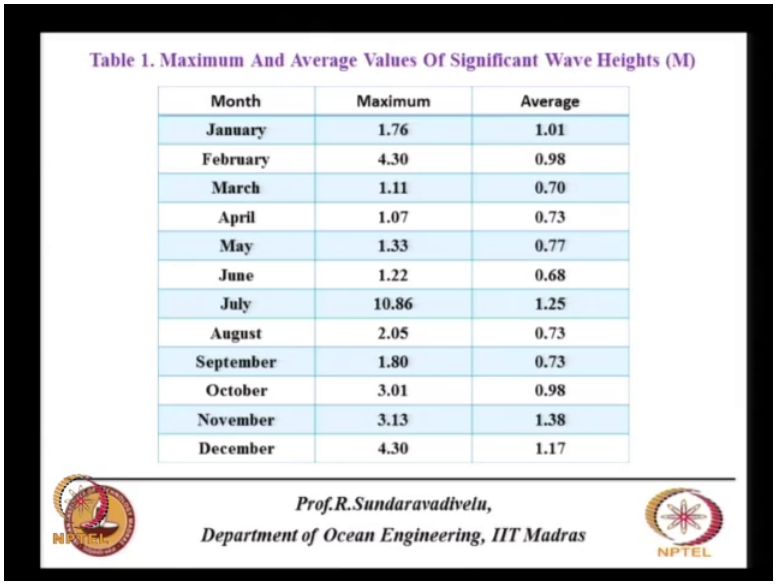

Then the wave period is between 8 to 10 seconds as given for the other case. And we have similar table prepared for north-east and non-monsoon also. You must be wondering based on the ship of the data from 1974 to 84, we occupied this documentation. If that is not available, we have to carry out some wave hint casting based on wind data, global wind data, we have a computer simulation considering the whole Bay of Bengal Ocean and input the wind data, from that you can get the wind data at any location in the world, sitting at IIT Madras.

Professor Sanasraj has developed a software for that. So now what we are giving is a significant wave height, what is the different months are given here, each month what will be the significant wave height. And what he has developed using that, in Cuddalore in July, we have about 10.86 metres maximum wave height, February also and November December also. But generally Cuddalore is affected by north-east monsoon, which is between October to December, the record is much higher than this, 9 metres also.

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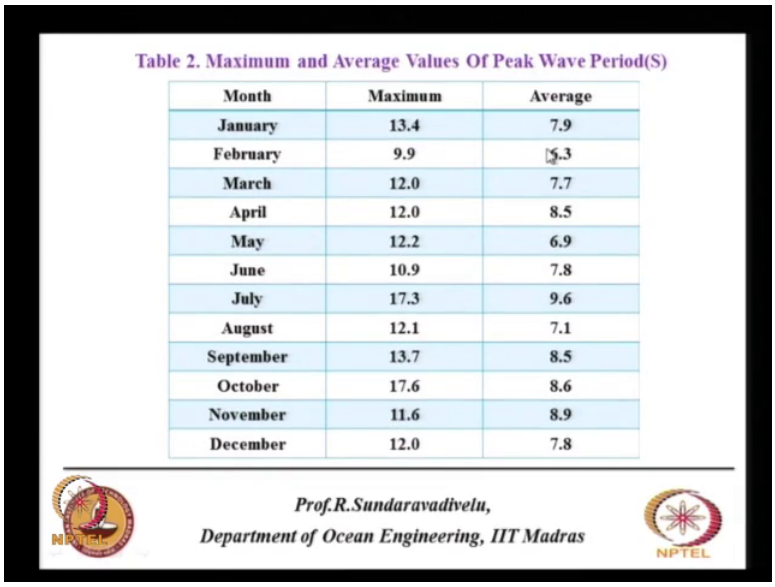

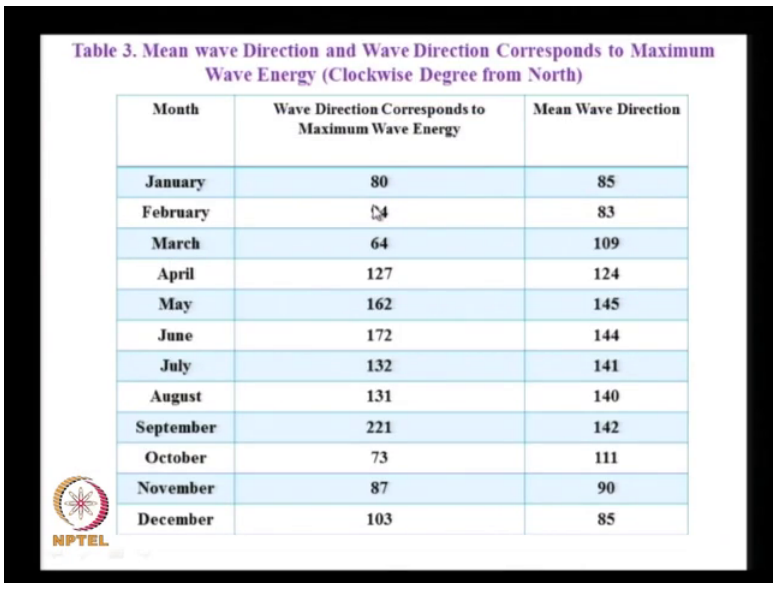

So this is about the peak period, peak period is a period at which you have the maximum concentration of energy, that is also given here. It varies from 8 to 2, 6 to 18 seconds. Then we have to find out the direction from the North, so between 80 and 94 degrees, the waves are coming from the east, 180 degrees, the waves coming from the south. So from this you

can find out, there are 2 directions given, mean wave direction is the mean of all the wave directions, wave direction corresponding to maximum wave energy is, we know which wave height is maximum corresponding to that wave height we have the maximum energy for that wave, what will be the direction.

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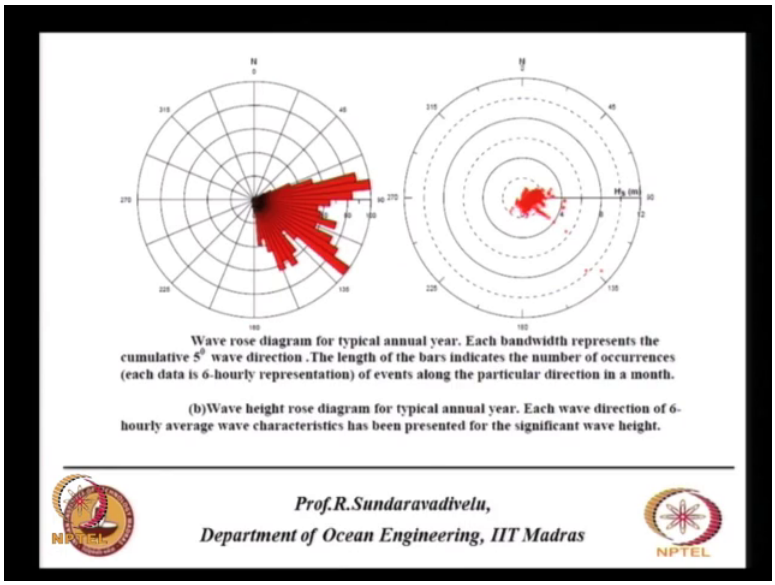

It is almost similar but in some cases there may be some difference, not very much. The figure you closely observe, this gives all the data what is given in the table. This is also a wave rose diagram, what is shown on the left-hand side. What is shown on the right-hand side is wave height rose diagram, this is called as the wave height rose diagram. This is known as the wave rose diagram for a typical annual year, each bandwidth, the presence, 5 degree wave direction, the length of the bars indicates the number of occurrences.

Each data is 6 hourly representation of events along the particular direction in a month. So from this you can find out what will be the, if we see here the most predominant direction with respect to the north-east between this 22, sorry 67.5 degrees to 180 degrees, in this quartet only you have the wave direction which is coming. This length indicates what will be the percentage of occurrence. This is 0 to 100, so it gives what will be the, I think it is the number of occurrences, 100 is the number of occurrences, not percentage. So 100 occurrences here, these occurrences if we take it cumulative, this cumulative is for 6 hours.

6 hours, how many number of waves, you know that many waves will come in this. This figure shows what will be the significant wave height, each circle represents 2 metre wave

heights, 2 metre, 4 metres, 6 metre, 8 metre, 10 metre and 12 metre. Suppose a point lies here, what will be the wave height?

6 metres.

What is the maximum wave height you getting? This is the point, what will be the value?

11 metres.

What is the direction? 125 degrees to the north, it is south-east. And more points are, if we see, the total number of occurrence, most points are within 2 metre. If you exclude this 2 metre circle, the points are much less. So if we take 4 metres, this also you can consider inside 4 metre. Then we have only 1, 2, 3, only 3 occurrences which are more than 4 metres.

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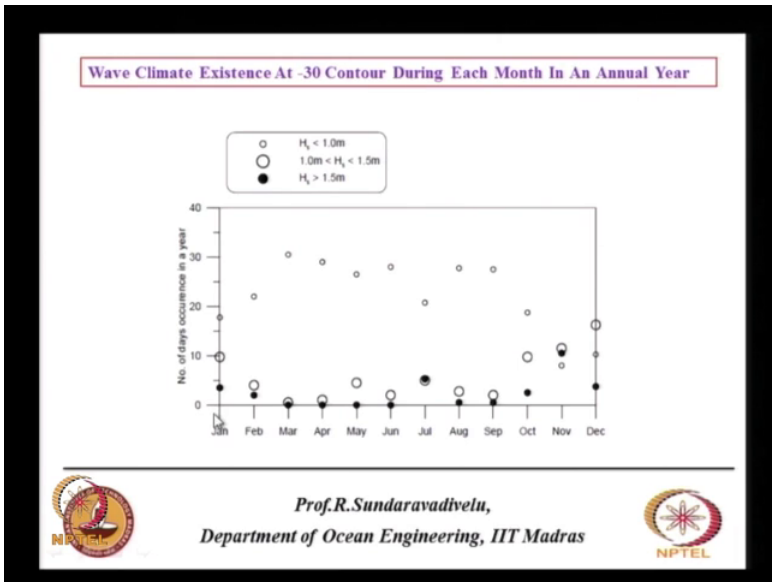

This wave climate, what we are discussing is the depth dependent. Whatever wave we are finding out, this we have to tell what water depths we are giving. Here it is 30 metre contour, each month in an annual year, so we have January to December, number of days of occurrence is given here. There are 3 symbols given, one is significant wave height less than 1 metre, significant between 1 to 1.5, significant greater than 1.5. Greater than 1.5 is 0 from March to June and August to September. This month the wave height will be less than 1.5 metre which is a typical wave height below which you can operate the single buoy mooring system.

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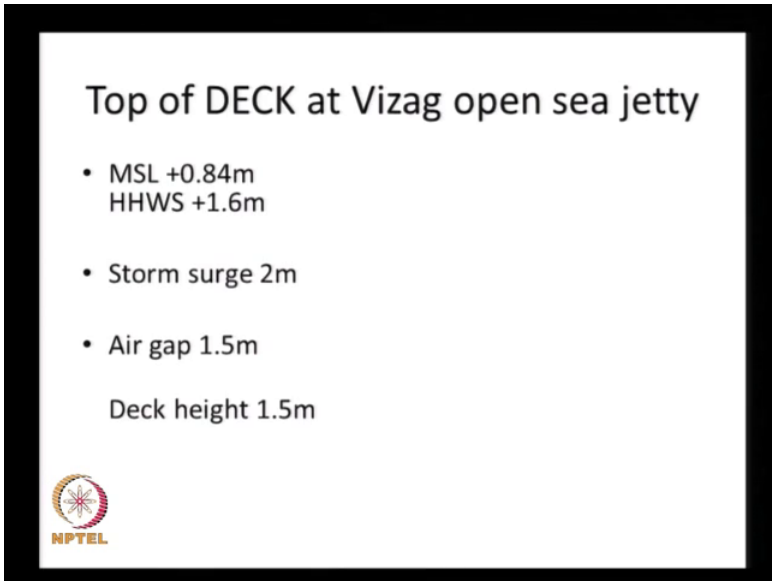

So this less than 1 metre, the number of days given here, 1 to 1.5 metre the number of days given here. So this gives another way of the presentation of wave climate, this is a 30 metre water depth. Now to conclude this lecture I am going to give a case study. We have open sea jetty with a breakwater which will be operated in calm sea condition, maybe typically about 9 months in a year this can operate. We have similar structure in Nagapattinam which was not affected by tsunami, the top-level of the structure, for CPCL is about +11 metre, the wave does not touch the top of the deck.

This is for Vizag, this is for open sea jetty, this is mainly used for seawater intake system. The mean sea level is left 0.84, highest high water spring is 1.6, storm surge is 2 metre, air gap is 1.5 metre, deck height is 1.5 metre. So we read the title information, we just search information, we need the air gap as per code, we need the deck height depending on the structural loading.

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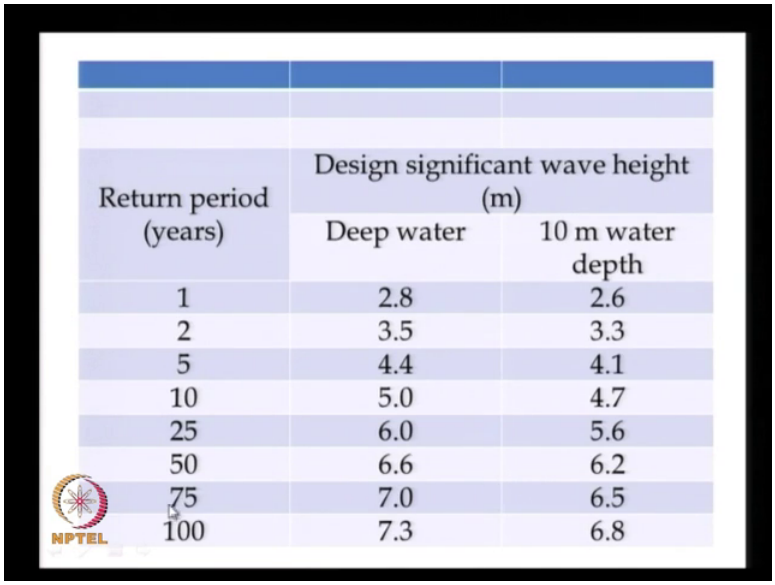

Return period (years)	Design significant wave height (m)	
	Deep water	10 m water depth
1	2.8	2.6
2	3.5	3.3
5	4.4	4.1
10	5.0	4.7
25	6.0	5.6
50	6.6	6.2
75	7.0	6.5
100	7.3	6.8

One more information what is required is the return period and the design significant wave height, in deepwater maybe 30 metre contour and 10 metre. Our jetty is located from 0 to 10 metre water depths, so we are taking a 10 metre water depths, what will be the wave height? At 10 metre water depths, compared to deepwater the significant wave height will be lesser because there will be some wave breaking and so many other factors which reduces the wave height.

So if we take one-year return period, deepwater is 2.8, 10 metre it is 2.6, if we take ten-year return period, deepwater 5 metre, 10 metre it is 4.7. Typically we take about 100 years as a return period, last class I was telling about the return period. Deepwater is 1.3 and 10 metre it is 6.8 metres, we have to take only this column, this particular value, 6.8. So we have all the information.

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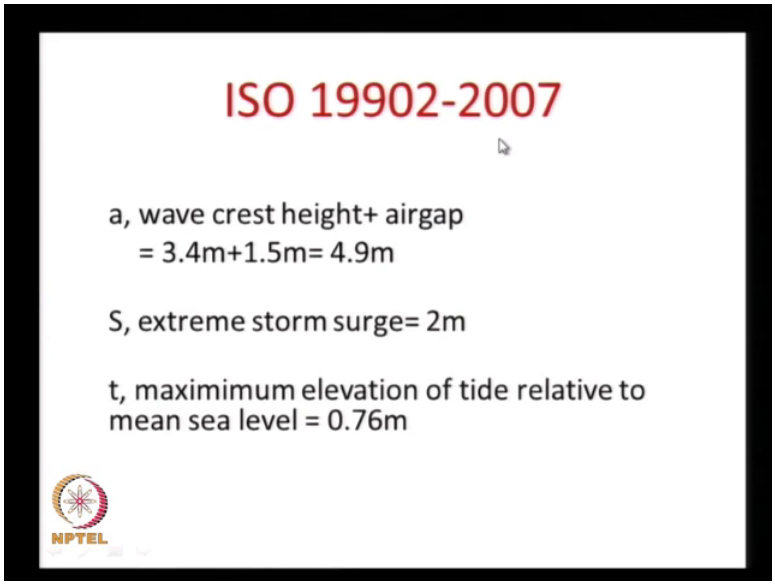

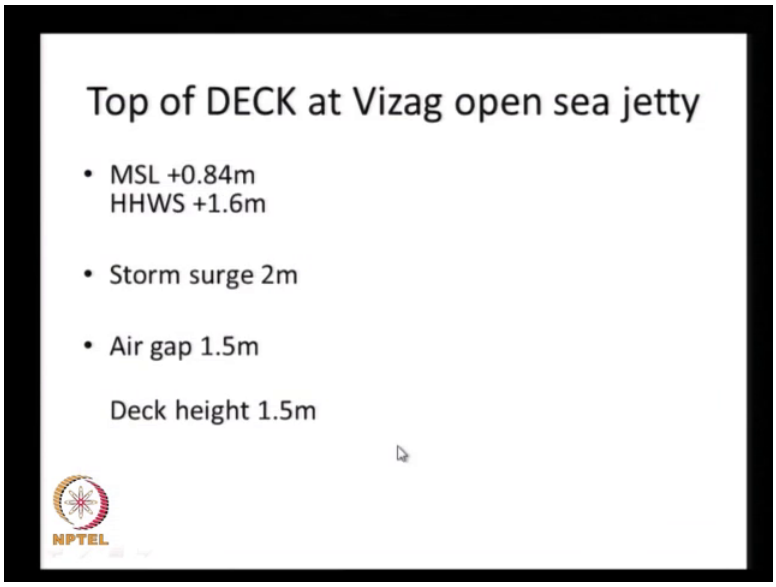

There is an International Standard Organisation code 19902-2007 it is published, it is the international standard in which I think more than 100 countries are participants including India. It is not a bureau of Indian standards, there are different codes, European code is there, EN number, American codes are there, IS codes are there. So this is ISO code, they want to define 3 parameters, a, S and t. A is the wave crest height + air gap, wave crest height is half the wave height, net 3.4, air gap is 1.5, you get 4.9 metres. You calculate this parameter a, S is extreme storm surge, that is to metre, t is a maximum elevation of tide relative to mean sea level, that is 0.76. So we have given mean sea level is 0.84, highest high water spring is 1.6, 1.6 - 0.84 is 0.76. You calculate a, S and t. Maximum wave height and extreme storm surge, will it act at the same time? Yes or no? No nodding heads.

Yes, it can.

It can. It need not also. Same thing with tight and wave also, right. So there is some probability you have to consider. So if the a and S, what is a, a is wave crest and S is storm surge. These 2 we say as independent or associated. Tide is going to be present all the time, you can call it as independent but it is an occurrence which will happen everyday, right. But a and S can act simultaneously or not simultaneously.

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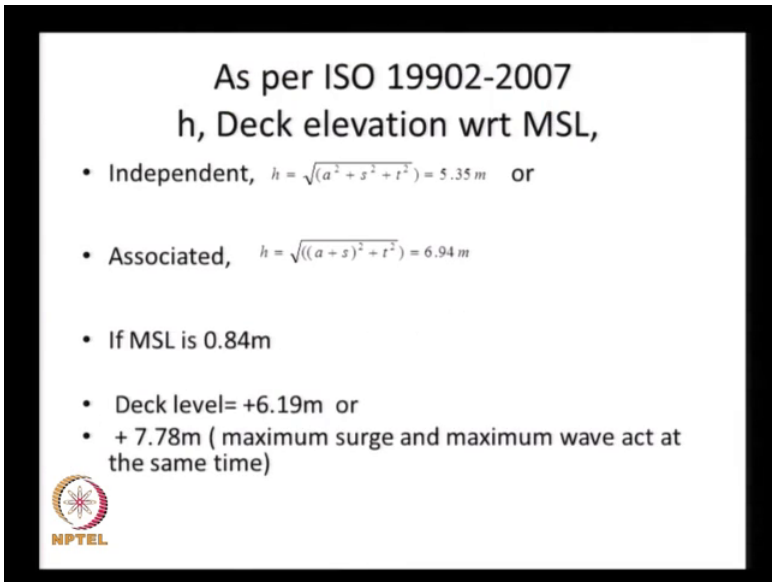

So this is called as root square of the independent variables. So the independent, if it is we have to take a square + S square + t square. If it is associated, a and S are associated, then you have to put a + S the whole square + t square. Before 2007 we want to simply add a + S + t. If you put a + S + t, what will happen, 4.9, 2.2, 0.76, that means 7.56, it is 7.56, correct no. Using that, we designed the structure before 2007 at the same location. We had put the top-level as + 8, assuming a + S + t, this is above the mean sea level.

NTPC had designed another structure after that, but NTPC wants to be very conservative, they have put the top-level as +10. Recently we are now doing one project for Hinduja, we have put the top-level as 7.5. So if we take the MSL as 0.84, then the deck level will be, you have to add 5.35 to 0.84 and 6.94 to 7.78, but we have kept the top-level as +7.5, which part we have done, because of a lot of cost implication.

And you have to follow codes, you can simply say I will add a + S + t, I will use some other air gap, all these things you do not have any say in that you cannot assume, you have to

assume means you have to assume based on certain principles, certain codes or certain publications. Okay, I will end this class today, you go freely now.