Fire Protection, Services and Maintenance Management of Building
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Lecture – 55
Periodicity and economics of condition survey

We will continue from where we have stopped. Look you know, last I think we were looking into the inspection schedule, we said that there are two types of you know three types of structures. Strategy for inspection three types of structures; class one, class two, class three; and two environments aggressive and non aggressive. Therefore, exposure condition you can defined with respect to this. And some of guidelines for periodicity of structural inspection were given. Where you have class one structure and very aggressive, you know exposure condition is very aggressive. There you know very severe condition there, you will do every two years. And in between you will do actually once routine survey, next year extended survey which means that you might use instrument also you can plan that accordingly, what you would do every one year.

For example; a nuclear reactor, you know structure somewhere in the coastal Gujarat or coastal Andhra Pradesh, you possible got to see it every year, I mean Tamilnadu, Kolapakkam for example, you know or somewhere on the western coast like Bombay and similar sort of thing. So, you got to see them every year; once routinely inspection schedule and then one with some instruments. So, you may I may have to relay for example; crack measuring. You know devices to even visually observe. And today you can have use drones and things like that, wireless communication. So, therefore, one has to use all those, you know you can do that.

While coming in coming to not so important structures, you may superficially do not important structure in non you know not severe normal exposure, you can just do it or may not do anything. Somewhere you might did once in 10 years that sort thing and routine maybe once in five years.

So, that is how one should look into actually a strategy should be decided, as a guideline I have given. But then these days you can do actually monitoring, complete monitoring.

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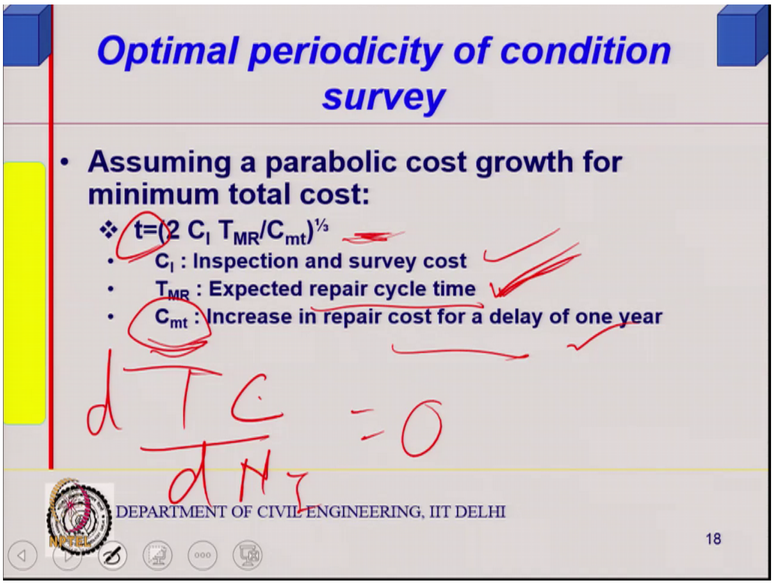

You can do of you know; you can where continuous monitoring if you are doing with instruments then the periodicity of inspection is 0 because, continuously you are monitoring it. So, you can instrument it, it is actually been done in many bridges. In Europe for example: Switzerland many of their bridges where actually instrumented with fibre optics sensing devices which will measure the kind of defamation. And then you can relate it to you know other properties like strain and derived properties, out of defamation.

So, how it is changing? Seasonally over period of time or if there is any damage, but normally such damages would come rarely as I said, deterioration is one of the major problem, especially when your exposure condition is very severe. And chemical sensing or sensing for distresses related to durability that is very very important. At the moment we have not really nothing commercial exactly, has come although attempts are there to find out the chloride, if it is in an chloride environment, how the chloride concentration is likely to change, might put a capsule inside the concrete and see if the you know chloride concentration is changing.

So, one can derive, a simple relationship assuming that parabolic cost growth. Using this kind of a curve that I showed you earlier, I showed you a curve like this earlier right.

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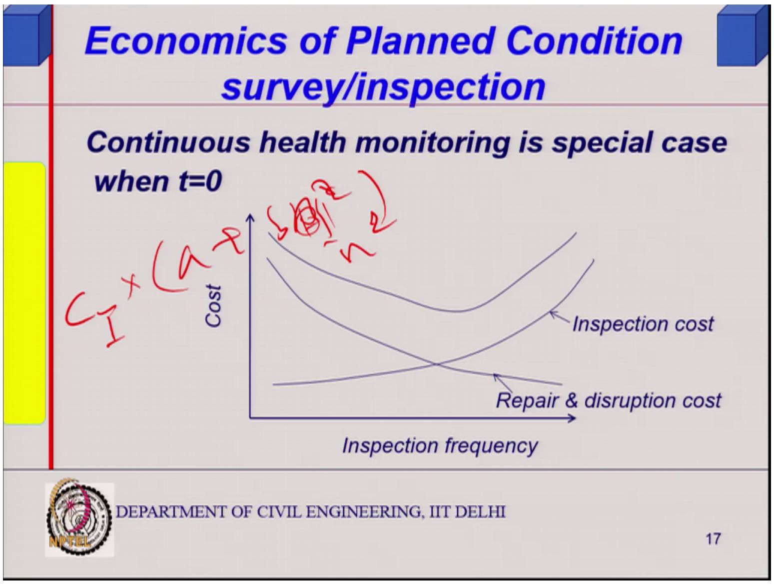

I showed you a curve like this earlier So, if, I know how the cost will increase right, so, how the cost will inspection cost will increase; supposing I know the cost of par inspection is C I as we have used earlier. Cost of a par inspection C I and with time it unit inspection cost increases something like a plus b t square or some such formula. You got to know this, but this is not very easy you know like inspection cost because, you know inspection cost will increase because of what if you are doing number of inspection.

So, if the periodicity of inspection is n per year, so, per year cost would be number of inspection, I mean 1 by n square, 1 by n square or something 1 by n square or something like that. You know 1 by n square or some, so just let me erase this off.

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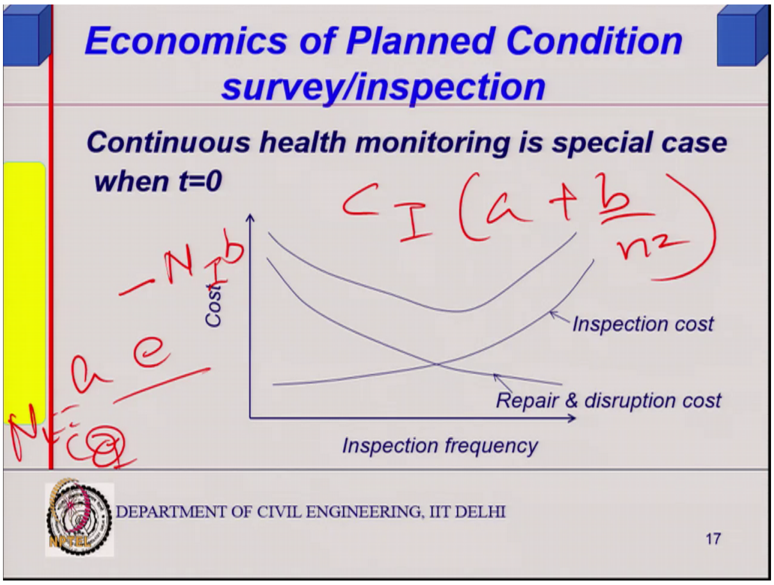

C I into a plus b by n square or exponentially might decrease, some sort of formula you might use we used. One expansion formula earlier a e to the power minus N I into some b b and something like that. So, this could be your inspection cost per unit inspection right. Or I mean there is a number of inspections, actually number of emergency calls were given like this.

So, inspection cost one can also increase because number inspection increases. It will be possibly, sorry this would be, this I think this is not correct, I mean this is not correct this, this is not really correct. Basically, this inspection cost will increase because if we increase the number of inspection.

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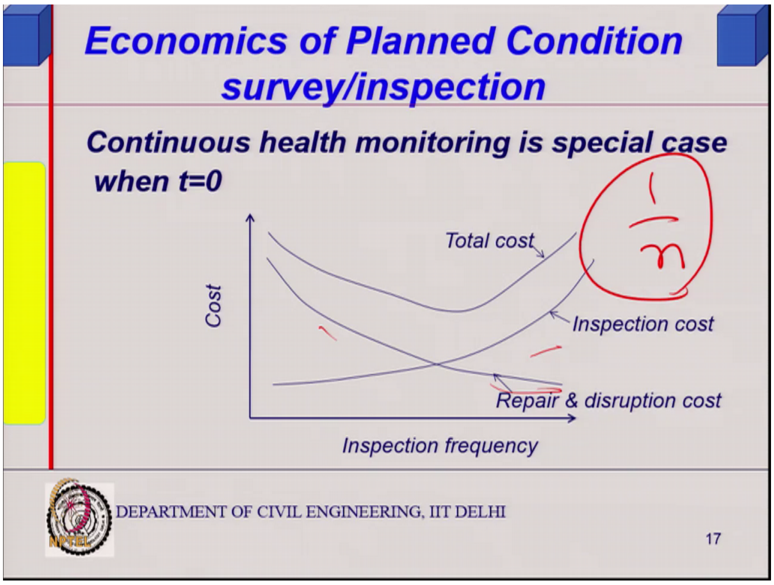

So, this is one thing the inspection will increase. Repair cost and disruption cost will reduce you do more inspection. So, if your periodicity of inspection is number inspection per year is n, then 1 by n is a periodicity of inspection right in years. And repair cost will be related to this. So, we actually earlier related repair cost to number of inspection because, we said that number of emergency calls will reduce. Here that cost should be if you increase the inspection, during the period of time. That is during 1 by n year, you might you know average repair period would be basically 0 to 1 by n.

Because either you have to repair next or you may have to repair you know, basically this will be related to this cost will be related. But, arriving at such cost is not very easy, you need some assumptions. And once you do this assumption you can actually find out the total cost expected repair cycle time, that is what I am saying which will be half the inspection time. So, you know this total cost T C one can minimise. So, d C T C by d number of inspection that we do, that and we put it equals to 0 and then you can obtain an expression of T equal to this. I just deliberately did not want to do the derivation so, this, but physically we understand because, there is you know we do not know it is very difficult to find out T mr at the moment.

For structural scenario for a given environment, how do we find out when the first crack we will appear, because I showed you earlier the acceptable level and normally acceptable level and serviceable to a limit. So, that rate of deterioration prediction is not easy at the moment mathematically, mathematical models are not there some empirical guideline you may have, but mathematical models reliable mathematical models they are not there at the moment very few. In fact, it is not there, I would say even if they are there, they are not you know not verified or things like that.

So, T MR finding out T MR is relatively difficult and C mt is a increase in maintenance cost for a delay of one year. So, if you delayed the repair 1 year then, this is a C mt is the cost. If you delay it in two years or you know, then it will increase not linearly it will not be double of it, but it will be some square term of t. So, that is what we said you know it parabolically increases. Using that kind of thing, you can actually derive this sort of formula.

But, knowing this is not very easy, knowing this is not very easy, it requires time. This might you might know, inspection on survey cost this you might know. So, t can be optimal inspection time can be determined in this way, but the guidelines till something mathematical is available to us we can use those guidelines which; I have given you earlier in tabular form. If you recollect, I have given you in tabular form something of this kind, something like this I have given you earlier. I am just going back again right, I going back again.

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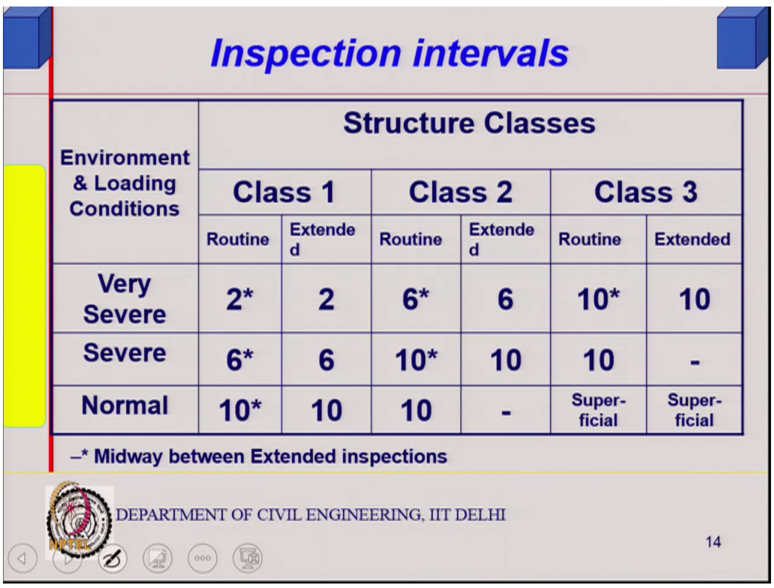

Environment & Loading Conditions	Structure Classes					
	Class 1		Class 2		Class 3	
	Routine	Extende d	Routine	Extende d	Routine	Extended
Very Severe	2*	2	6*	6	10*	10
Severe	6*	6	10*	10	10	-
Normal	10*	10	10	-	Super-ficial	Super-ficial

So, this is what I gave you inspection interval, till there something mathematical you can use this.

And for t equals to you know special cases t equals to 0, where you are doing continuous monitoring, continuous monitoring. But as I said that difficulty is you can monitor some of those mechanical issues, like defamation etcetera. But these are not major issues in many cases, defamation issues are not major cases. Defamation or defamation, it is induced by some chemical changes then, it is important. Then, you know it will come to the maintenance cost.

So, if you study for failure of buildings or maintenance cost of building structures; it will be mostly largely in Indian scenario, it will be due to river corrosion and which is not a structural problem. So, you measure the strain defamation you will not get anything, but somewhere there is falling of concrete would occur because cover concrete is you know is fall down because of river corrosion.

Even in bridges once looks as this is one of the major problem all worldwide, number of failures because it prevent unattended is this. Other failures is as I said one can do a survey and find out look into the net and you can find out major problem will be related to something of this kind still (Refer Time: 10:17) fatigue becomes some time a problem.

So, this is the kind of issue actually, is related to you know relevance of maintenance and inspection.

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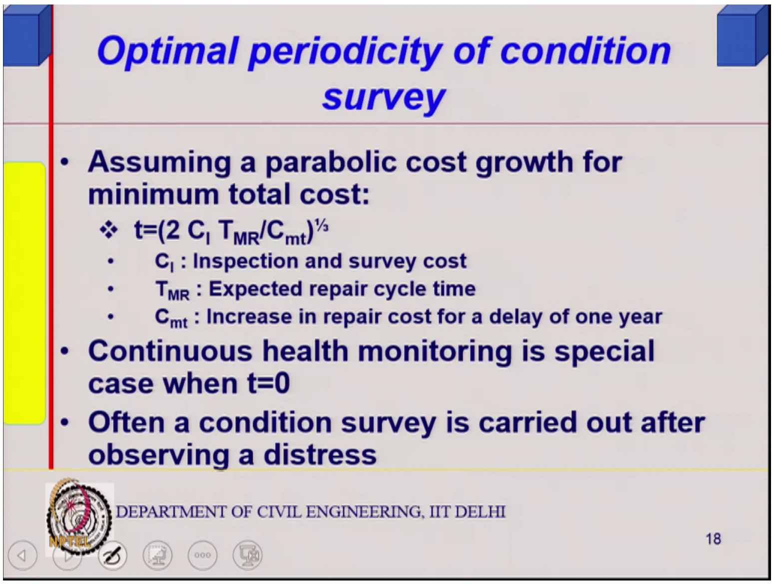

So, that is what I think the I just finished discussion in the last class, I finished discussion in the last class.

So, let us progress from there right, let us progress from there.

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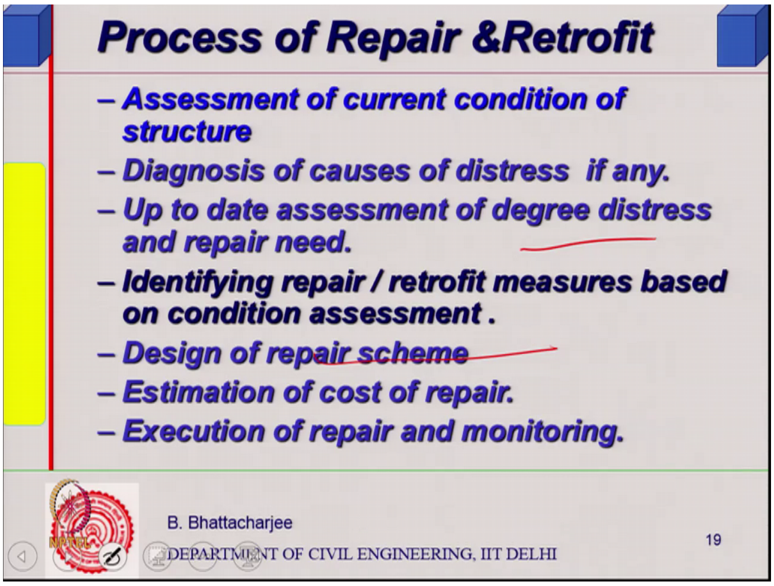

Now, if you want to do repair of structures is the same like, maintenance first assessment of current condition which I have already shown you. Diagnose the causes of distress anyway, up to date assessment of degree of distress that would be care. And then, once you have done that diagnose it quantify it the amount of repair required by inspection, then you can make an estimation. If it is repair total condition survey has to be done, to find out what is the total area which is to be repaired. And once you know that from time to time and even if you are you know expected that normally structural repair or repair special repairs including, you know repair due to corrosion and things like that corrosion falling or corrosion distress that is not envisaged in design. You do not you think that nothing will happen.

But when it comes then you have to keep a track. And if you are doing regular inspection obviously you will keep the track and then do the repair. So, once you have done the inspection, found out the area of repair right and here the repair cycle of complete renovation of the structural may not be allowed because very important structure you will do repair. But you might see what is the cost increase and if the cost of repair is more than that is required half the at least refurbishment or 60 percent of the refurbishment of the whole thing you might do a complete renewal as we discuss the economics earlier also.

So, first you find out, what is the distress and degree of distress. First of all if you know area of patch repair for river corrosion is required, then you can estimate what is the cost. So, from condition assessment you find out like that and then you can estimate the cost. And then methodology of repair the quantum of cost will depend upon the methodology repair here actually. Methodologies are more or less straight forward let us see if we can discuss some of them if time permits. Then design of course, the repair scheme and it should be cost of repair comes from estimation of cost of repair.

So, you got do a condition survey to estimate the cost of repair even complete right.

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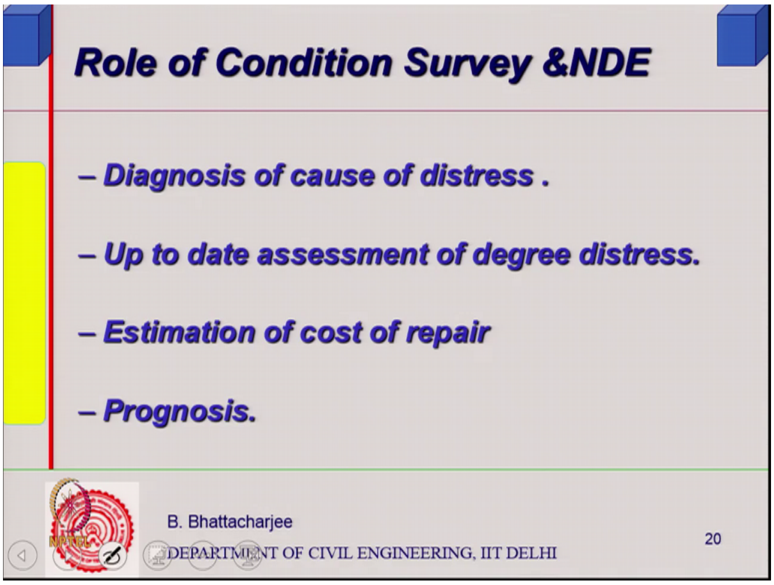

So, that is what it is. So, you know conditions survey first, diagnosis of the cost of distress, I mean cause of distress. And the cost of distress actually, that is what estimation the cost of repair that is what you do from a condition survey through.

Then you can also do a little bit of what we know prognosis. If you do not do the repair, how will it progress? Again we do not have really good models to do that kind of thing, but statistically you can do some provided you do periodic maintenance, I mean periodic inspection. Last year this many number where problematic or showing signs that it may become bad, this year it is increased to something more, and next year where will it go you can find out. So, some statistics you can use.

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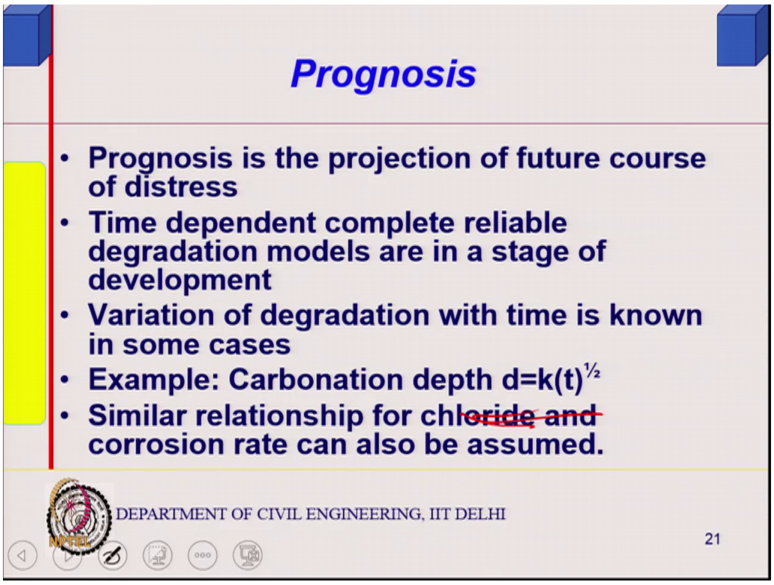

So, let us say an example; you know prognosis is nothing, but is the projection of future course of distress. So, time dependent complete reliable degradation models are not there at the moment. And variation of degradation with time sometime we know, for example, if I know degradation will vary with root over t, t to the power half depth of carbonation for example, it varies you know approximately, it varies with k t to the power half, some models say the basis is there physical basis is also there for this model.

So, what I can do is if, there are similar relationships available for other kind of distress that also I can look into.

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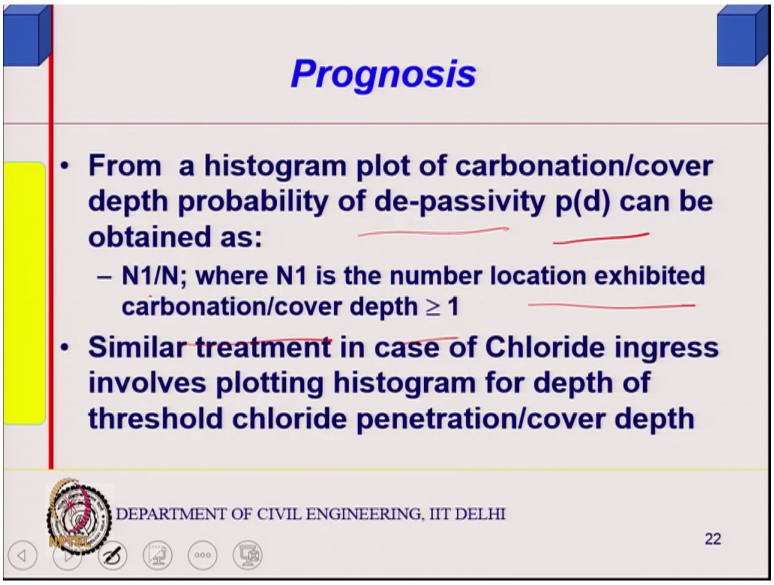

And prognosis means I do have histogram plot, because carbonation phenomena I think, I must have mentioned that carbon dioxide from the atmosphere enters into the cover concrete. And when ph goes down below certain level the steel may start actively corroding. That is what we call de passivation occurs.

So, if I measure carbonation to cover depth then, probability of finding the number of locations depassivatedm, would be given by this; n 1 is the number of location exhibited carbonation to cover depth more than 1, n is the total number of observations I made. So, probability of finding carbonation depth exceeding the cover depth is given by n 1 by n, where n 1 is the number. So, I did one some year I have done in at a given time right.

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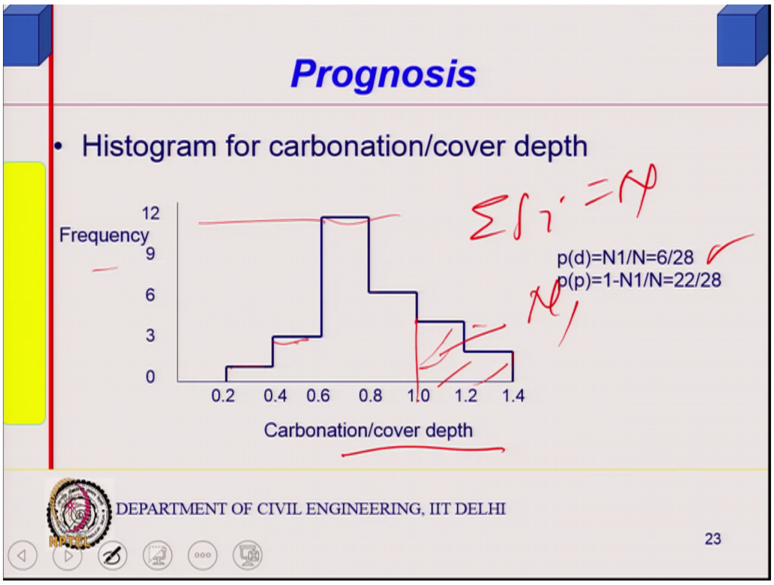

And then I can plot histogram. So, histogram is carbonation to cover depth at a given time, I can find out. So, n 1 number, so this is the frequency. So, total max this is the total number you know, this is a total number will be sum of this plus, this plus, this. This is the frequency diagram in this case, it is actually 1 plus 3, 4 plus 11, maybe 11 plus 4 is 15, 15 plus 6, 21, 21 plus maybe 4 25 plus 2, 27. So out of 27, I see that, carbonation to cover depth has exceeded in 4 plus 2 number of them.

So probability of finding a location carbonated on that particular type of measurements is, given by this is my N 1 and this whole total sum total of all fs sigma f i is equal to n. So, you know, it would show you 28 of them are there actually So, 6 out of 28 should you know, cover depth more a carbonation depth more than cover depth and 22 showed less. So, my probability of finding carbonation depth exceeding is this you know 6 by 28.

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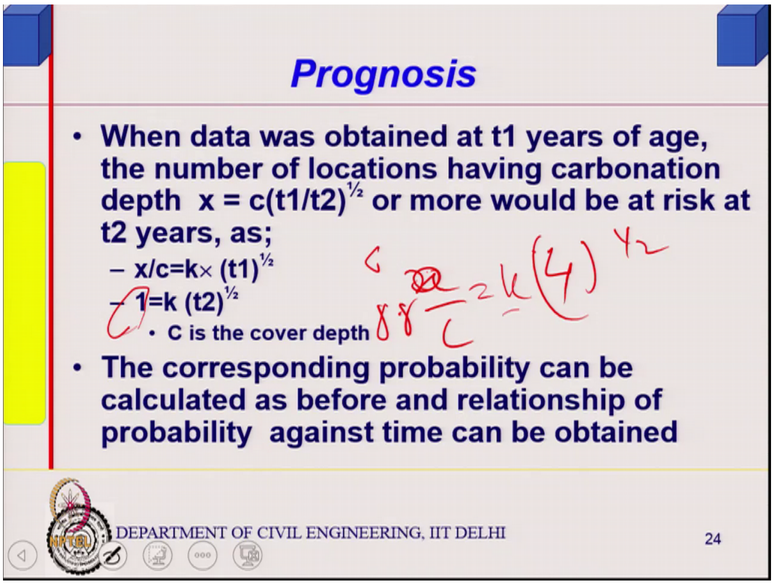

Now supporting I know that after some 5 years of time, the relationship is t to the power half. So, the carbonation to cover depth is some constant t to the power half right. So, if this is the time I have found out, what is the time it will when it will become 1 for most of them that I can each one I can find out.

For example; it was 0.8 at 4 years let us say show x by c x is the carbonation depth, c is the cover depth was let us say at 4 years, was some k into t to the power half 4 to the power half. So, at 8 years or 9 years how much it would be; I can find out because this was let us say you know this was 0.8 let us say. So, 0.8 just let me to write it like this properly.

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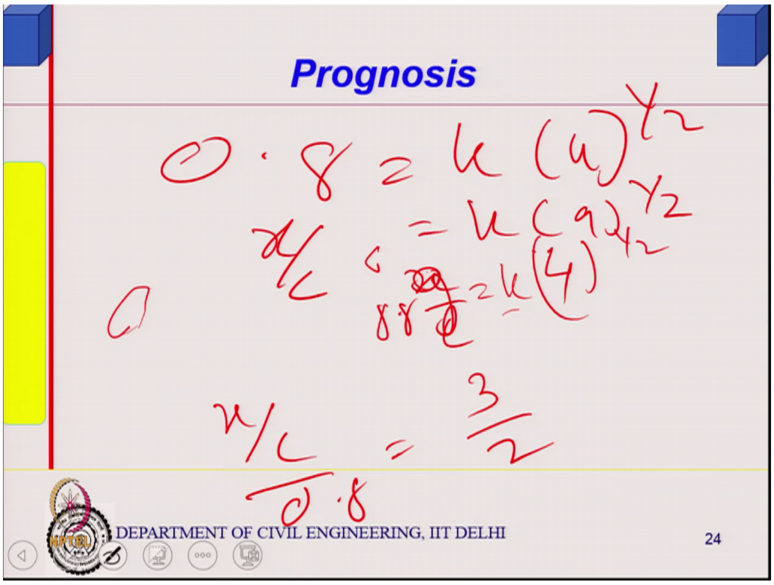

0.8 was x by c at the age of 4, so 4 to the power half. At the age of 9, I want to find out how much this value will be, so x by c is unknown to me same, k 9 to the power half.

So, if I divide you know the ratio of x by c by 0.8 will be equal to 3 by 2. So, it will increase by 1.5 times you know, so, it will become 1.2. So, if I want to find out what is the time when x by c will be equals to 1 that I can find out, and then I can future futuristic histogram I can plot. So, after 5 years this was the histogram this was the histogram now.

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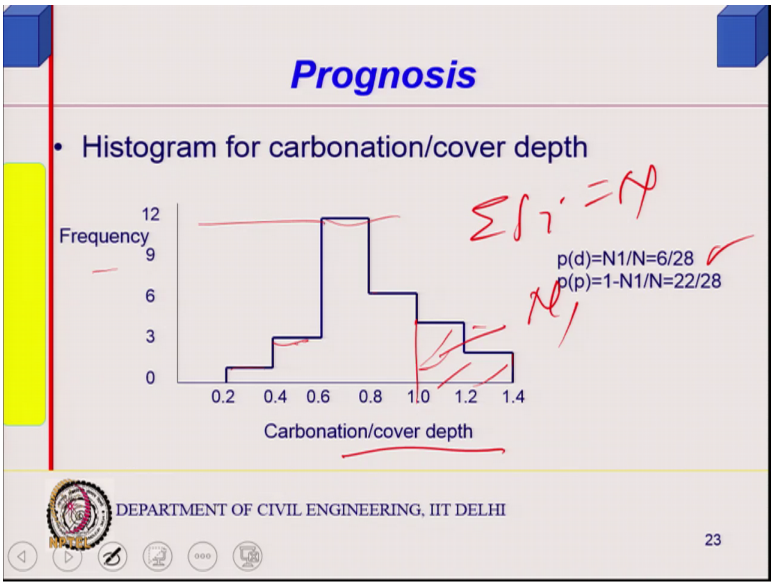

And if I have reliable model relating to time then after 5 years or after 10 years, what will be the histogram I can find out using this kind of formula, if I know t relationship right.

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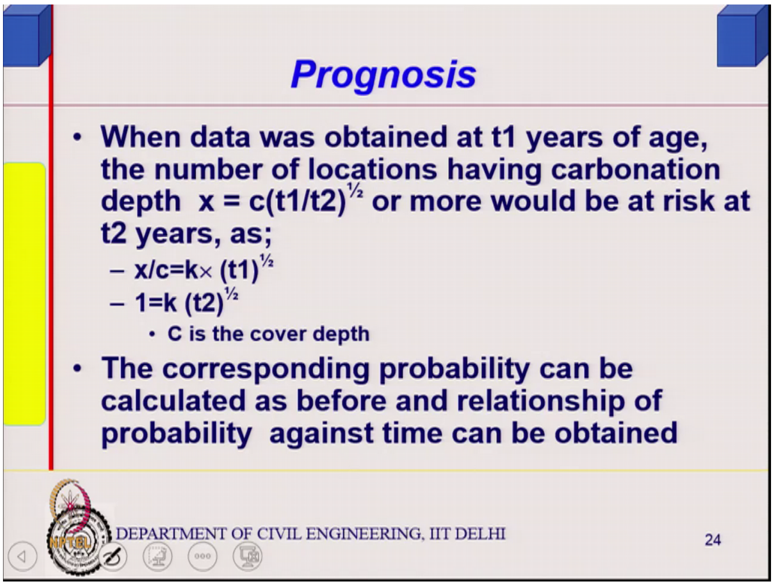

So, corresponding probability I can calculate out and this probability, how it changes with time then I can find out. How this probability over the whole structure changes with time I can find out. Therefore, I can find out when I should actually do at what probability, at when the probability exceeds a certain value I had possibly must do my repair. So, in future when you say do that, you know repair or treatment against carbonation or you know change the cover concrete possibly that I can find out. So, that is that is what it is.

Also one can use more sophisticated statistical tools like Markov processes.

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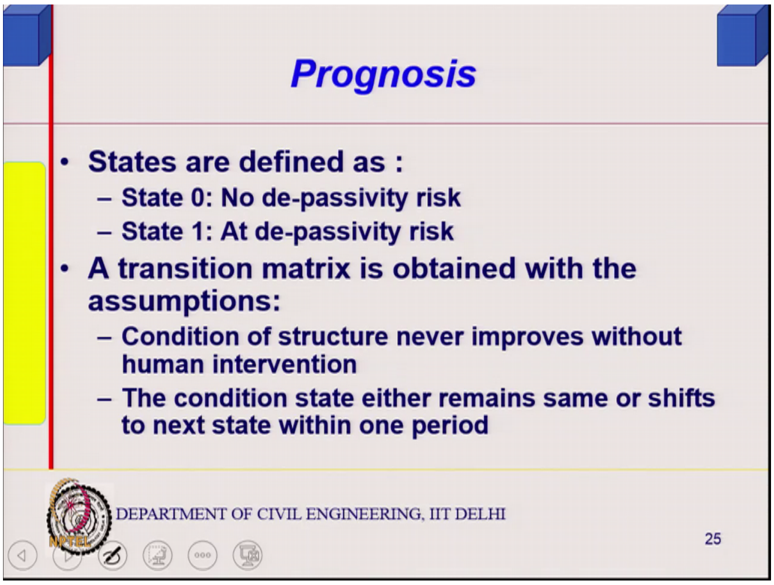

So, for example, I might define state 0, no passivation restate 1 that is de-passivated you know, de at de-passivation risk. So, no de-passivation risk, 2 states I can define. So, transitional probability if I am going to 0 to 1 state that I can find out and you we can use Markov process and thinks like that. So, one can obtain such transition matrix and actually you know find out future when it is.

Where I think, I leave it at this stage because at the moment real datas are not available to us, but you can use this. So, you can use a transition matrix assuming that, condition of structure never improves without human intervention. And conditions state either remains same or shift to the next state. So, that is Markovian process. One can actually use this kind of process also, and one can actually obtain the initial probability matrix i.

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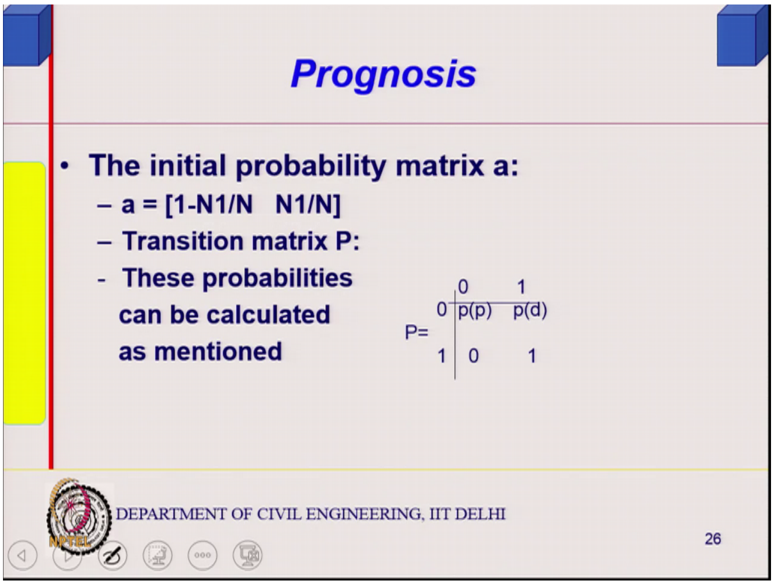

Because I am not, if you were interested you have to first looked at what is a Markov process, which I am not going to talk about here. But you can you can actually use this kind of processes as well in order to arrive at future scenario.

So, I think this is the strategy for repair of inspection and repair of structural distresses structural distresses. So, we can look into this, one can actually other site absolute probabilities after. So, Markovian process also one can use.