Fire Protection, Services and Maintenance Management of Building
Prof. B. Bhattacharjee
Department of Civil Engineering
Indian Institute of Technology, Delhi

Lecture – 54
Repair, Rehabilitation and Retrofit

So, some more institute test which can be done on concrete you know institute test related to durability. So, one is initial surface absorption test.

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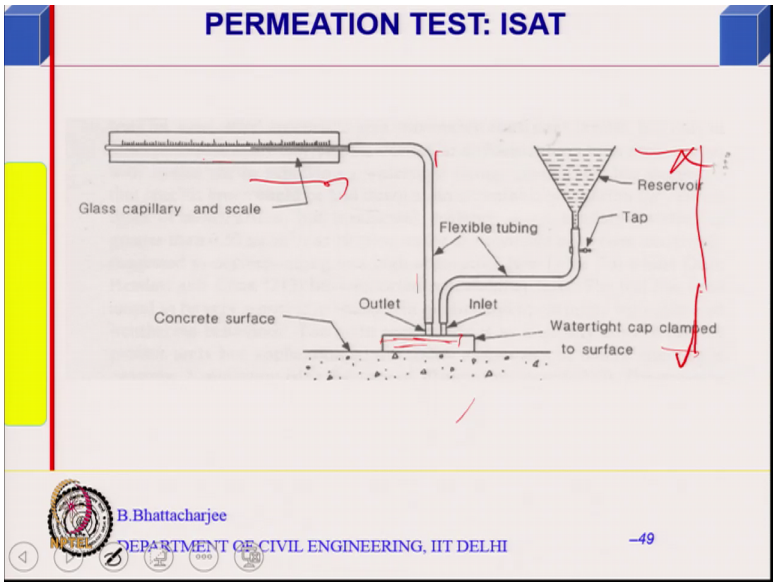

It is a British code test what you do is you have a constant head reservoir right 200 is 200 mm 20 centimetre. So, nothing, but a panel and there is a pipe now there is you know you can close it. There is a clip or tap here which can close this is this is a kind of a watertight clamped to surface right. So, this gets filled with water to start with and this is same height as this in there is a capillary tube where any flow of concrete flow of water can be measured.

Now what you do? You saturate this first and then hold it. After 10 minutes you open this and see the rate of flow through this in terms of millilitre per metre square per second right; 10 minutes, 30 minutes, 1 hour, 2 hour sorry this is called initial surface of absorption test higher this value concrete is more permeable in other words is poorer concrete. All qualitative no quantitative nothing you can really say about how long your repair cycle will be etcetera .

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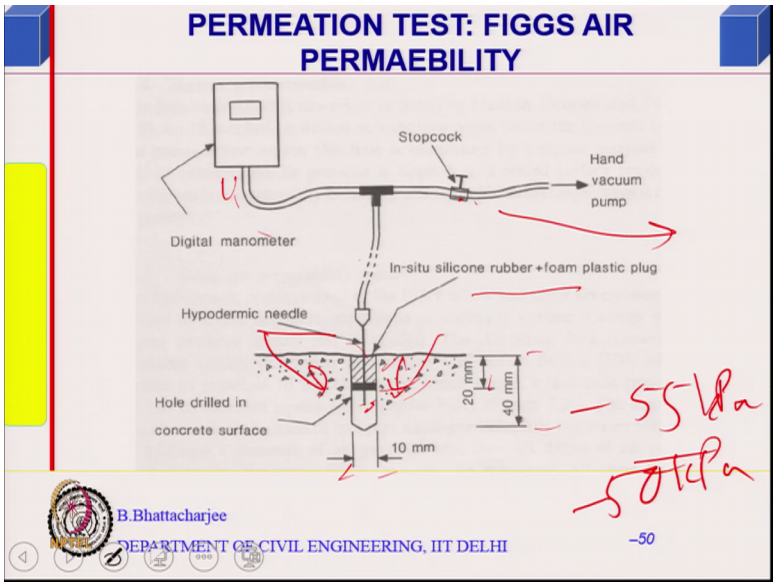

There something called fix air permeability test something all fix water permeability test I will describe one of them. So, fix air permeability test, what you do? You drill a hole here and this a rubber seal you know, hole drilled onto the concrete surface height is around 40 mm and this is 20 mm up to 20 mm you have a silicone rubber seal right. So, in situ silicone rubber seal plus form plastic plug , then there is a hypodermic needle injection needle you pass through it and this is connected to a hand vacuum pump and this is to a meter; this is to a meter.

So, what you do you evacuate this portion you evacuate this portion with the concrete now this 10 mm 20 mm 40 mm, you just evacuate this portion up to something like 55 kilo Pascal vacuum or 60. And then close the tap at let is say 55 kilo Pascal. Now what will happen? The vacuum will get reduced how the air will enter from this side into this cavity from the side and vacuum will get reduced vacuum pump you have stopped at 55 kilo Pascal minus 55 kilo Pascal and then it will air will enter through this and note the time at which it has gone to 50 kilo Pascal or some such values you know over a range. So, if this time is high it means that concrete is less permeable. If it is low, it means that is it high permeable. So, again qualitatively you can measure the permeation quality of concrete.

There are many other test which have come of late auto clamp test torrent test several of them right several of the permeation test have come. But all give you some qualitative

ideas. So, you want to compare one concrete with concrete it is possible. In fact, one of ideas is that by the side of your structure you put some concrete specimen dummies and from time to time measure this observe them and measure them and they can be linked to the performance of the structure. So, performance based design some measurements you can do some in situ measurement, but some dummies also you can use not an easy job, but you can do it in some important structures. So, all this permeation tests two of them.

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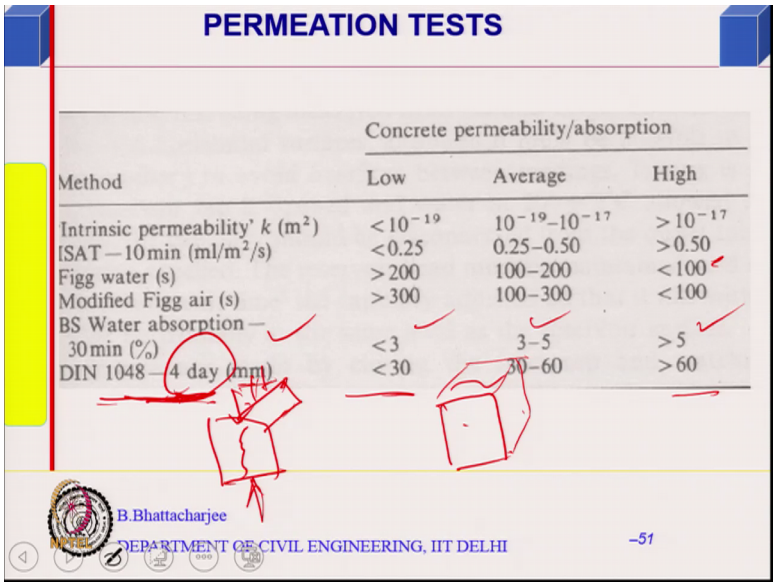

I described there is another BS absorption test what you do you cut a 75 mm core and put it in an absorption tests must in distilled water for half an hour in some standardized procedure the amount of absorption. If it is high, it is a bad concrete high permeably high permeability moderate permeability and low permeability. So, this way it can be classified.

For example, ISAT 10 minutes if it is less than 0.25 millilitre per metre square per second, then it is low permeable. If it 0.25 to 0.5, then it is moderate and if it is more than 0.5, then it is highly permeable. So, you might put your criteria that it should be at least you know you should not be below above this value. I missed out one test din d din this is the German. Now, it must the en test. So, what they do? They actually subject a cube subject a cube. What are you know? The subject a cube under hydraulic head; that means, apply water pressure from one side not this sides right I mean or even for 3 side does not matter I mean the code would tell you how much it is.

Then what you do? You find out how much then you split the split the split this the split test like we do in cylinder. We can do split test in cube also. What you do in case of the split test? In cube also what do you do in case of split test in cube apply a line load right this is your cube apply a load along this line right apply a load along this. So, show it will split. So, you split it and find out what is the depth of penetration of water. Now time of applying this hydraulic head is fixed amount of hydraulic head is fixed the depth of penetration is a measure of permeability. So, it is finished in 3 days something or that order you know. So, 1 day 4 millimetre 4 day test millimetre is given is given 4 day test millimetre din 1048 1045 I think, there you know like the German codes gives you this.

So, less than 30, it is good; more than 60 it is highly permeable . So, BS water absorption test less than 3 percent, 3 to 5 percent, greater than 5 percent is bad and modified fixed air permeability which I showed . So, this is actually I used at site sometime maybe used at site because the simple core you take out core, but then it is semi destructive you can say ISAT; also we have used in site.

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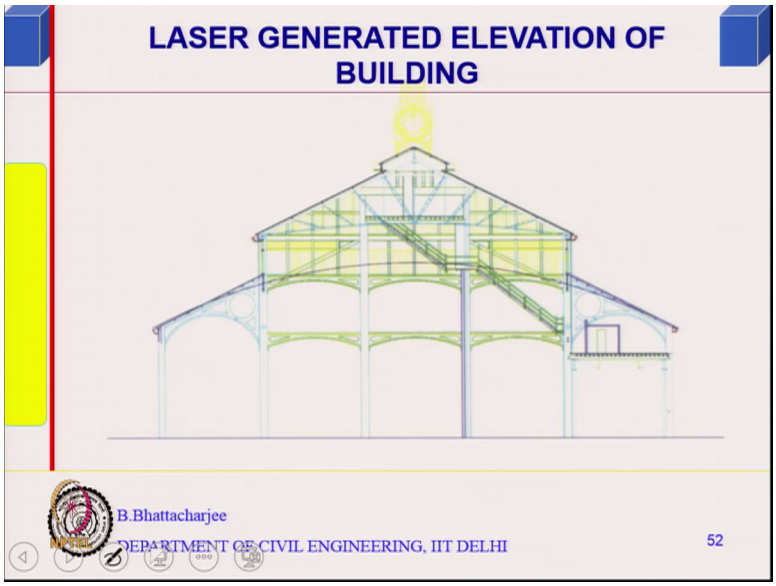

So, other kind of tests that one can do is laser generated complete elevation of building it could look like this today people can use drones to do you know visual survey. It is been done then wireless pass on the information, but it transducer has to be what we talked about and what is the purpose that is more important? You have to decide why you are doing this what are what you want to do what is the objective and what informations as

you want to get that part is important the drone those instrumental technology would not tell you that, but you do select the right kind of transducer. So, using laser steel structure one can actually it will be obtained.

So, these are the some of the non destructive testing and some of the other tests involved in generally condition assessment of building structure and finding out even repair cycle some cases right. The one of the advance stiffness structural health monitoring which uses different kind of sensing sometime they would like to measure the response to dynamic load right and find out how the stiffness is are changing and all that. So, those are more mechanical damage detection related. They are all subjects based on those many of them would look into mechanical aspects, but deterioration aspect is where the maintenance is.

Damages you can determine by various techniques actually or structural health monitoring cannot tell you about at the moment because the transducers are not available for deterioration measurement. Right if there is a damage that has occurred; let say, due to earthquake that possibly stiffness would change some other cracks up come damage is different than deterioration is a gradual process I think I must have given you the definition earlier and damages due to loads.

Students: Loads.

Is related to load. So, this people do you everything synonymously that is not correct retrofitting rehabilitation repair all are all are not same thing in think I have given you different results. Similarly damage deterioration they are different issues actually deterioration can lead to long term you know long term deterioration can lead to damage, but damages are usually quickly they come during accidental, overloading, earthquake sometime fatigue damage could be there over a long period of time mean where here stress reversal is there. So, that is it that is related to this.

Now we will look into some strategies. So, you know as I said that people do to bridle up with definitions of repair rehabilitation and retrofit I have I might have given you once, but let me repeat it again.

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Repair relates to restoring the functional performance to an acceptable level that is what we defined earlier. Also and we talk in terms of patch repairs small areas repair rehabilitation is for the rehabilitation is for the rehabilitation is for the complete structures.

Like something like renewal we talked about you know the link between our maintenance strategies. We discussed about and retrofit is currently acceptable standard. You know retrofit to a current to acceptable standard means nothing may have gone wrong, but still you might do a retrofitting because it is not up to the currently acceptable standard. You know we define maintenance etcetera. So, that profit fits into that sort of thing right even the functionally it is performing fine. Like example is of course, in structural scenario is that seismic risk perception was changed risk perception was changed not really anything else have change. So, you think that you should do strengthening it or something more you know more capacity increase or whatever it is you want to do in some manner or detailing you want to improve.

So, sometimes strengthening is required if you find the actual structure was weak, then whatever it should have. So, the strengthening; so, repair retrofit rehabilitation and strengthening may be a part of the last yeah retrofit as well as rehabilitation also right then some more definitions.

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Damage can occur due to loading beyond capacity damage or distress can occur due to deterioration or degradation of material leading to serviceability limit failure right. So, this can occur over a long period of time.

So, most often degradation or material do not lead to collapse, but you need a maintenance. It will be it would you know cost of maintenance would be there. So, sometime people get really scared. For example, you find a crack at the parapet level between the parapet and the slab of the roof or you know the floor top you know roof top level parapet where parapets starts you find horizontal crack people get scared. Is it going to is the building? Going to gets collapse perhaps not you go to do this.

Similarly, if you see a corrosion cracks one river or couple of river showing corrosion science of corrosion cracking. It does not mean that structure will immediately collapse, you do not attend them then it will collapse. So, you have lot of time available here and therefore, this is related to maintenance more will rather maintenance then collapse scenario right. So, this is what it is did I did I define the life before. So, life is as you know I already defined you. So, life is life we I have already defined now the deterioration etcetera related to durability. So, they should perform concrete structure should perform safely unless deteriorate by environment.

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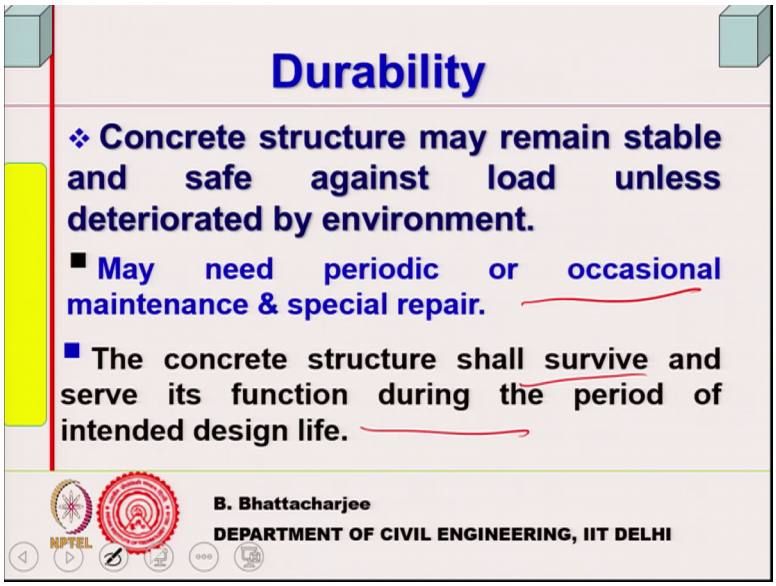

So, when we talk of you know durability is related to deterioration and it should it shall survive and serve the function during the period of intended design like that is what we have seen earlier also. So, you might need periodic or occasional maintenance that is what is the point. So, thus the strategy has to be defined with regard to this we have looked into nondestructive testing.

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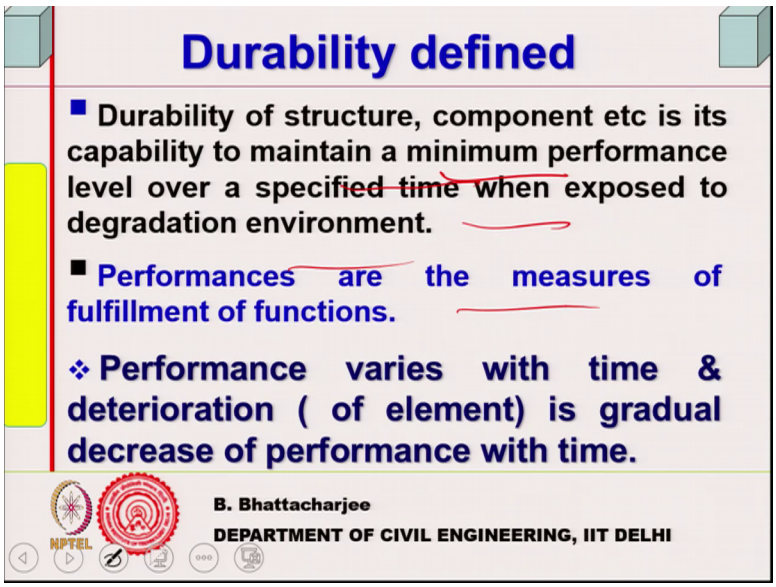

And we have also seen importance of inspect inspection etcetera in case of other components of building. So, if you look at structural element, then also we have this issue. So, we will look into this. So, let us define durability first.

Now, durability is defined or its capability to maintain minimum performance level for a specified period of time in a given environment given environment where you exposed it right. So, it must be able to show performance functional performance whatever we supposed to do. Supposing it is supposed to carry load, it should be able to carry the load or there is you know like load performance is one of them and there could be others performance as well.

So, deterioration and degradation is you know related to durability in this manner. So, it is the capability to maintain minimum performance for a given period of time in a given environment where deterioration can occur performance measures of the fulfilment of functions whatever it could be and performance varies with time deterioration is gradual decrease of performances with time.

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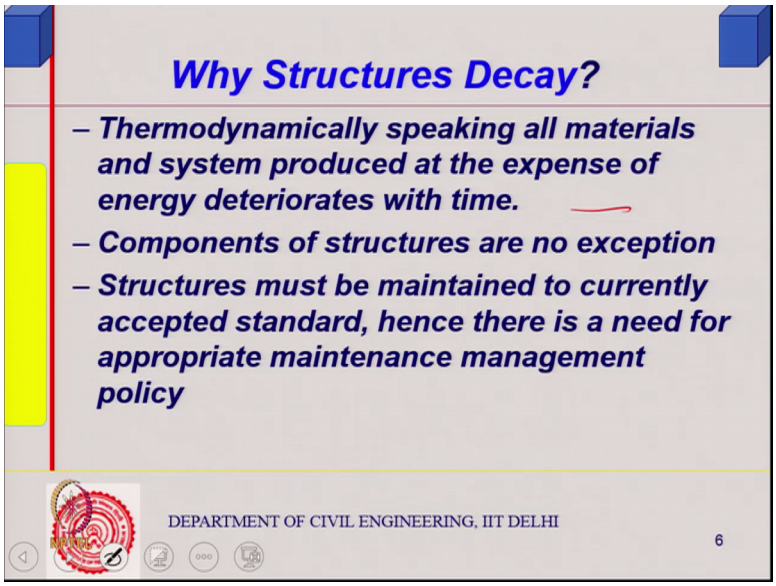

Now, structures or materials will really they will decay because they are manmade produced the expensive energy. So, they will actually show some sort of decay because you have there not at stable minimum chemical potential level. So, all material system produced at the expense of deteriorate. So, is a case of structures and therefore, you must

maintain them to currently accepted standard same concept hence there is a need for appropriate maintenance management principle.

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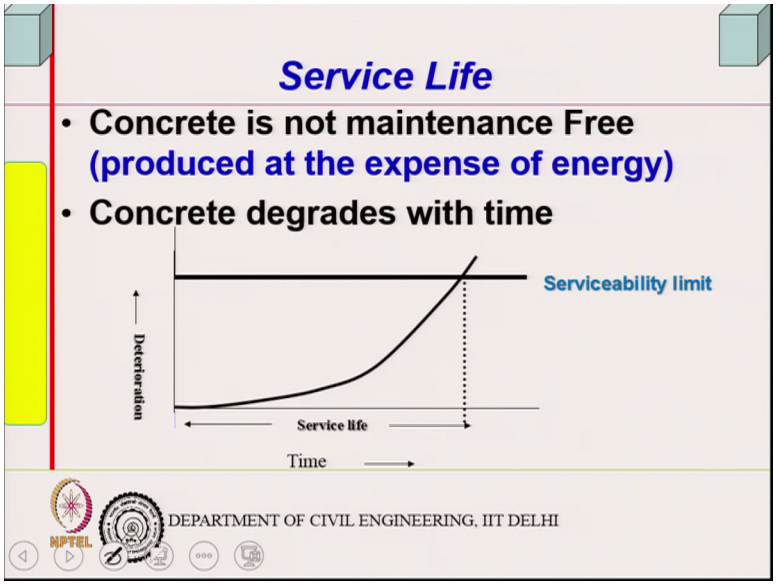

We have defined service life earlier I think we defined this service life earlier. So, that is what it is. So, you know maintenance strategy we have to right.

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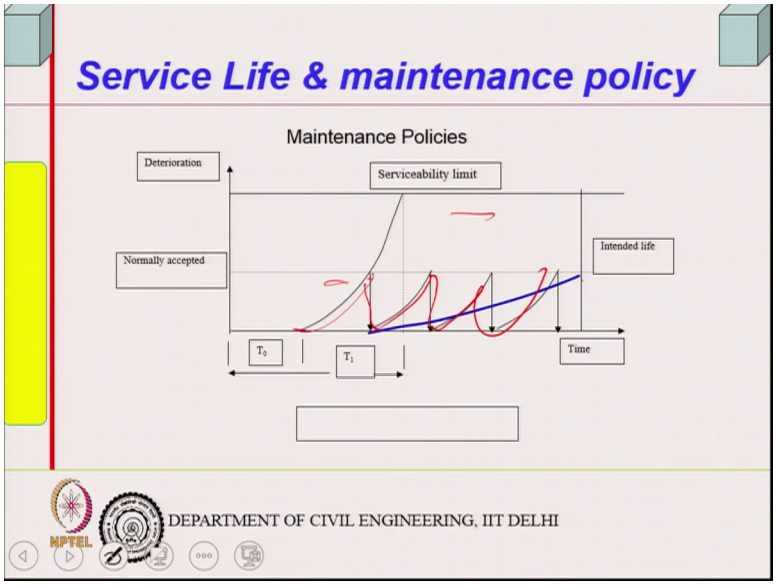

Now, maintenance policies could be you know alternative maintenance policies could be possible something like this. That you use a material or a system which deteriorates then you repair bring it back to original state again it goes and goes and goes. So, you do

several repair in the life of the structure, but this is very combustion because the cost involved will be also into disruption cost and sort of you know it is an uncomfortable scenario for the user. So, you may not actually do the repair exactly at the serviceability limit may be some normally accepted level you might do the repair, but a good repair would do it would be such that you will not need any further repair once you repair the deterioration process in slow down and it will reach to the intended design line.

In fact, you should have maintenance free service life you know maintenance free life intended design life structures because this maintenance do costs destruction cost discomfort you know it is not something is something is crack people do not feel very comfortable about it and we have to repair the cost involved is too high. So, all these issues are there now this can still happen because you cannot envisage the environment deterioration environment truly 100 percent truly you it determine you know envisage the situation is not very easy. So, if there is a deterioration occurring you repair it in such a manner that it goes up to the N that is the idea.

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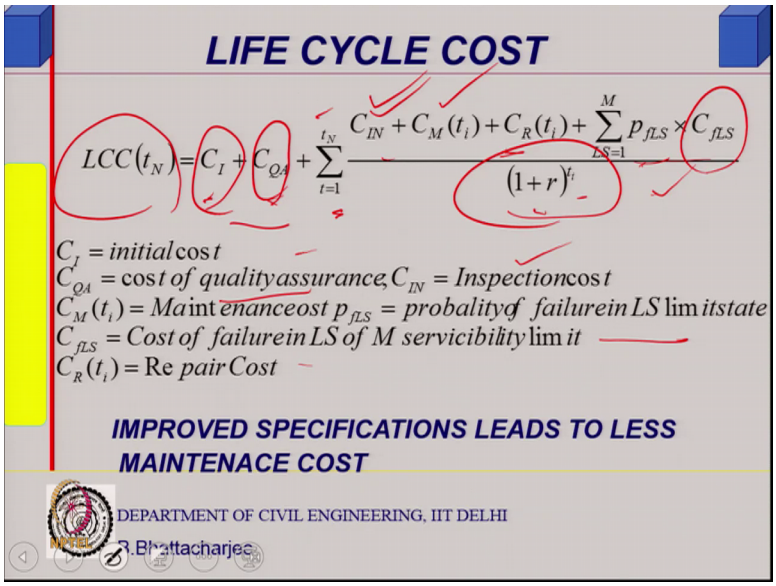

Now, in such situation of course, we have already looked into life cycle cost sometime, but here this is slightly more elaborate I believe then the equation that I give you earlier. So, there is the initial cost this is more important for various kind of structures. Now there is the cost related to quality assurance which could be different for different level of quality control quality assurance it can be different. So, is the pure initial cost

construction quality maintenance cost is something like this which is which occurs in the beginning. So, this is all in present worth from now these costs are inspection cost.

So, you go to do periodic inspection that is what we have seen in case of other components building right. So, inspection cost then there is a maintenance cost and then you can associate with the probability of failure serviceability limit failure probability and then cost of serviceability limit failure. You know the probability of failure in 1st year 2nd year or 5th year 10 year etcetera others should be 0 anyway and you can multiply this. So, this is the probability P p Lf is the probability of doing the repair and which is we have seen in case of buildings roof covering and things like that all of them we will not be done in the same time. So, even structural elements if there is a possibility of deterioration since they will not be out of 100 only 20 building showed problem or 20 structure showed problem. So, probabilities can be associated in this manner and then this is the interest rate and time. So, r is the interest rate t i is the that particular year. So, I going from 1 to n for all n years.

So, repair cost is there is a repair costs this is the repair cost and this is a probability of cost of failure. If there is a failure even after doing repair you know. So, damages you it might even may have to pay lot or rebuild or whatever it is. So, this kind of a model 1 can think of for the life cycle cost including the probability of failure and things like that right. So, generally inspection is a must what I am trying to show here is that there is an good system of maintenance would involve inspection right. So, inspection is must.

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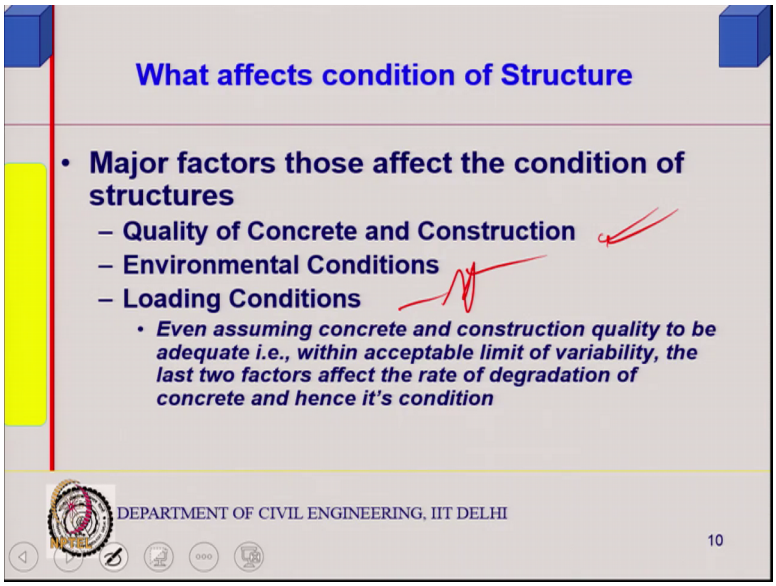

Now, obviously the quality is very important that is what we have seen. So, far environmental condition also loading condition is important loading condition is important because of fatigue loading one will be more susceptible to damages rather than where you have static load.

So, the last two factors are too important environmental condition and then loading conditions right even if this is good then also one must look into this.

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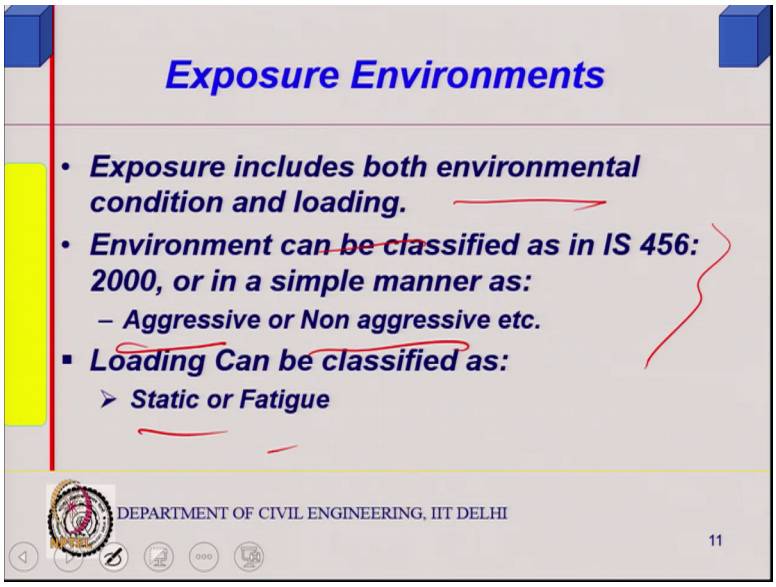

So, exposure environment basically it should include both environmental and loading exposure environment because loading environment is important well things like IS 456 or the prescriptive was do it for durability take care of durability at the beginning, but when you are looking to inspection we simply classify them as aggressive and non aggressive environment and loading static and fatigue because I said the fatigue could be more dangerous.

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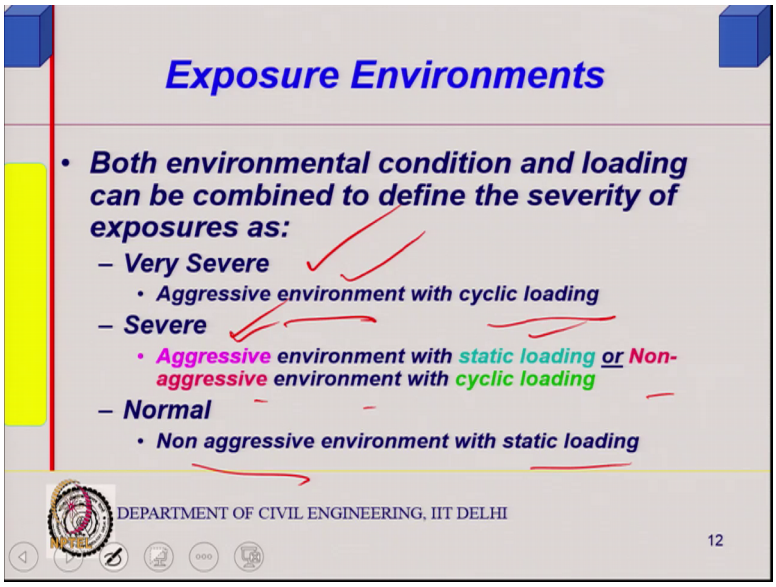

So, you think in terms of exposure environment you have very severe exposure environment considering both loading and you know both loading and environment. So, if aggressive environment cyclic loading or fatigue, then I call it very severe situation. If it is aggressive environment with static loading or non aggressive environment is cyclic loading, then I call it severe and normal means non aggressive environment with static loading. So, which are actually aggressive environment suppose you have a thermal power plant in coastal area there are one or two in Gujarat right now or some factories for example, cement factory Ambuja cement factory is all most sea shore.

Now, the very close to the sea is the chloride can come by aerosol movement of the aerosol. They can come and you know like actually accelerate the process of river corrosion. So, this is definitely an aggressive environment or where wetting and drying is occurring right wetting drying is occurring. And then non aggressive would be I mean

you know non aggressive would be this kind of situations are not there cyclic loading and this is well understood stress reversal is there wherever it is.

So, then we decide discuss I mean we define also importance of structure if the structure is very important I should inspect it frequently more frequently, then a structure is not. So, important for example, a boundary wall even in aggressive environment I may not see it every year, but if it is nuclear reactor structural or a turbine generator room. I better respect it you know more frequently. So, that is what it is. So, we define importance of structures.

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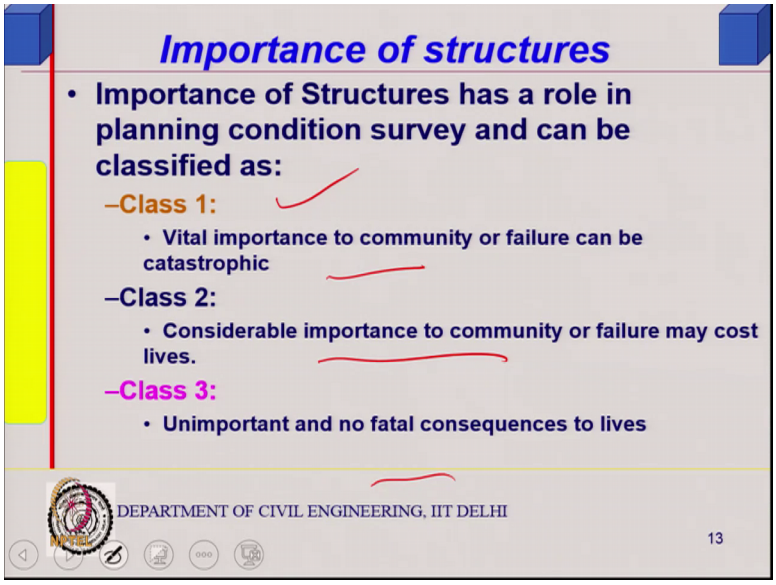

. So, first is importance of structure is first one is vital importance to the community can lead to disaster catastrophic lot of people may die this is important to community failure may cost life this is somewhat moderate considerable importance and class three is unimportant right. So, what the strategy suggested for inspection is something like this.

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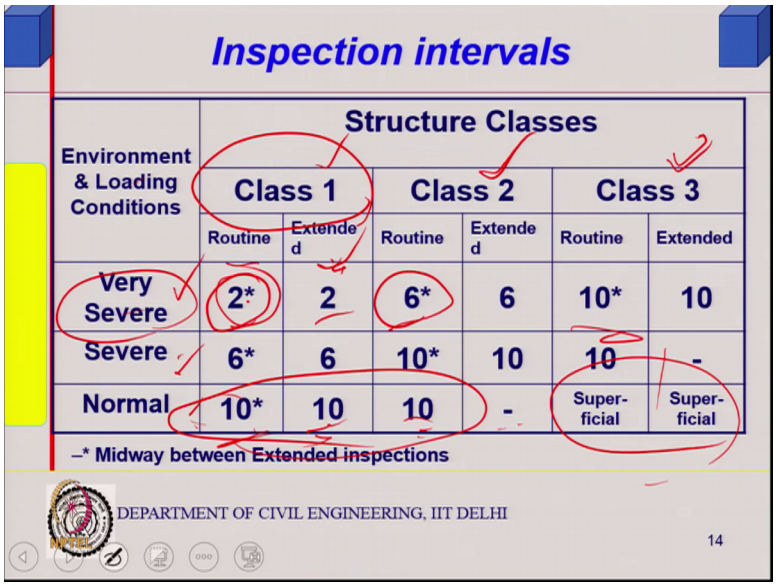

You know it is suggested inspection table is suggested something like this that if it is environment and loading condition exposure is very severe normal class 1 is most important structure not. So, important structure I mean less important structure and not. So, important structure; so, if it is class one type of structure you must do inspection every 2 years if it is an very severe like the example I was given thermal power plants close to sea shore right or you know all over those coastal areas of the country or something similar because it can also damages I mean stop the power supply to many places. So, that kind of situations even it could be measure bridges strategic bridges.

So, for examples there has only 1 bridge in 1962 war 60 to 65 war I think between north of Assam and south of Assam. So, like that you know he knows about that; so, Brahmaputra our Brahmaputra. So, there is only one and it has to be protected if you do not protect it part of it gets disconnected no supply to those area. So, this is very strategic. So, this should have been maybe now then a many more, but all of them are actually class 1 type bridges are usually long bridges they are class 1 type because they can cause lot of you know it that decision has to be made.

Then class 2 are some sort of community halls and things like that that kind of structures which are of considered the considered importance can be catastrophic one has to take make decision related to this which one you want to classify how important you know nuclear reactor on, they will automatically fall into those. So, here you do 2 years

inspection every year routine means generally mostly visual, but some small instrumental extended means highly instrumental lot of instrumental you might do depending upon the situation what you envisage what you I mean what you visualise what is the kind of deterioration possible what are the damages possible.

So, extended is basically instrumental. So, you have 2 years. Every 2 years you have routine; that means, this year I do routine and 2 years later I will do again routine, but in between year I will do actually extended. So, every year I am doing in this kind of situation class one with very severe are you do every year inspection 1 year routine next year extended which means that maybe you use more instruments you know like ground survey things like that. I mean depending upon whatever is available how you were look at it, how much money you want to spend on the whole thing to save the repair cost later on.

If is class 2 same 6 years; that means, every 3 years you will do something 3 years one ones routine next 3 years later you do extended again 3 years later. So, in between years you just do routine between two extended phases and if it is class 3 not so important structures 10 years and you come down this way you do not do anything superficially you look at it. And if it is severe environment I mean normal condition normal not severe normal environment this is 10; that means, every 5 year you will be doing something and here you do not have to do even something.

So, if this could be a suggested strategy by experts European experts actually and one can follow this kind of strategy quantifying you know modelling them is not easy, then you go to know the deterioration rate which is still gray area of our research right. So, because you remember economics I talked about. So, cost growth and damages are like this right.

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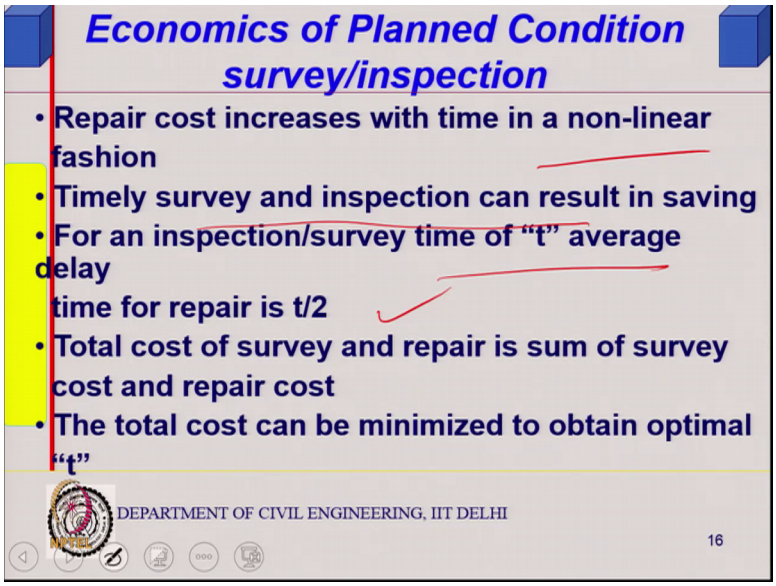

So, repair cost increases with time in non-linear manner cost was increasing in non-linear manner and timely survey and inspection can result in saving.

So, average repair if you are doing inspection every t years average repair time will be t by 2 it will not be more than that because either you will pick up yesterday the deterioration was started you have picked up today or you have miss today inspection you have done it starts tomorrow. So, on an average you one can think in terms of 2 by 2 total cost of survey and repair the summary you know you one can minimise this cost, but I think I will going to that model.

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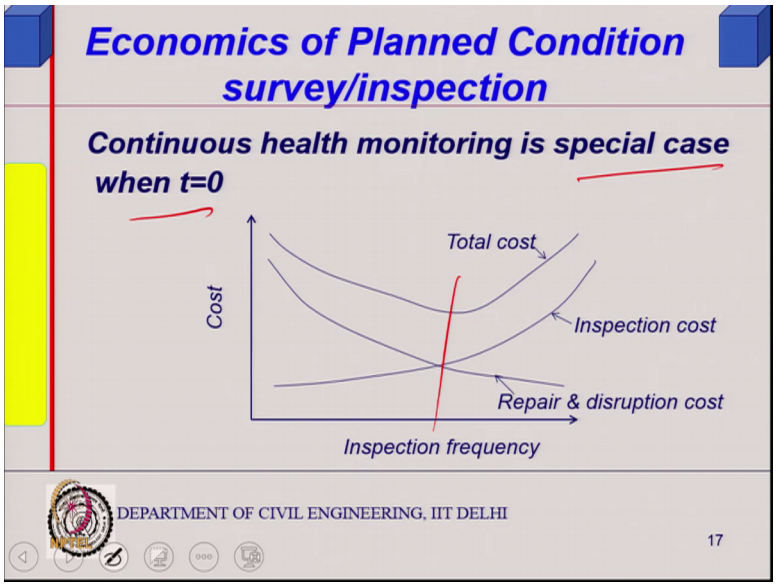

That model needs that kind of a model would need actually finding out the rate of deterioration. So, inspection cost increases in this manner repair and disruption cost will decrease there is an optimal point, but quantifying them is still a challenge at the moment you know quantify how much deterioration will occur at what time is the challenge if you know that then you can easily model this.

So, total cost minimisation one can do continuous monitoring is nothing, but is a special case where my inspection time is 0. So, you know monitoring continuously. So, t is equals to 0.

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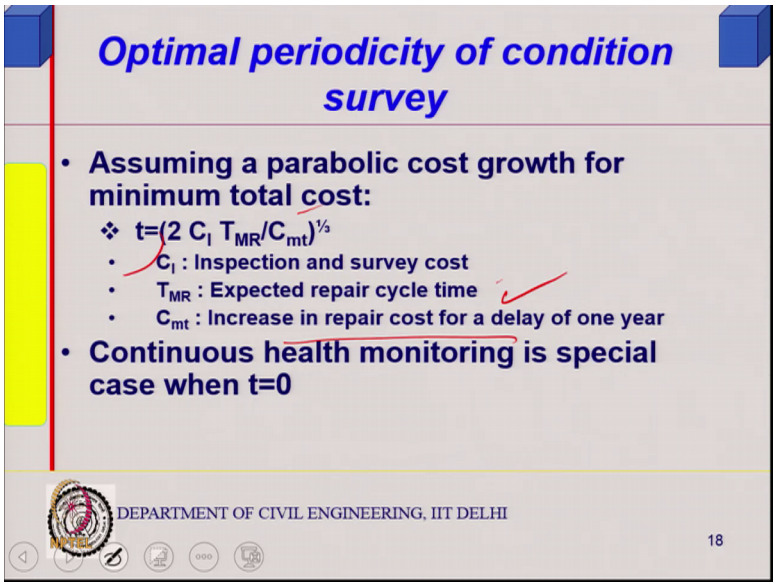

So, one can model this as a I saying, but then the T MRs is expected repair cycle time one can model this actually from those cost curves, but you going to know optimal you know and also rate at which actually the C mt is the increase of repair cost for a delay of one year this kind of model. One can obtain right t is the optimal inspection time you can simply write the equation and differentiate it.