

**Fire Protection, Services and Maintenance Management of Building**  
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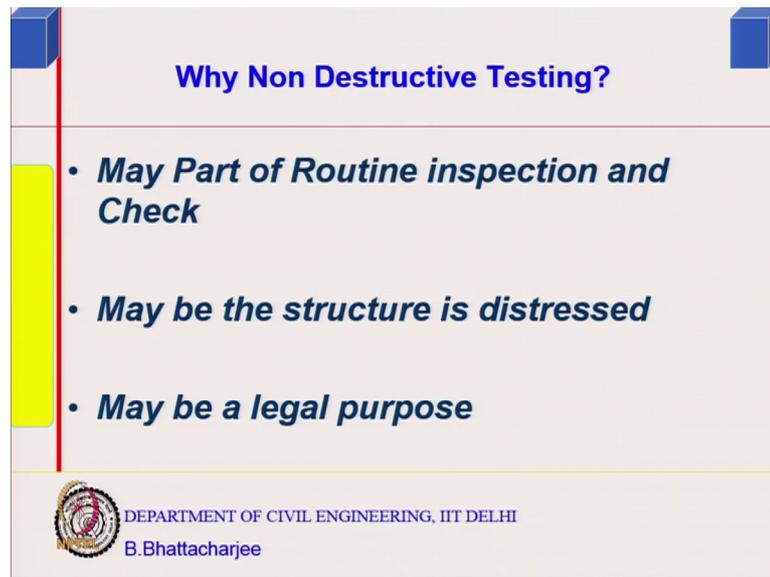
**Lecture – 44**  
**Condition survey and health evaluation of buildings**

So, having looked at the plan part of maintenance system and we said that possibly our structural system would not need any maintenance, foundation frame etcetera would not need any maintenance, that is what we said. But this is may not be true almost for whether a structural system or non-structural system, but since safety is involved, you know as far as structural system is concerned.

Non-structural items functional performance might be effected but safety may not be effected to a great extent. But structural system both safety and serviceability could be effected. So, we would look into how do we handle the structural system. Because this is not uncommon today, that most of the quite often the structural system shows some sort of deterioration, because we have not been able to foresee the condition and the deterioration.

So, quite often this condition assessment is done through non-destructive testing. I said visual observation is a must. So, when we talk of inspection visual observation is must, but then instrumental observation also we will be doing. So, let us see how we go about it. So, we do some time non-destructive testing right. Now this could be part of routine or you know.

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**Why Non Destructive Testing?**

- ***May Part of Routine inspection and Check***
- ***May be the structure is distressed***
- ***May be a legal purpose***

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Routine inspection part of routine inspection and check now, obviously you will not do it every day or every year you will do it sometimes. So, this should be part of the routine inspection and if there is a defect you have seen you have to always do it.

So therefore, the why we do we have to do it, because it is part of routine sometime legal purpose also we will have to do it. Supposing I am giving the house for you know building for lease or rent. So, depending upon the owner, I mean the agency tenant basically. So, you may have to now I will give an example. So, that is legal purpose. I will give an example actually. I will give an example for example; a bank you know decides to higher your building. Or even purchase the building. Now it was not meant for bank functional change is occurring. The safety security safety is fine, but the security is most useful you know I mean is a major concern for them.

So, in that case they would like to know what is the condition of the structure as a whole because rest of the thing they can change. There can be alterations of the space that can be done functional aspect they can change, but structural system they will not be able to change. So, they would like to know what is condition. Besides that, even the loading condition because if the function changes loading condition might change.

For example, you convert a particular office building to a bank building bank might requires walls whose concentrated load is higher. Now example is of course, that bank building is no longer there, if you see in Delhi Mathura road you know within Delhi

before Faridabad you enter those areas are industrial areas earlier. Now many of them have become office many of them have become office spaces office premises or molls or things like that.

Now, one of the building which was partially constructed and actually was meant for an industrial building by some individual or some group. Then a bank decided to purchase it. Now banks requirement was that in this area certain areas we will keep our olds fireproof. So, it is made of heavy metal heavy steel and it is weight was concentrated one ton per metre square or one-meter square area one ton per metre square. Normally in the even industrial floorings are not designed for that. So, they would like to know whether this is fine or in general aspect the overall condition is structure. So, these are legal purpose. This is legal purpose there could be more legal purpose of the similar kind.

So, sometime we do this investigation in order for legal purpose or if there is a damage to the structure either because of slow deterioration process or accidental damages because of fire or earthquake or similar sort of thing you know. So, these are the purpose wise this. Now you see as I said that we possibly thought that there is no need for doing looking at the structures. Well, inspection steel would be a need I would say. That you may not even you develop your maintenance profile you may not keep the replacement cycle within 60 years, but inspection steel maybe necessary. You might still do a condition assessment once in 5, 10, 20 years whatever it is depending upon your type of building we will see that importance of the building and exposure condition, because materials you know.

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**Why condition survey?**

- May Part of Routine inspection and Check
- May be the structure is distressed
  - **Early distress due to intrinsic cracks**
  - Early distress due **poor construction practice**, material problem or over loading (construction related or natural)
  - **Long term deterioration & durability problem**
- **May be a legal purpose**

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This I have said that you have because most of this systems or materials are manmade. You know will just let me let me just come back I will come back to the slide, but I am talking of I am talking of this actually scenario not here, because these are all manmade. Since, these are manmade the large chance of chance of many of them actually this diagram is not here, but anyway I will draw it myself and then talk about it. Sometime later on this diagram will come the one I am going to show you now is something like this.

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**Why condition survey?**

- May Part of Routine inspection and Check

*Handwritten diagram:*  
A graph with 'Potential' on the vertical axis and 'Time' on the horizontal axis. A curve starts high on the potential axis and decreases over time. The word 'Kinetics' is written above the curve. The text 'Stable nature' is written near the start of the curve. '60%' is written near the end of the curve. A horizontal line is drawn across the graph.

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Manmade system they are produced with the expensed of energy. So, any manmade system whether it is part of building structure or bridge or whatever it is.

So, actually what you have done you have given some potential energy to it you have raise it you know you they have made it made of energy. So, they would like to dissipate this energy. So, this is the potential level energy and we need to like to dissipate them. Now question is therefore, there is you know this has always with time they would like to they will be at tendency to come back to it is stable state. This is the stable state stable natural state stable natural.

So, for example, if you made steel, it was iron no which is the stable state you have given energy to extract the iron out of it and alloyed it with carbon etcetera to make it steel. So, therefore, you have given some energy potential energy to potentially you have raised. Same is the case with cement. It was limestone and silica now you have made it cement out of this by giving some energy by heating etcetera calcining or whatever you call.

So, most of the manmade systems are at higher potential or higher chemical potential level energy potential level which you would like to deteriorate you know dissipate. So, therefore, they would like to come back to this natural state. Now how do they come back at what rate do they comeback that would depend you know at what kind of read it is coming back that would depend upon what is called kinetics. Rate will depend upon that rate can be controlled. You might you might see that it deteriorate it might you might slow down the rate.

For example, a steel rod kept outside will start rusting, but if I paint it black with epoxy painting it will rust at a much slower rate right much slower. So, this rate can be controlled, I mean if I keep can keep the rate. So, slow that it almost remains in the same condition for next 60 years, then I have served my purpose you know my life of this one is 60 years. If I keep it, I mean it will be also depend upon this protection unit cost.

So, I might decide that I will do it in this manner or may not do it. For example, if I make stainless steel the material itself. So, I have actually alloyed chromium nickel etcetera, etcetera. Now chromium form a what is called a passive layer of a oxide which is colourless. So, it is colour does not change you do not see the oxide formation, but that oxide layer protects.

So, similar sort of kinetics can be controlled, but potential would always there will be a tendency to you know deteriorate. So, structural systems are not free from deterioration or it is kind of a material degradation it is not free. So, it will require at least inspection if not repair and replacement in very important building. And that is why we are discussing that is why you are discussing you know the condition survey is required.

So, as I said it is a part of may be part of routine, if it is distress there can be distress of different kind particularly concrete system we are looking at. So, there can be some kind of what is called intrinsic cracks, early distress due to intrinsic cracks, or maybe because of poor construction right. So, some sort of overloading or long term deterioration what we call durability problem.

So, there can be situations particularly with concrete which can show early cracks what we call intrinsic cracks coming because of thermal, you know thermal reasons that is heat of hydration and similar sort of thing. And other one is shrinkage. There are various kind of shrinkage in I mean drying shrinkage is called the major one we will look into. So, this is one maybe there are some problem with the construction itself.

Now obviously, in case of steel this does not come in that manner, thus normally in steel structural steel. Obviously, you will do protection all the time now painting would be done and repainting, repainting you will be doing, but over a long period of time if it is very long period of time and they have a reversal of stresses or repetitive loading the fatigue cracks might come

So, steel is therefore, is you know it is generally is well behaved relatively more predictable, but in later stages of long term if it is 100 years old the bridges and all that the inspection might be required. So therefore, the conditions always important right; legal purpose I have already told.

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**DEFINING THE OBJECTIVE**

- *The objective may be estimation of characteristic strength or grade of concrete for checking the structural stability.*
- *To evaluate the adequacy of strength for repair and rehabilitation purpose.*
- *Objective may be simply to judge the quality of concrete.*

So, objective generally is first in case of concrete. Of course, the objective would be tool. If it is either for legal purpose or because the some deterioration, I might sometime I might find like to find out what is the in situ characteristic strength of concrete in situ strength of the concrete. You see in situ strength would be different than what has been actually done in the laboratory cube strength which you have done for quality control purpose, but actual structure in situ strength might be quite different

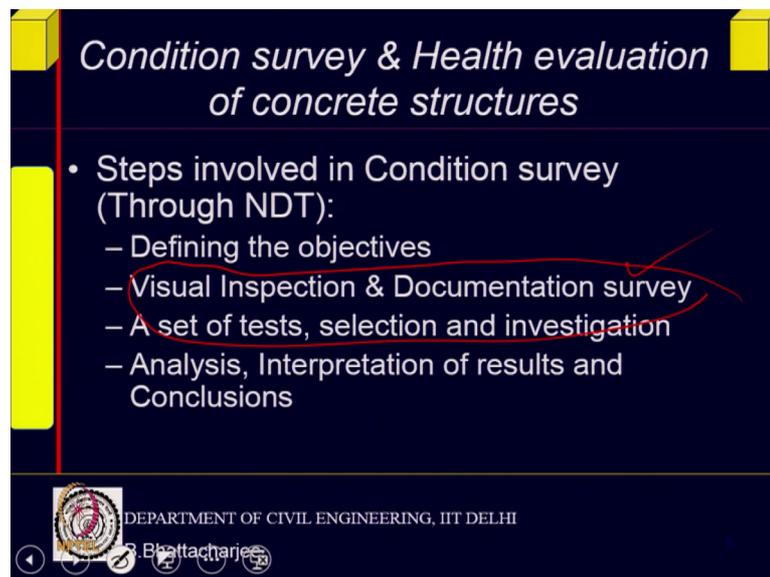
So, sometime I would like to know; what is the grade of concrete in structure. If it is actually shown some signs of problem, if it does not show a sign of problem there is no cracking nothing then I may not do it actually. If I suspect all the places I may not do non-destructive testing to identify it is condition, but some cases I might do. So, grade of concrete I might like to do where are structural stability is in question. For example, I was giving legal purpose of the bank building, in that case the load would be now changed therefore, I would like to find out what is the grade of the concrete right.

Otherwise just for you know adequacy of strength for repair also some time for repair purpose I want to do repair. I would like to know also; what is the strength some retrofit corresponding to current earthquake code I might like to find out the strength. So, grade of concrete I might find it. So therefore, I define objective if the objective is to find out the characteristics strength I can state this objective is finding the estimating the characteristic strength of concrete estimating the characteristics of concrete. So, that is

my objective clearly, I have to state I might say that as you know accessing the quality of concrete that is different. That objective is different qualitative or quantitative that I have to specify. So, very clearly one has to state.

Simply large you know this is simply judge the quality of concrete this might be a scenario in case of dispute. And if the quality is bad then you might find the grade of then you might get interested in the grade of concrete alright.

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*Condition survey & Health evaluation of concrete structures*

- Steps involved in Condition survey (Through NDT):
  - Defining the objectives
  - Visual Inspection & Documentation survey
  - A set of tests, selection and investigation
  - Analysis, Interpretation of results and Conclusions

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So, steps involved in such ones are when I am doing through NDT or otherwise first step would be of course, define the objective it could be when diagnosis. For example, there is a crack; what is the reason for this crack what is the reason for this crack. So, that is diagnosis and this way I must clearly specify my objective. The objective number one could be diagnosis of the distress diagnosis for the diagnosis for the reasons of the cracks. Estimate number 2 objective could be estimating the characteristic strength of in situ concrete in situ characteristics frame.

So, this is how I should clearly do then; obviously, all the time it follows with a visual inspection and document survey. Visual inspection is must I may not do an instrumental work inspection, but visual survey is always a must. And visual survey means visual inspection means as first find out what is the nature of the crack. Today, you can even you know you can photograph them. You can even record them and the systematic way you can actually keep track you know keep them in your records.

Then document survey means check the drawings. Because if you have as built drawing available as built drawing which should be available after the construction is over, I relook at the drawing and prepare as built drawing. That is very important one drawing fit for construction you know first is the drawing then there is one certified fit for construction design of is gives you then the construction actually occurs.

When there is a construction there may be some deviations. So, after that as built drawing that should be or rather existing drawing that should be available to me. Now this I might survey document survey document survey also might require for example, some problems might occur during the construction phase, say something like some sort of you know something like let us say I will give, in building we are talking of building in buildings it might suddenly there must be during construction phase there must have been a fire.

For example, the hotel building there is a hotel building earlier it was Lodhi hotel changed to some multinational hotel I forgotten the name. During there was you know newly constructing the hotel demolishing the Lodhi hotel original there, was a fire during construction phase. So, these records of this one document survey should be available to me when I am looking at it later on. There was a fire some rectification was done etcetera, etcetera. So, document survey means seeing the drawings, seeing any record that is available in bridges this happens quite often maybe the well got tilted so much or maybe there was a flood during halfway through the construction, the well actually got washed away. So, you have to redo the wall or maybe shift the location. New wall must have come in something of that kind.

So, or because the river change it course which happens in big rivers like Brahmaputra or Gange particularly Brahmaputra you know it changes it is meandering of the river. So, bridges this happens quite often.

So, this records what has happened this should be part document survey then I know what is happening actually. So, visual inspection the documents survey then followed by that analysis and interpretation of the result right and drawing a conclusion. Then after that I will be doing some test and investigation and then analysis of the result.

So, first is visual observation documents survey then analysis a set of test I decide I decide the set of test and also the number of test is important. Because if I just decide any

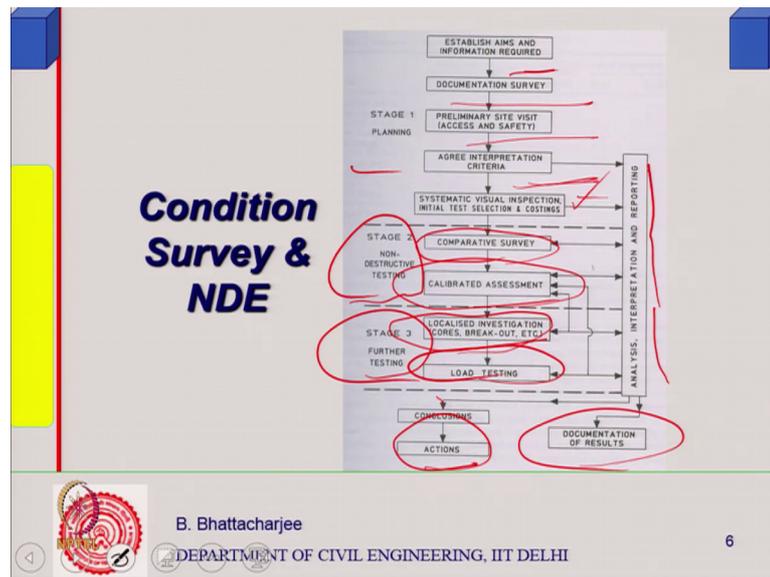
test in every test this is not worthwhile I know there are plenty of examples consultant, if they understand the system properly, if they understand the deterioration and everything properly they would not give wrong advice of wrong test.

For example, if a building is 6 months old or under construction building and you have seen some problem honeycomb for something, you do not say that you do a test for what is called carbonation, in concrete RCC building. I am talking about carbonation is carbon dioxide reacting of the atmosphere reaction with the calcium hydroxide produced from cement hydration and then reducing down the alkalinity of concrete.

This has got it is implication on corrosion we may not go into details, but sometime we will be talking about that a little bit more. Now 6 months old building you do not expect carbonation or during the construction you do not expect carbonation, but some somebody might suggest do the carbonation test as well that is not right. So, all that I am trying to say is objective and correspondingly I must have test. And more the number of test I increase my accuracy, but I increase my cost also. So, it has to be optimal balance we will see that how we do it.

So, set of tests the selection and then followed up the investigation. Once the results are available analysis interpretation of results, and then I come to the conclusion that this is the cause or this is the state of affairs degree of damage or this is a repair scheme I need. So, that is what it is right. So, then this recommendation involves you know repair scheme what I need. So, that is what it is alright. So, this is schematically shown here in this diagram condition survey.

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And NDE for example, establishment of aims and you know first one is aims and information required, first is aims information required is document survey then. Obviously, then you do is condition, you know this you do a survey you do a document survey then what is aims and what is required for example, diagnosis of distress and things like that.

Then; obviously, preliminary site visits sometime after site visit you say that I have to go up you know why the people inspector have to go up. So, therefore, all logistics etcetera etcetera. Then basically sometime the owner all agencies involved must agree come to an agreement with this will be my methodology this is what we will do it etcetera. So, that is that is you know and that is criteria also you decide.

Then systematic visual inspection, this is must systematic visual inspection and then some survey some calibrated assessment, because I might like to get the strength we will see that sometime later on, then localised investigation something like core pull out test etcetera. And if you are also doubting the integrity of the structure as a whole you might do even a load testing. One is testing the material finding out their properties and then recheck into the design, put it into the design other one is doing localised load testing we will come to that all of them one by one.

Now, all these information finally, we will go you know to analysis interpretation and final basically reporting that we will be doing. So, all this information go, and once this

comes I come to a conclusion then the extent. So, then basically documentation of the results and what I am supposed to do that will come.

So, you can see first stage is this stage 2 is this some non-destructive testing stage 3 maybe further testing. Not always I do something, might I do partially and then I decide if the result is like this I will do more testing if the result is not like this I will not do the testing you know. So, that decision now this true for bridges also or anything of that kind you know or the bridge maintenance system is much more you know pretty systematic they have all their maintenance system available. Building is a problem because too many items too many trades and what I call you know the importance of the structure is not as much as the bridge as usual see somewhat later on.

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**Visual Survey and preliminary observations**

- Visual survey is carried to have general idea about the structure, nature of distress if any.
- Document survey
- Collection of information from users

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So, visual survey and preliminary observation very important ones some of this some of these things might get repeated with more emphasis later on, because I might talk about visual survey somehow. So, this we generally carried out to have general idea about the structure nature of distress, if there is any then document and collection of information from users this is very important collection of information from user. I mean this user might be simply the security person who has been there for last 20 or 15 years.

So, sometime something may not be somebody might have missed recording. Or even because of apprehension must be reported. For example, there is an supposing there is light tremor earthquake, lot of people show this cracks have come after the earthquake.

When you go and talk to the persons who have been there that is a security personnel or similar personal no this is there for last 15 years. So, this kind of thing happens. So, basically users means everybody as much as information we can collect. Some of those things first what means the first time when the distress was observed recording might have taken place later, but somebody who is a non-technical person or a user might have actually see it earlier. So, such informations are important.

You can do also diagnosis during visual survey. If you know crack patterns, you can identify the nature of the cracks. For example, looking at the nature of the crack 90 percent of the time in concrete structures you will be able to identify why it is occurred, because every cause manifest itself in a given form of visual distress right. Supposing I have moisture marks then I know that there moisture leakage has is been occurring. And if you see rusting; that means even if you do not see the steel rusted steel at the moment reinforcement inside, but you have seen the brownish colour of the stains which means that basically rusting might be occurring inside. So, visual observation this kind of thing happens and if this crack then pretty easy to actually identify.

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**Diagnosis during visual survey**

- Diagnosis of causes of distress is complex in some cases.
- Cracks can be diagnosed through visual observation
  - ❖ A, B, D: Elastic settlement
  - ❖ D, E, F: Early Shrinkage
  - ❖ G, H: Thermal
  - ❖ I: Drying Shrinkage
  - ❖ J, K: Cracking
  - ❖ L: Rebar corrosion
  - ❖ M: Alkali agg. reaction

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For example, the varieties of cracks are recorded by people and these sort of diagrams are available in many literatures right. So, there are classified as A B C D etcetera, etcetera as you can see. For example, A you can see here B you can see there C you can see there I will define what they are right then you have got D I G H M E F should be

there somewhere F, A B C D E F G H I and there should be L there should be J somewhere there should be L I can see.

So, I is there any way it does not matter we will we will see each of them. So, this is for concrete system. This is for concrete system right, but this is not you know this, still there are lots of other cracks which are omitted out these are largely the some of the intensive cracks and some intensive cracks means not because of the load. Some of the cracks which might come because of deterioration right typical cracks that you see not exhaustive actually there are more right.

So, structural cracks are not covered in this, but other cracks are covered. So, for example, ABC you see is what is called plastic settlement or plastic shrinkage cracks now if you look at concrete let us say this is a cylindrical and you know it is just a concrete this is a concrete, let us say concrete element vertical element. Now u fill it in I fill it in with, you know I have just have concrete there right I might concrete out concrete inside this.

And what is the colour I want to use, let us say this. So, inside there is a motor is there and these are aggregates. Now, you know concrete system is concrete system in this plastic state is made of material of different specific gravities, commonly used cement is ordinary Portland cement whose specific gravity is 3.15 and specific gravity of water is 1 specific gravity of water is specific gravity of water is 1. So, w is 1, c is 3.15

So, what will be the tendency what will be the tendency to come up? So, water comes up water has a tendency to come up cement has a tendency to go down. So, you do not see uniform density of the material there and this results in what is known as bleeding. Now, when such bleeding occurs actually the plastic settlement; so whole of the solid material subside, I mean you can even visualise it as stokes law larger particles also particles are there. Larger particles and higher specific gravity they have a tendency to go down water has a tendency to come up. So, there is a subsidence of the whole thing, there is a subsidence. You know one of the ways you measure the bleeding is subsidence, but generally there will be subsidence.

Now, supposing I have a reinforcement here supposing I have a reinforcement here you know I have a reinforcement here somewhere there is a reinforcement what will happen

concrete in the from the top will like to subside, but it will get stuck here concrete from the side will subside right.

And this results in a crack just forming a kind of a crack on top of a the reinforcement, if the settlement is high. Now you will not see always, but if you see it might have occurred because of this. So, plastic settlement crack occurs you know you see them within first 48 hours itself especially this is associated with high bleeding. So, typically a for example, a is an aggregate even some large aggregate might show a reinforcement you might see cracks around the aggregate or the reinforcement.

And here for example, a is all reinforcements. So, it is a pattern you can see the pattern is almost like straps you can see longitudinal reinforcement there are cracks right on top of it. So, these are plastic settlement cracks can happen when you have overdosing of the admixtures made it to flowing, water has a tendency to segregate and come out of a bleeding is occurring. So, you might see A B C are actually plastic settlement cracks why C there is haunch, there is a haunch like this right there is a haunch like this. So, the concrete here has settled more concrete here is actually restricted. So therefore, you might see a crack and just one. So, this c cracks are near the haunch. So, these are plastic settlement cracks right.

And then D E F is early shrinkage cracks E D F these are drying. Plastic state is 48 hours then shrinkage cracks you might fine, because what will happen is as the concrete dry off moisture is removed out of the concrete surface. You know the structure the microstructure of the concrete has a tendency to shrink. I can go into the theory of shrinkage, but I do not want to do that at this moment, but analogy I can give clay. Clay if you dry off it shrinks if you add water it swells.

Now, cement hydrates had something similar happens not exactly the clays I will say larger sort of particle cement hydrate gel are still final level. So, when water goes out of the gel pores, there can be shrinkages there will be collapse of the gel. You know inter layer the collapse of the inter layer between the gel sheets and things like that chi sheets. And all I do not think I am going to that case concrete science part of it.

But shrinkages do occur in cement paste as the dry off. So, this kind of if it is drying off from the surface, surface is like to shrink and inside may not allow it to shrink, because inside did not shrink it is still continuing moisture. So, if something trying to shrink and

somebody is restricting, it what will happen the one it will be restrained shrinkage induced tensile stresses.

So, you might see cracks. Normally you see it in thin structures because surface area is large lot of drying is occurring compared to volume. So, where of large surface area compared to volume shrinkages could be an issue. So, DEF for the shrinkage type of crack some of them are crazing. For example, k is what is called crazing also because of such kind of fine cracks clustered around like as if you have put a mesh or something that kind.

Usually, they are not deep, but shrinkage cracks sometime can be drip also the DEF type of cracks can be some time they can be there might go even deeper sometime one can through. And through in case of very thin wall without is drying shrinkage not properly cured lot of drying has occurred in summer months of Northern India composite monsoon climate, or desert climate this can occur right.

So, def are of those early shrinkage thermal cracks occurs in massive structures you know where retaining wall for example, a large structure. Now they are the issues something different surfaces become cold, it is dissipated to heat while the heat of hydration that is produced just inside is still warm.

Again the same situation the surface wants to shrink because temperature has come down. Inside it still warm does not you know providing a restrained to the surface. So, you might get cracks in massive structure. Mass concrete sort of thing where the volume to surface area ratio is large, where volume is less surface area is large shrinkage where volume is more surface area is less in that case larger volume you might get thermal cracks. So, these are you know examples of like thermal cracks some cases you might see thermal cracks. Some case you might see thermal cracks g and H, H then J K are crazing as I said fine cracks coming out of shrinkage aesthetically they are bad otherwise they are not very dangerous.

Reinforcement corrosion cracks you will always see parallel to the reinforcement bar right. Because rusting would has cost expansion of the metal product, product of rusting is more it occupies more volume than the metal itself in case of steel 7.85 is the density. Rust will have once you know can be one forth one third of that density could be much much less rust product. So, they tend to expand and cause cracking of the cover concrete

and you find the crack along the parallel to the reinforcement bar itself like it is shown here. So, then the other kind of cracks which you might see is called alkali aggregate reaction there are give rise to what is known as map cracking.

So, map cracking you will say find tracks all around the aggregate. And if you actually take out those aggregates you will find the white growth of silica gel, alkali silica reaction product white coloured alkali silica gel you might see because, in some of those alkalis in the cement react with some of those reactive silica from the aggregates mineral certain minerals. For example, opal quartz (Refer Time: 35:38) they are the one kind of the certain types of silica, silicates can actually form a kind of gelatinous structure which absorbs water and then cause expansion. And you see what is map cracking usually the aggregate you can take out. If it is sulphate attack, then you can take out. And find you know various attacks also you can actually do further analysis on that. So, some of the crack pattern are here.