Retrofitting and Rehabilitation of Civil Infrastructure
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Lecture 07
Identification of Distresses

Hello friends, welcome to the NPTEL online certification course. Retrofitting and Rehabilitation of Civil Infrastructure. Today we will discuss Module B. The topic for Module B is condition evaluation and testing.

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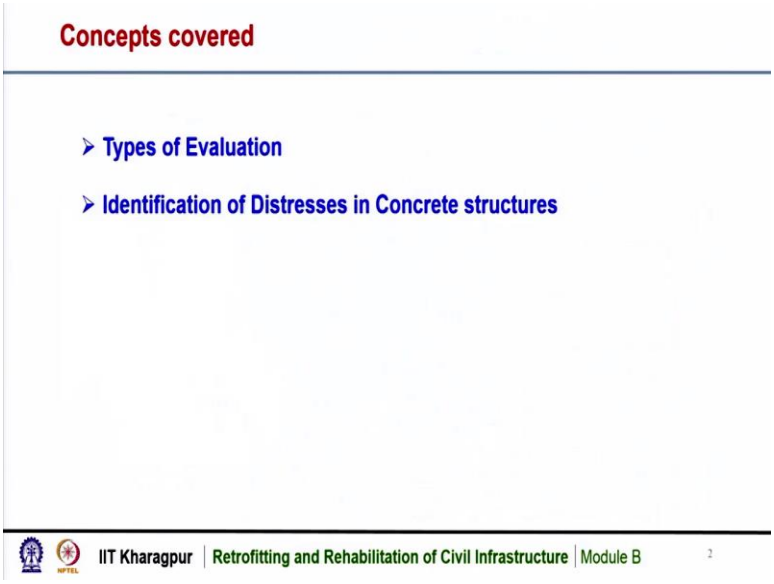

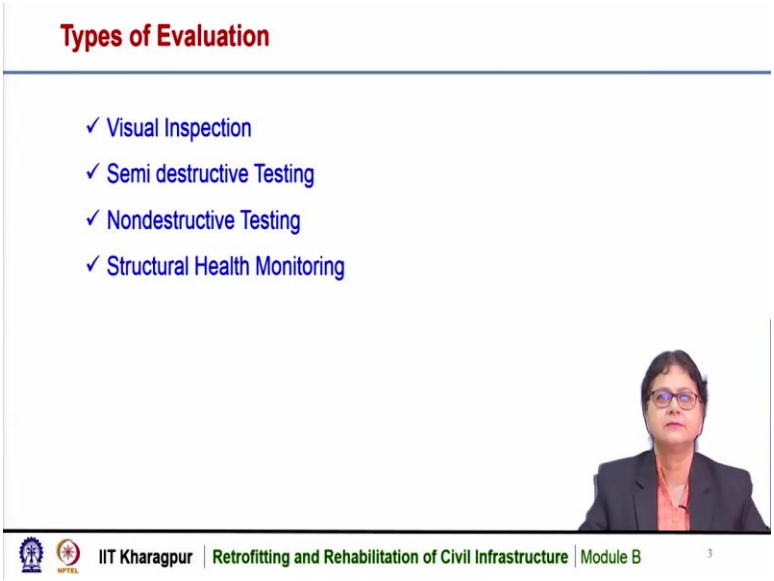

The concepts that will be covered today are types of evaluation and identification of distresses in concrete structures. All infrastructures are getting deteriorated due to aging. We have discussed in the previous module that there are several reasons of deterioration of infrastructure. The deterioration may be due to faulty design or improper construction practices, there may be some foundation related issues or there may be several material related distresses.

At the same time, there may be earthquake or fire type of distresses due to which the structure may get degraded. And that degradation may cause the poor performance of the structure and also reduces its service life. Because of this deterioration, the structure may even collapse before its design life. Therefore, it is very important to evaluate the current condition of the infrastructure.

There are several ways by which the existing infrastructure can be evaluated. The first and foremost is the visual inspection. For any evaluation, it is important to first inspect the structure visually and based on the visual inspection, if it is felt necessary, then further investigation may be carried out. Further investigation may be a series of semi destructive or non-destructive testing by which we can evaluate the condition of the structure. The evaluation can also be done based on structural health monitoring.

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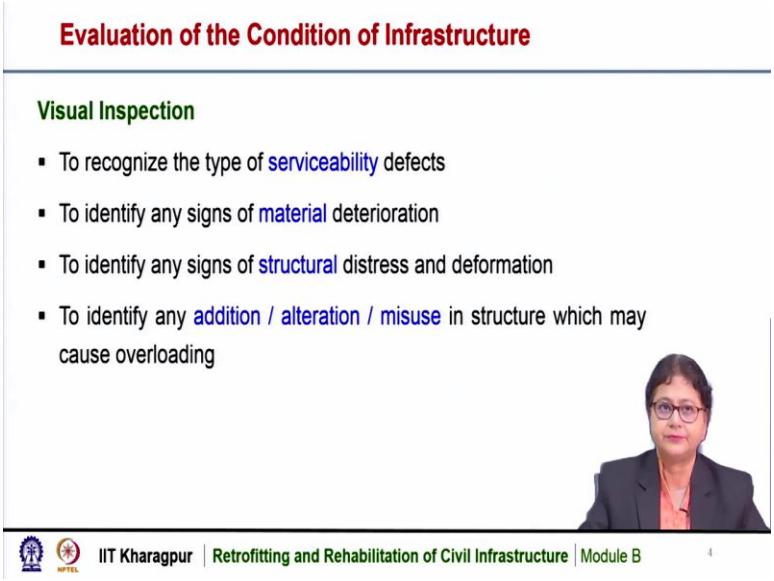

For any investigation, the first step is visual inspection. So, it is important to recognize the type of distresses that has occurred on the structure by first visually observing the structure and its

component. It is important to recognize the type of serviceability defects for example, if there is any large deflection or buckling of the member, so, that can be recognized. It is important to identify any signs of material deterioration.

The material deterioration may be due to corrosion effect or due to sulphate effect and that needs to be identified in the visual inspection. It is very important to identify any signs of structural distress and deformation on the member. Because structural distress may cause the reduction in the strength and that may result into the less performance and durability. So, it is important to identify any structural distress on the member.

Also, it is required to identify any addition, alteration, or misuse that has been done in the past on the structure which may cause overloading. For example, a building has been designed and constructed as a three-storey building, but over a period of time, some one or two stories have been added that may cause overloading on the structure and which may result into deterioration of the structure or in case of a bridge.

The bridge has been designed and after some time to improve the riding quality, one layer of wearing coarse has been added and if that wearing coarse also may get deteriorated over time and then again another layer of wearing coarse to be added to improve the riding quality. So, this may increase the dead load of the structure and that may cause damage to the overall structure.

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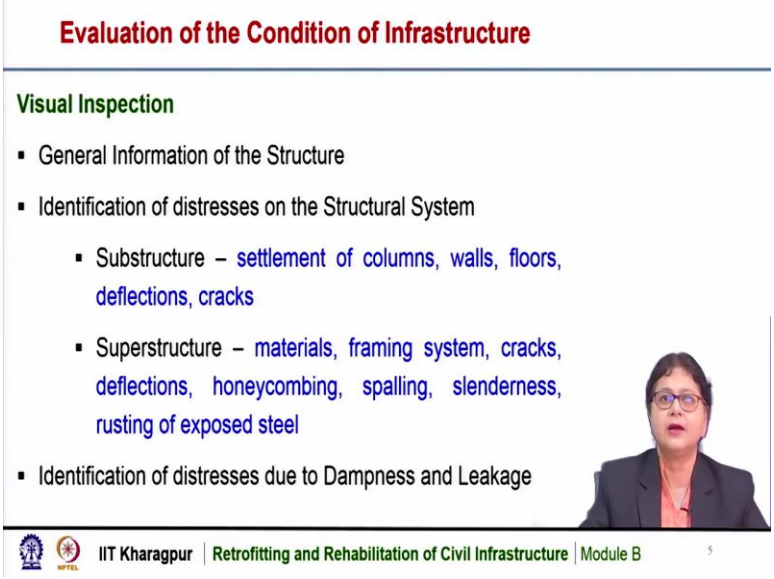

So, in visual inspection, we have to identify several components, the first thing is to get a general information of the structure. For example, if it is a building then it is how many stories are there, what is the type of foundation and the columns and beams and other details we need to have those informations.

In case of a bridge, we need to identify or we need to get the information about what type of bridge it is, whether it is a concrete bridge or a steel bridge. What is the type of foundation, how many piers, how many longitudinal girders are there. So, all these general informations we need to get while carrying out a visual inspection.

From the visual inspection, we need to identify the distresses on the structural system. The distresses may be in the substructure, as well as in the superstructure. In substructure, we need to identify whether there is any settlement of the columns or foundation has been taken place, if any large cracks are there or not. So, that those things we need to identify in the substructure part of the infrastructure.

In the superstructure part, we need to identify what are the materials if there is any degradation in the material, if any problem is there in the framing system, any large cracks or deflections occur on the member or honeycombing or spalling has been occurred. So, these things will tell us that the structure or the structural member may get distress. So, it is important to identify all those distresses in the substructure as well as in the superstructure part of the infrastructure.

Then, also it is required to identify the distresses due to dampness and leakage for all types of infrastructure it is important to drain out the water. Because, if water is not drained out properly, water may get percolated through the material and that may cause damage to the concrete to the bricks or to the reinforcement.

The reinforcement may get corroded due to the reactions taking place between water and oxygen with the steel members. So, that may corrode the reinforcement. So, it is important to identify the distresses which may be caused due to dampness and leakage. So, the visual inspection will tell us the general information of the structure and also on the different components of the structure we need to identify the different types of distress.

And that distress is maybe due to load associated distress or due to construction related distress or dampness or leakage or material related degradation. So, these things we need to identify from the visual inspection.

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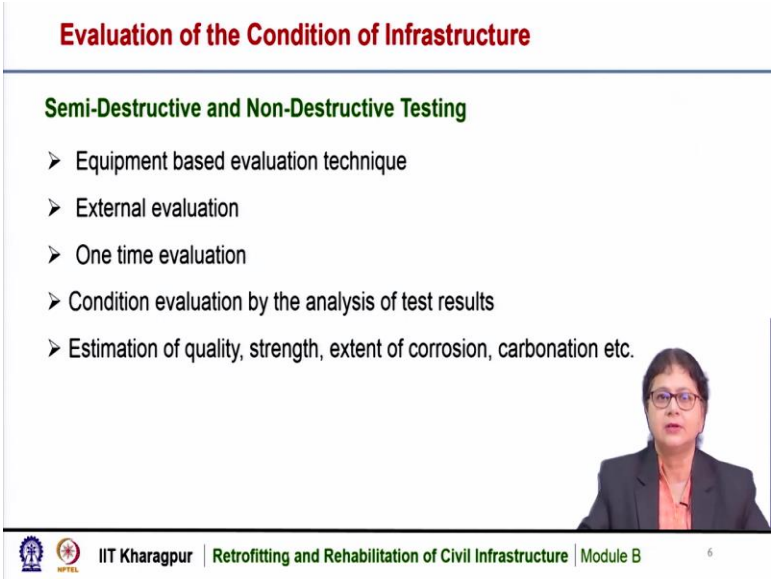

After carrying out the visual inspection, further investigations need to be carried out and that investigation may be done by semi destructive and non-destructive testing. The semi destructive and non-destructive type of evaluation is equipment based. For this purpose, specialized and sophisticated equipment are needed. And with that, we can evaluate the structure externally. This type of evaluation is also one time evaluation.

One of the main advantages is that we need not to close the structure for this type of testing. So, the structure may be still in its use and the testing may carry on. In the semi destructive and non-destructive type of evaluation. By analyzing the test results, we can evaluate the condition of the structure. We can estimate the quality of material we can estimate the strength of the material, extent of corrosion, carbonation et cetera.

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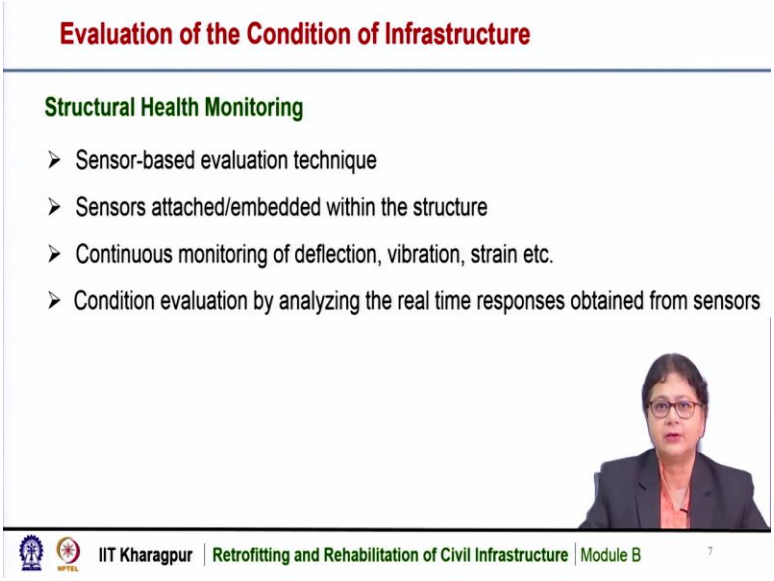

Structural health monitoring is also another type of condition evaluation. It is a sensor-based evaluation technique. In this technique, a number of sensors are attached or embedded within the structure. It could be a new structure or it could be an existing structure in case of a new structure, the sensors may be embedded during the time of construction or if it is an existing structure, the sensors may be attached or embedded afterwards.

And these sensors are connected to a data logger and the data logger is again connected to the system where we can get the data. So, due to the loading on the structure, the structural response is collected through the sensors. And by analyzing those responses, we can evaluate the condition of the structure.

The responses what are collected generally deflection or it may be vibration, strain, or acceleration and by analyzing that we can get the real time condition of the structure. So, by analyzing, the real time responses obtained from the embedded sensors, the current condition of the structure can be evaluated effectively.

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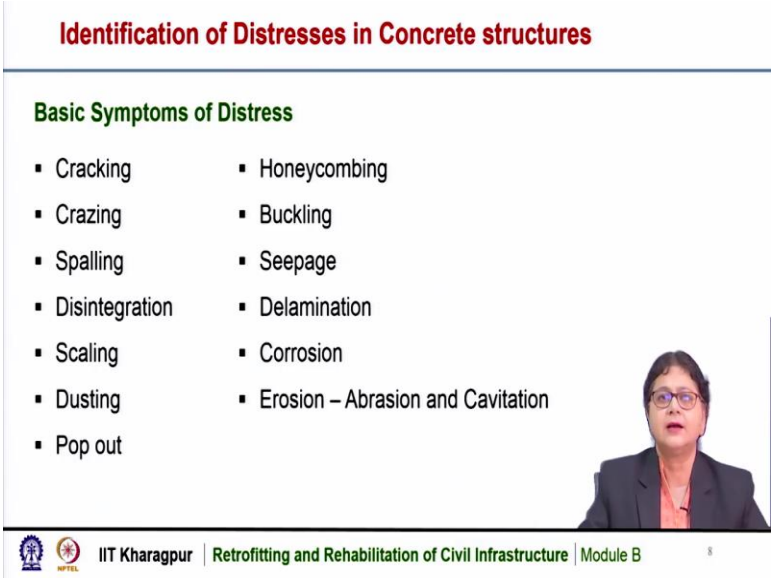

While carrying out the visual inspection, it is important to identify the distresses in the concrete structure. There are several symptoms of distresses, that may occur due to several reasons due to load associated causes, due to poor construction practices material degradation. But there are some basic symptoms and because of these we can understand that there may be some deterioration of the structure.

The basic symptoms are generally cracking, crazing, spalling, disintegration, scaling, dusting, honeycombing, corrosion and so many others. Cracking is one of the most common type of distress that occurs in concrete structures. And due to many reasons, the structure may get cracked.

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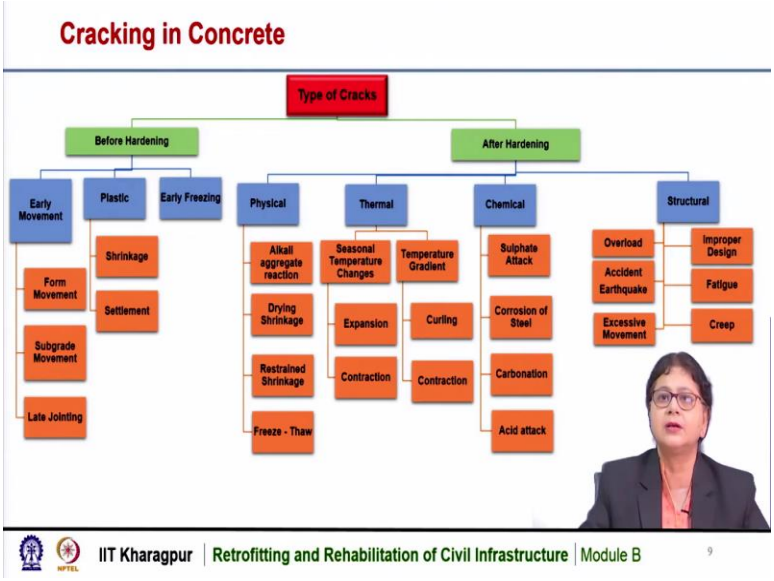

You can see here in this chart; we have shown that the cracks may be of several types or the reason of crack may be of several types. You can see here the cracks may occur in a concrete member before it is hardened or after it is hardened. Before it is hardened, when it is in the plastic stage. In that case also the cracks may appear if not properly cured or not properly compacted or if the joint cutting is done at a later stage or there may be shrinkage effect or settlement.

So, all these may cause cracking on the structure and it may be in the plastic stage when the material is in the plastic stage. So, that type of distresses may also occur. After hardening also concrete structure may get cracked, it may be due to alkali aggregate reaction, because of the reactive aggregates or it may be drying shrinkage, freeze thaw type of effect. So, all this may cause cracks on the hardened surface of the structure.

Thermal effect may also cause cracks due to expansion or contraction or due to curling effect it may result into cracks on the surface. The effect of several chemicals we have discussed in detail in the previous module that like sulfate attack or carbonation corrosion. So, all these may also cause cracks on the concrete members or cracks may also appear due to several load associated issues like improper design or repeated loading or creep effect or earthquake etcetera.

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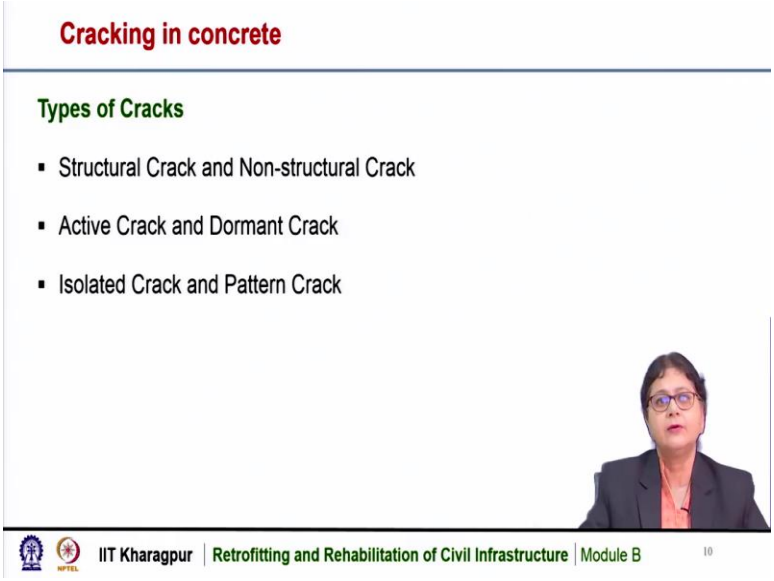

Cracking in concrete may also be differentiated in many ways. It may be differentiated as structural cracks or non-structural cracks. We may also differentiate it as active crack and dormant crack or we may also call it an isolated crack and pattern crack. So, let us see how these types of crack look like.

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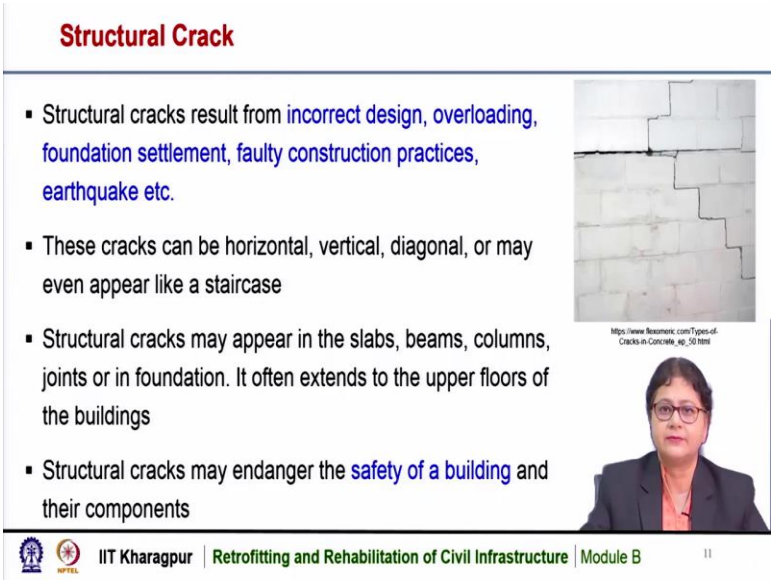

Structural cracks result from incorrect design, overloading, foundation settlement, faulty construction practices, earthquake effect et cetera. So, if there are several load associated distresses say overloading or repeated loading or if there is faulty construction practice and that

may result into lesser development of strength that may cause structural cracks on the members. These structural cracks maybe horizontal vertical diagonal or in any direction also with making some angle and may even appear like a staircase. Like a zigzag manner, like a staircase.

You can see in this picture, it may be the cracks appeared on a brick wall, but it may be due to the foundation settlement, in non-uniform foundation, settlement may result into severe cracks on the superstructure. The structural cracks may appear on any member of the structure, it may be on slabs, beams, columns foundation or even at the joint. And these cracks if they appear it will often extend to the upper floors of the building.

Structural cracks are to be treated very carefully, because these cracks may endanger the safety of a building and their components. So, if whether it is due to load associated or due to poor construction practice, the structural cracks are an indication that the structural strength is inadequate. So, it may endanger the safety of a building and their components.

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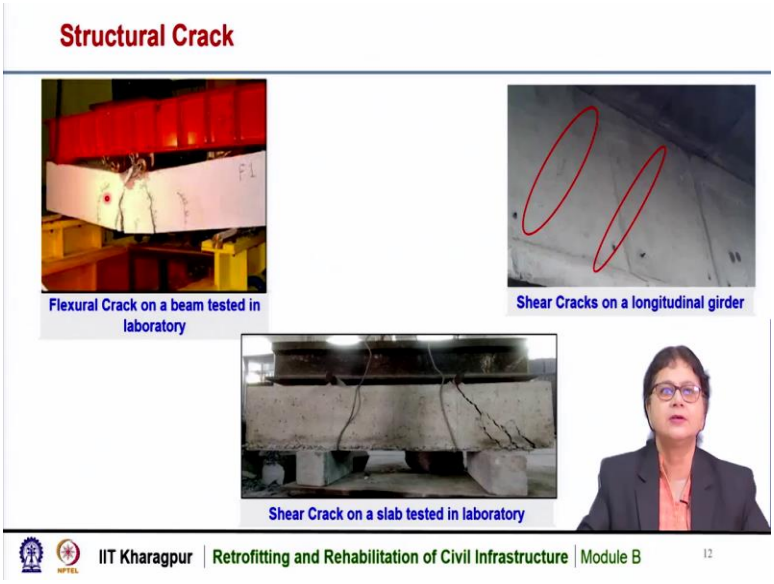

Here we are showing some examples of structural cracks. Look at this picture, this is a typical beam under flexural loading. Due to the loading, flexural cracks appeared from the bottom of the beam, you can see here a number of flexural cracks appeared in the beam. This is a slab tested in our laboratory under the loading, the slab undergoes cracking you can see here typical shear cracks appeared on the beam on the slab.

This is an example of a longitudinal girder. When we visited the site, it is a part of a flyover which has been recently repaired. And a typical shear crack appeared on the longitudinal girder, see here two shear cracks appeared on the web of the longitudinal girder.

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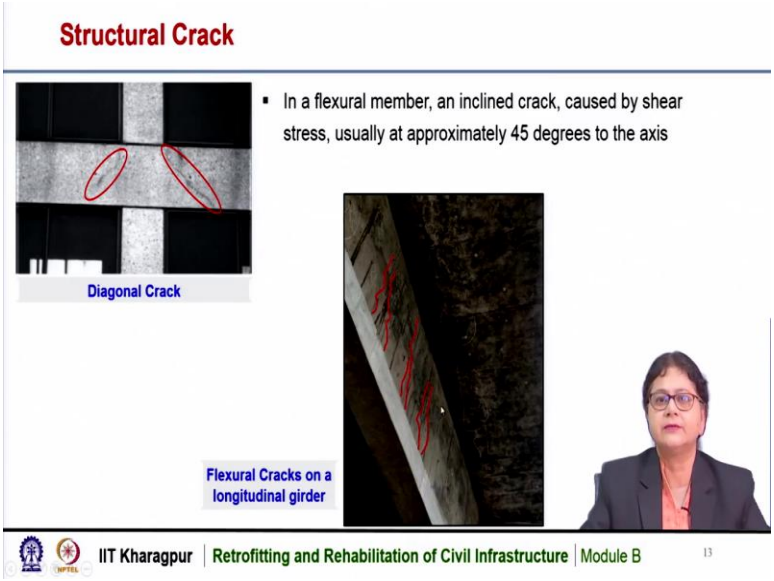

We have seen that there are several flexural cracks also on the longitudinal girder. You can see here in this picture, the very fine flexural cracks here I have marked it. So, these are the flexural cracks appeared on the longitudinal girder. This is a diagonal crack on the member which is an incline crack caused by shear stress usually at 45 degrees. So, you can see here that diagonal cracks and these are flexural cracks on the girder.

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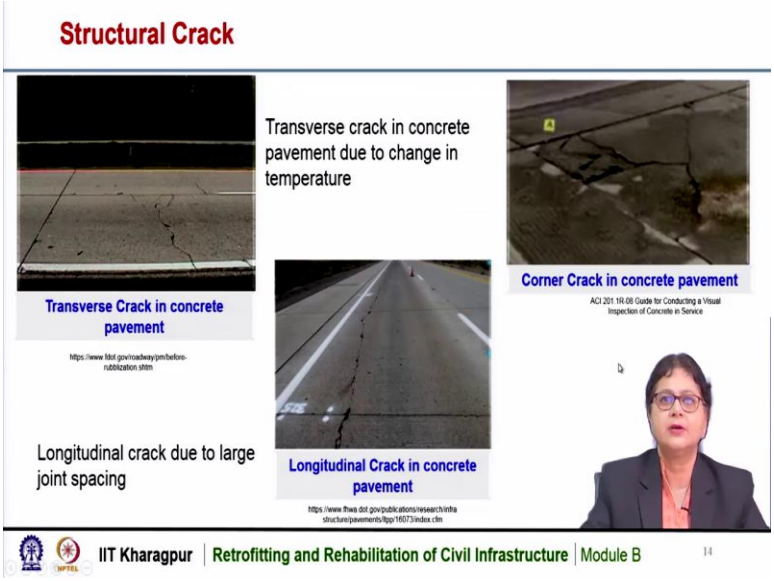

Structural cracks may also appear due to the effect of temperature. These are the pictures of concrete pavement you can see here that a typical transverse crack appeared in concrete pavement due to the effect of changing temperature. Look at this picture, this is a longitudinal crack appeared in the concrete pavement. This is the direction of the traffic and this is the longitudinal crack that has been appeared.

The possible reason for this crack is that the joint spacing. The joint spacing is too large and that is why due to the effect of development of large stresses, these cracks appeared on the pavement. This is a picture of a corner cracking in the pavement. Corners are also the location where high stresses developed. So, cracks may appear at the corners and in many cases we have seen that corner cracks are there on concrete pavement.

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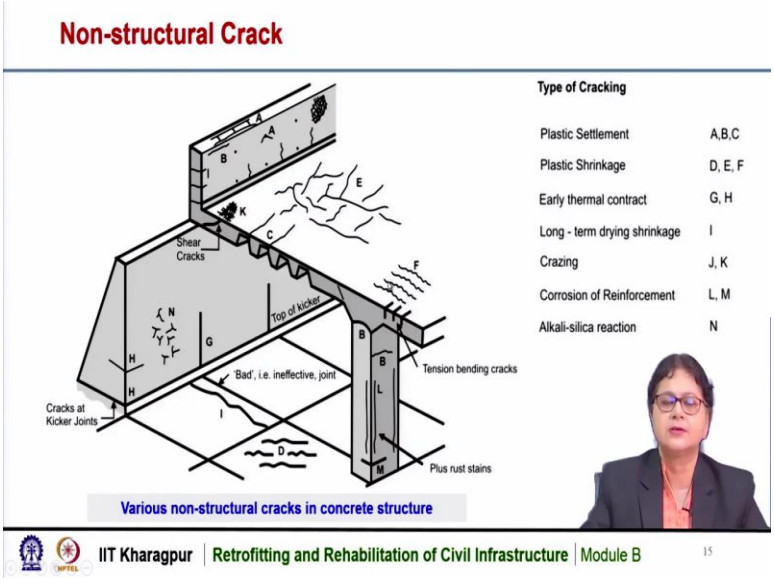

In addition to structural cracks, there may be several nonstructural cracks. This is a schematic diagram where several structural as well as non-structural cracks are shown schematically. See here that these are the shrinkage cracks appeared randomly on the structures. This on the slab, the shrinkage cracks have appeared. This is shown here schematically, this is the tension bending cracks appeared at the top cantilever part.

These are the longitudinal cracks, you can see here that these cracks appeared on this column because of the corrosion of steel reinforcement and these are also shrinkage cracks here. And this is the cracks due to alkali aggregate reaction, just scattered cracks appeared on one component of the structure. This is a shear crack a typical shear crack and this is a type of crazing type of cracks very fine cracks on the structure.

You can see here that this is crazing type of cracks that are there on the structure, these are very fine cracks that may appear and which are non-structural, but that may cause further damage.

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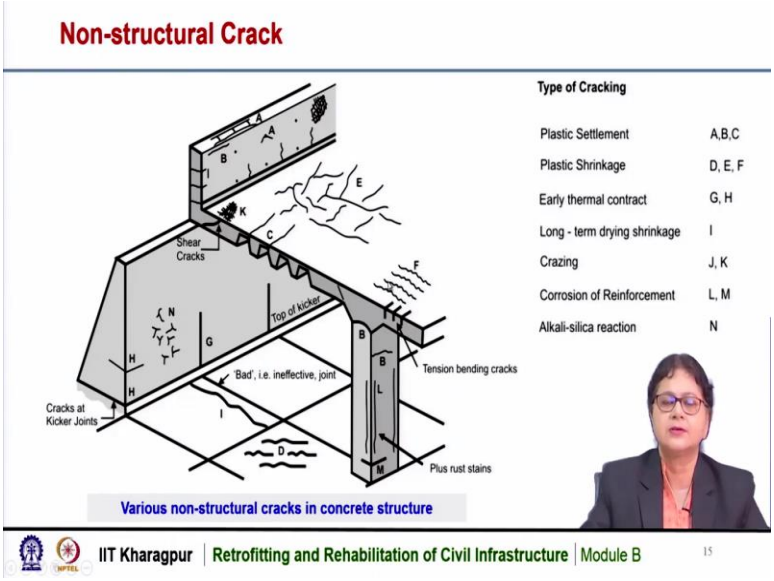

We can also differentiate a crack as active crack and dormant crack. Active cracks are those cracks, which are actually live cracks, which expand and propagate in length, width and depth over time. So, these cracks are generally formed due to overloading or due to thermal expansion or due to some weathering effects or so. And these cracks are such that they propagate within the material to cause further damage.

So, we also call it live cracks and look at this picture, it is an example of an active crack on the structure. Cracks may also be dormant in nature, usually the cracks which are not propagating over time, then we call it a dormant crack. So, these cracks are not that harmful, but it may appear on the structure.

For example, shrinkage cracks, shrinkage cracks appeared if there is no proper curing, there is a loss of water due to evaporation. So, shrinkage cracks may appear. But these cracks may not be that harmful, because they may not be active or propagate. So, they may be called as dormant crack.

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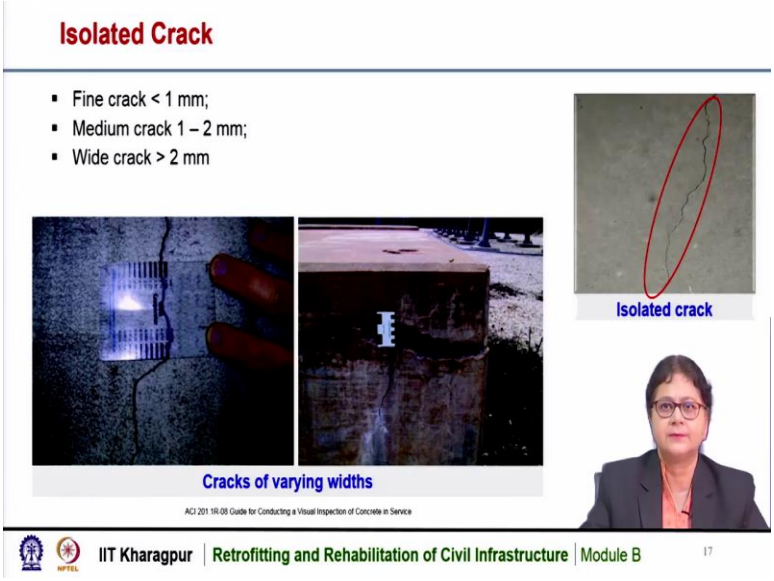

Cracks may also be differentiated as an isolated crack and pattern crack. An isolated crack, you can see here it is an isolated crack. This also on a flyover, when we visited, we found that several cracks were there and these were isolated cracks on the structure. Based on the width of the crack, you can also differentiate that whether it is a fine crack or medium crack or wide crack.

A fine crack generally is less than one millimeter or medium crack maybe 1 to 2 millimeter and wide crack maybe more than 2 millimeter. But there is no hard and fast rule that you have to call it a medium crack when it is 1 to 2 millimeter. But generally, it can differentiate as fine medium or wide cracks.

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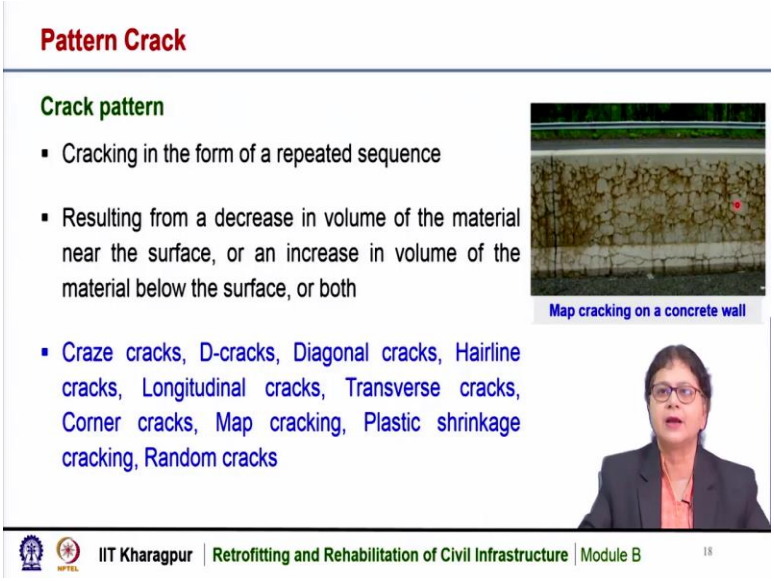

Pattern crack is also found in concrete structures. And this pattern cracks are appeared on the structure in the form of a repeated sequence. This is resulting from a decrease in the volume of the material near the surface or due to an increase in the volume of the material below the surface or due to the effect of both or it may be due to the effect of several material related degradation. This type of pattern cracking may appear.

Pattern cracking may have several types, it may be craze cracks, D-cracks, diagonal cracks, hairline cracks, map cracking, random cracks, etcetera. So, all these cracks form a pattern on the structure. And based on that pattern, we can also identify that what type of distresses are there on that structure, which may cause this type of cracking on the surface.

Look at this picture. This is a typical picture of a pattern cracking. See here, the entire concrete wall is under map cracking due to the action of alkali aggregate reaction. This is the typical picture of map cracking on a concrete wall.

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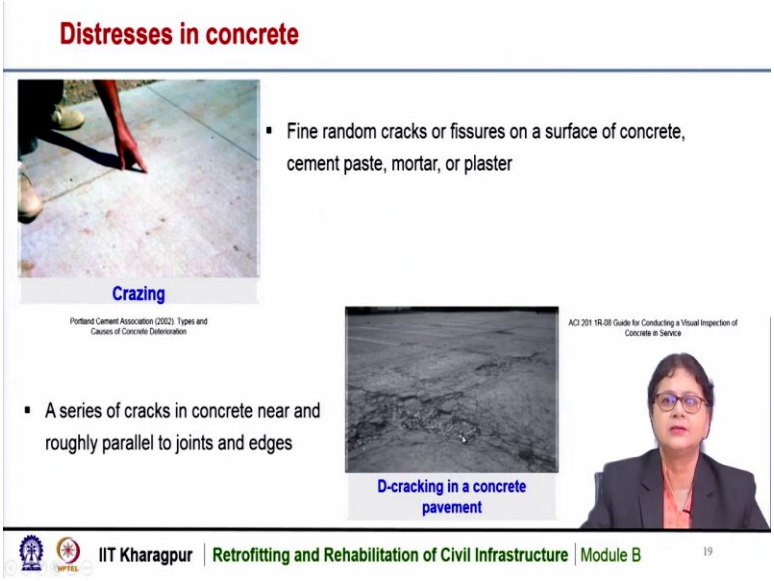

Here we are showing you some of the typical distresses that may appear on the concrete structures by which we can identify that there are some distresses. Look at this picture, this is a crazing type of distress, this is a fine random cracks or fissures on the surface of concrete or cement paste or mortar or plaster. So, these types of fine cracks appeared not very wide, but very fine cracks appear as craze crack. Craze cracking or crazing we call it.

This is a typical D-cracking in a concrete pavement. This is a series of crack in concrete near the joints you can see here in concrete pavement there are joints and these joints may get distressed and because of that there may be cracks near the joints. So, the series of cracks near or roughly parallel to the joints or edges may cause D-cracking on the pavement.

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These are plastic shrinkage cracks which are very common in all concrete structure, if it is not properly cured during the time of its construction. So, cracks may appear, that occurs on the surface of a fresh concrete soon after it is placed or when it is still in the plastic state. So, this type of fine shrinkage cracks may appear on concrete structures. Spalling is also another type of distress and that is also quite common in existing structures.

A fragment usually in the form of flake or a mass is detached from the concrete member and this type of distress we call it spalling. So, you can see here that there is a loss of mass on the concrete pavement and some portion of the concrete is spalled out, look at this picture. This is also a from ROB (road over bridge). Which is under repair at the moment it near Kolkata and the structure is damaged.

See here that the concrete is spalled out at this portion. This is the girder you can see that our longitudinal girder and supported on pier and pier caps and this portion the concrete is lost due to spalling.

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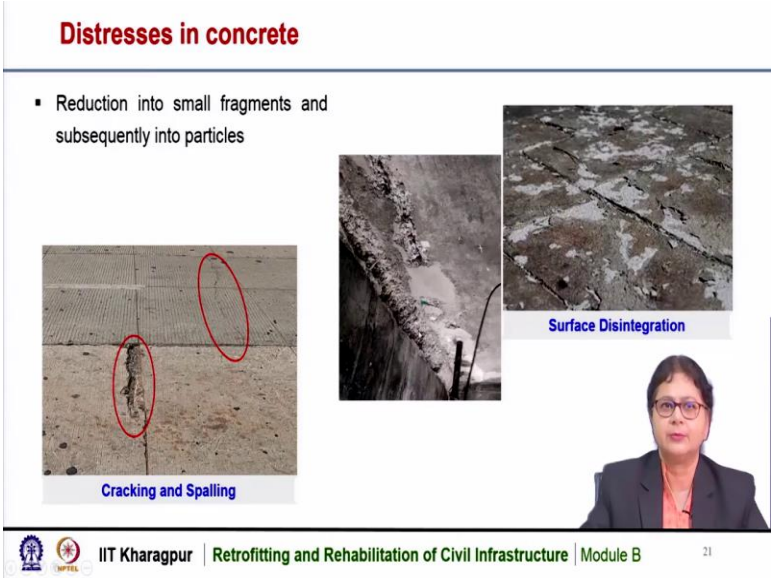

Look at this picture, this is also a special type of concrete pavement, it is a concrete overlay where you will find that cracks appeared a transverse crack and spalling also occurred on the pavement. This is surface disintegration, look at this picture, this is the surface that is disintegrated, possibly due to the effect of freezing and thawing. And this is also another picture of a flyover. When visited we found that several surface disintegrations occurred. The reinforcements are exposed and the structure is damaged.

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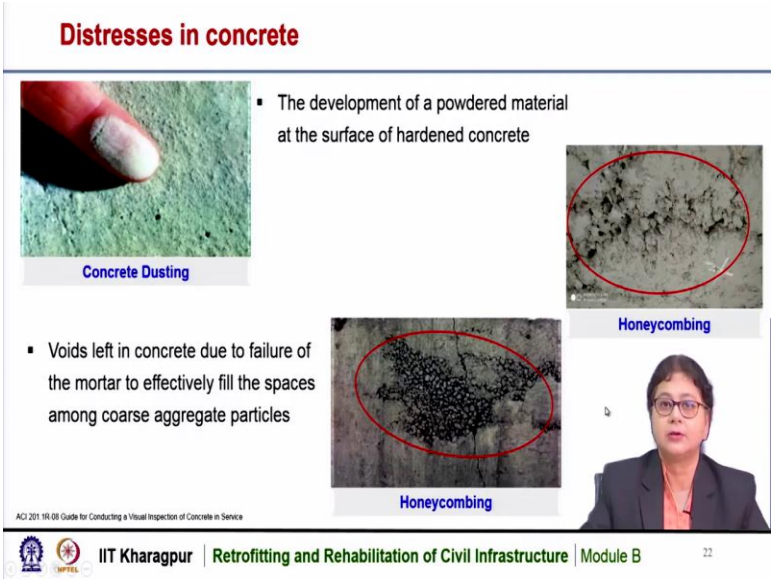

Concrete may also be deteriorated in the form of a dusting. The development of a powdered material type of thing may appear on the surface of the concrete or on the cement mortar. So, you can see here that a powdery form appeared on the surface. So, this is called concrete dusting. This is maybe due to improper construction practices or a brush and type of distress. Look at this picture. This is a typical picture of honeycombing.

This is also a picture of honeycombing. Recently when we visited, we found that this type of honeycombing is there on a structure which is only 8 months old. Because of poor construction practices, maybe the shuttering joints were not slurry tight or the compaction was poor. So that leads to honeycombing type of distresses. So, voids are created in the concrete due to failure of the mortar to effectively fill up the spaces and aggregates are exposed. So, this is a typical honeycombing picture of the concrete structure.

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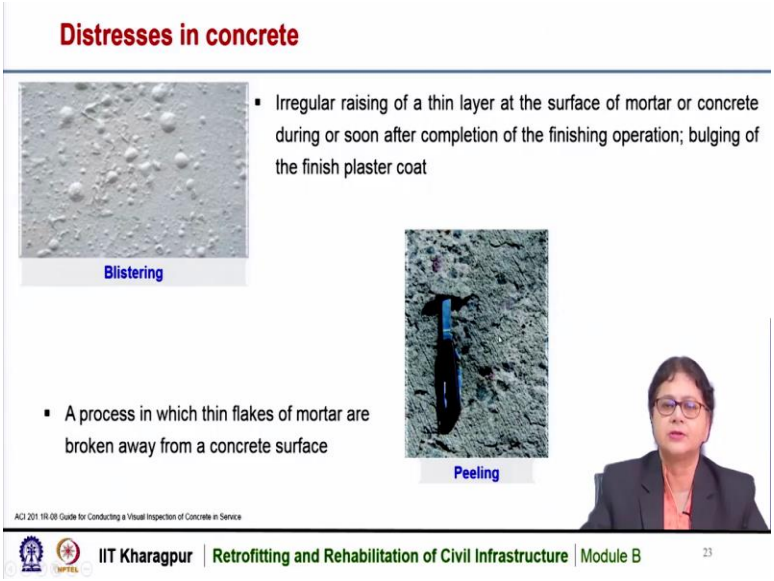

Blistering, blistering is also another type of distress. This is the irregular raising of a thin layer of the surface of mortar or concrete during or soon after completion of the finishing operation. This is like a bulging of the finishing plaster. So, if the finishing is not done properly, there may be small voids that may appear below the surface this is called blistering. Sometimes the surface get damaged and disintegrated and a thin flake of mortar may come out. So, this is called peeling type of distresses in concrete structures.

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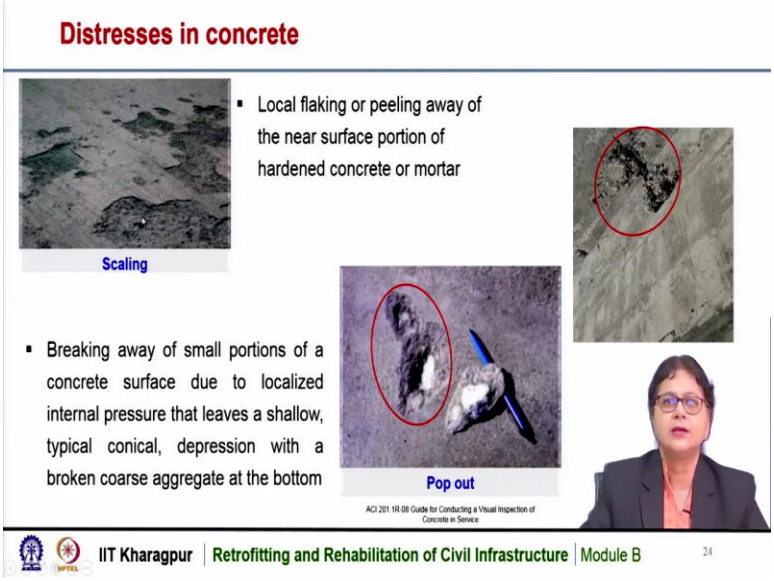

This is scaling, scaling is the surface is disintegrated, a local flaking or peeling away of the near surface portion occurs from the hardened concrete. So, look at this picture, maybe it is due to freezing and thawing type of distress. So, this type of scaling type of deterioration of the surface may occur. This is pop out, pop out is breaking away of the small portion of a concrete surface to localized internal pressure that leaves a shallow conical shaped depression with the broken aggregates.

So, look at this picture the aggregates have come out and there is a hole type of distress on the concrete surface. Look at this picture, this is also from a flyover under repair at the moment and this is the portion which is damaged you can see here, the girder and the deck slab joint and some amount of material is lost due to pop out and surface disintegration.

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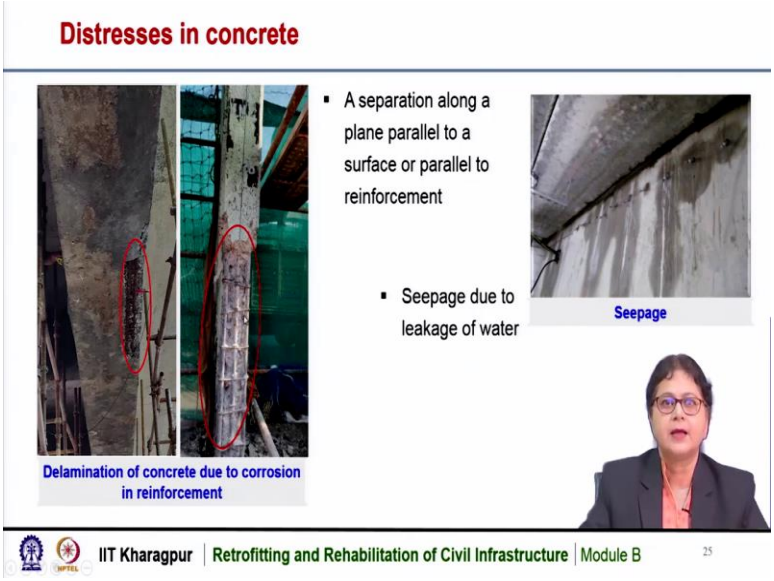

Delamination is also another type of distress in concrete, which is found in structures which are affected due to corrosion of reinforcement. And as we have discussed earlier that due to corrosion, there are cracks developed and that cracks generally run parallel to the reinforcement and if many more cracks appeared that may cause a spalling of the concrete member. So, the portion of the concrete is lost and this is a Delamination type of distress.

So, all these are from the real life structures. So, this portion of the reinforcement is exposed and the concrete is lost due to delamination. So, the separation along the plane parallel to the surface or parallel to the reinforcement causes delamination type of distress in concrete members. Distress may also be due to seepage. Look at this picture, this is a seepage type of distress in concrete members due to leakage of water.

If the members are not watertight, particularly water retaining structure or so, then water may penetrate through the member it may cause damage to the concrete as well as damage to the reinforcement. And sometimes it makes serious distress on the member and reduces the strength considerably. So, this is a typical seepage type of distress in concrete structures.

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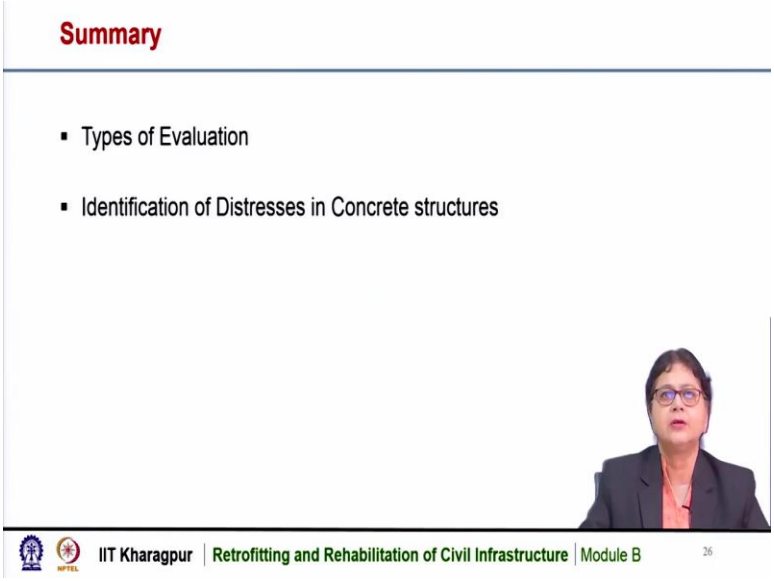

So to summarize, we have discussed the type of evaluation, the first and foremost the visual inspection, after the visual inspection if it is found necessary then a detailed investigation need to be carried out using semi destructive or non-destructive type of testing. And that by analyzing the results of those testing we can evaluate the condition of the structure. Evaluation can also be done using structural health monitoring by using a number of embedded sensors into the structure.

After that we have discussed the several distresses found in concrete structures. And how to identify the several distresses. The distresses maybe delamination or disintegration of the surface or maybe cracking, spalling, etcetera. So, we have discussed how to identify all these types of distresses in concrete structures. Thank you.