Retrofitting and Rehabilitation of Civil Infrastructure
Professor Swati Maitra
Ranbir and Chitra Gupta School of infrastructure Design and Management
Indian Institute of Technology, Kharagpur
Module A
Lecture 02: Causes of Deterioration

Hello friends, welcome to the NPTEL Online certification course, on retrofitting and rehabilitation of civil infrastructure. Today we will discuss Module A. The topic for Module A is deterioration of concrete structures.

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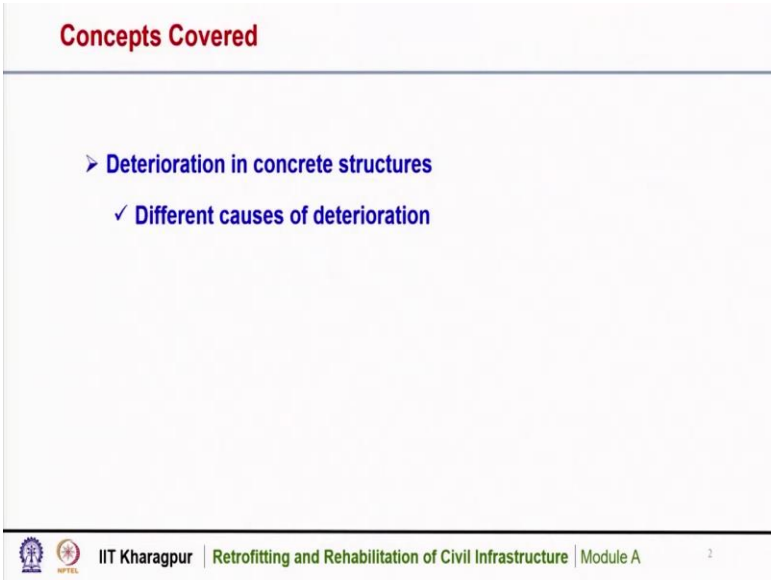

Today, we will discuss the different causes of deterioration in concrete structures.

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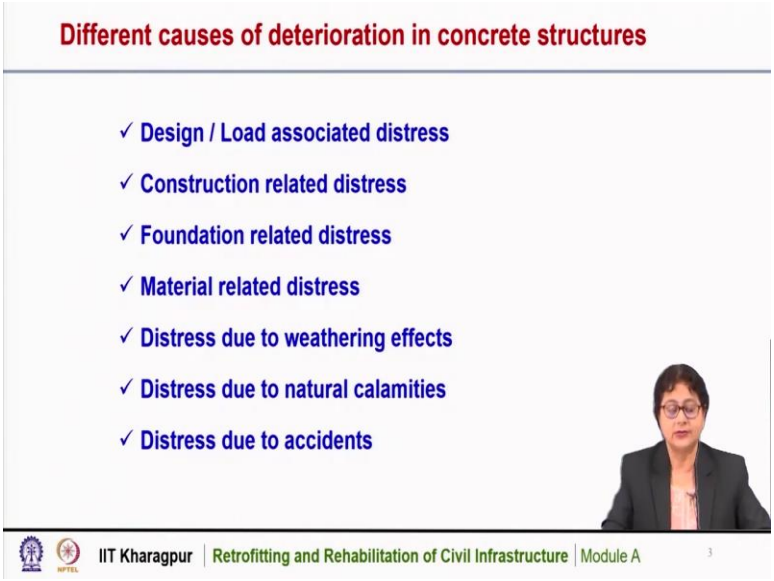

All infrastructures are deteriorated day by day as we grow old and our health deteriorates, so is our infrastructure. Now, if we want to know that, why our infrastructures are getting deteriorated, we will see that there are several reasons for deterioration of infrastructures. The reasons could be due to design or load associated distress, it could be due to several constructions related issues, there may be problems in the foundation that may cause damage to the structure.

There are several material related distresses due to which the structure may get distressed; all infrastructures are exposed to environment. So, there are several weathering effects that may also cause distress to the infrastructure. Several natural calamities may cause damage to the structures like earthquake or storm. And in addition to that, there may be some manmade accidents like fires, that may also cause damage to our infrastructure. So, in the next few minutes, we will discuss all these distresses, all the reasons for these distresses in concrete structures.

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Design or load associated distress may be due to faulty or inadequate design, due to overloading or due to change in functional performance of the structure. Faulty or inadequate design may be due to improper assessment of the design load for which it has to be designed or improper assessment of the material behavior or due to the improper estimation of the soil strength and its characteristics.

You can see here in these pictures that due to inadequate design or faulty design the structures get damaged. Overloading is also another issue due to which there may be severe damage to any structure. You can see here this picture; this is a factory building in Bangladesh and this has been badly damaged and collapsed due to overloading the structure may be designed for such load and if over a period of time it is subjected to overloading that may cause serious damage.

Another example of overloading which causes collapse is the recent collapse of Majerhat Bridge in Kolkata. The bridge was an old bridge and it was not maintained properly throughout its service life. As a result, it gets deteriorated. However, to improve the riding quality a number of layers were put on the deck slab to improve the surface condition and that increases its dead load. And that is one of the main reasons for the collapse of that bridge in recent times.

Change in functional performance may also cause damage to the structure. For example, a residential building which was serving for several years now can become a commercial building.

And that may cause excessive load on the structure and it has not been designed for that additional load due to the commercial activity and that may cause damage to the structure.

You can see here in this picture a bridge which was earlier designed and constructed to take lower volume of traffic. However, over a period of time the traffic has increased and heavy vehicles were moving on it that may cause damage to the structures.

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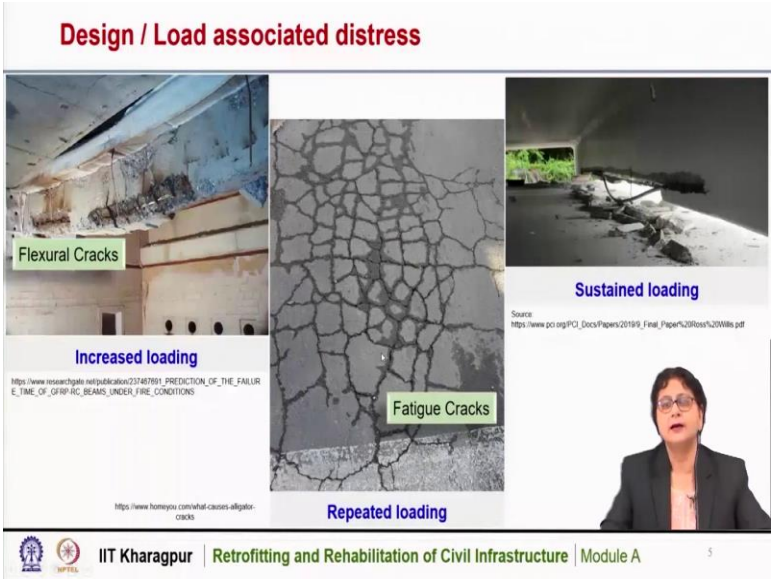

Increased loading, sustained loading or repeated loading may also cause severe damage to any structure. Due to increased loading condition, the structural component may get distressed; there may be development of cracks, flexural cracks or shear cracks, you can see here, that may develop on the structure which cause damage to the member.

Due to sustained loading, the structure may get deteriorated, there may be excessive deflection and due to the effect of crepe, there is damage. You can see here that the structure is damaged due to sustained loading. Some structures are subjected to repeated loading, for example, a road pavement where the repeated loads are due to the moving vehicles.

Machine foundation is also one such structure which is subjected to repeated loading due to the movement of the machines and that may cause fatigue cracking on the structure. Due to fatigue, the structure may fail at a stress level lower than its strength. As a result, cracks are initiated and

it propagates throughout the material. And a number of cracks are created on the surface that may cause failure of the member.

So, you can see here that this is a picture of a road surface, which has developed a number of cracks due to fatigue. And this is a common picture on Indian roads where many of our roads are damaged due to the repeated loading.

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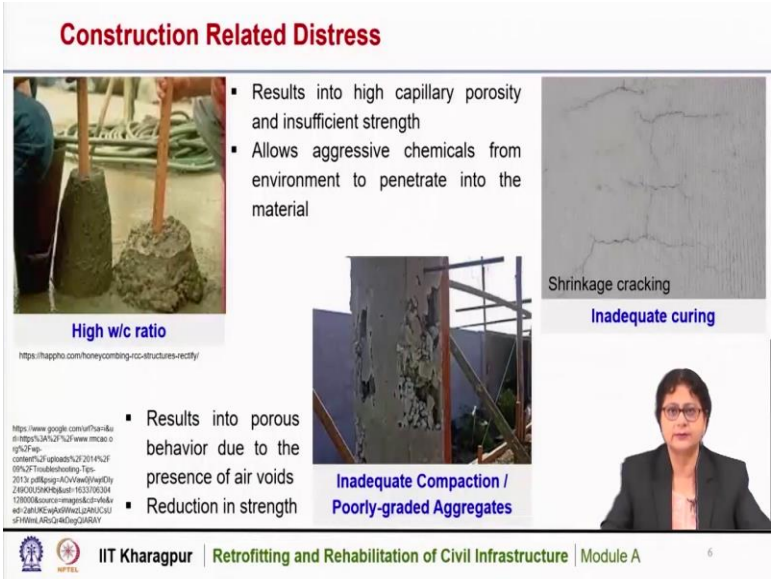

There are several construction related distresses that may affect the performance of a structure. In many cases, a structure which has been designed nicely may behave or may perform poorly because of poor construction. There are several construction related issues that may affect the performance and the overall durability of a structure.

For example, high water cement ratio or inadequate curing, inadequate compaction, using poorly graded aggregates all these may cause damage to the structure. To improve the workability sometimes more water is added and that causes high water cement ratio, which results into high capillary porosity and also insufficient strength. The strength is reduced if more water is added.

When the curing is inadequate, you can see that a number of cracks are developed on the structure due to shrinkage and which allows aggressive chemicals from environment to penetrate into the material which further damages the structure. Here you can look at this picture, it is due

to inadequate compaction of the mix that results into porous behavior and honeycombing in the structure. All these results into reduction in strength and poor performance of the structure.

Recently we have visited one site, where there are a number of grid separators constructed. They are not very old, only six to eight months old. However, due to poor construction quality, all the structures get damaged because of inadequate curing, because of inadequate compaction and poor quality materials also used. So, a lot of honeycombing cracks have been developed on those structures.

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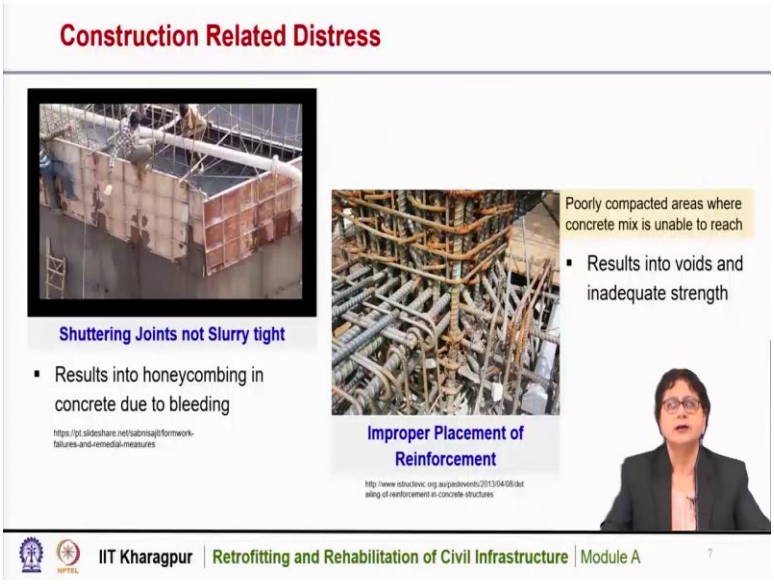

Shuttering is an important requirement for the construction of concrete structures. Shuttering should be properly placed, properly aligned and properly slurry tight, if the shuttering joints are not slurry tight, then the cement sand slurry may come out from those leakages, you can see here if it is not slurry tight cement sand slurry may come out from that and that results into honeycombing of the structure.

Another construction related issue is improper placement of reinforcement, sometimes if reinforcements are placed so densely that the concrete mix is unable to reach in that area. So, the area becomes poorly compacted, this results into voids and inadequate strength of the member. Sometimes the reinforcements are not properly curtailed to their desired length and that may also cause problem, inadequate strength development to the member and results into poor performance.

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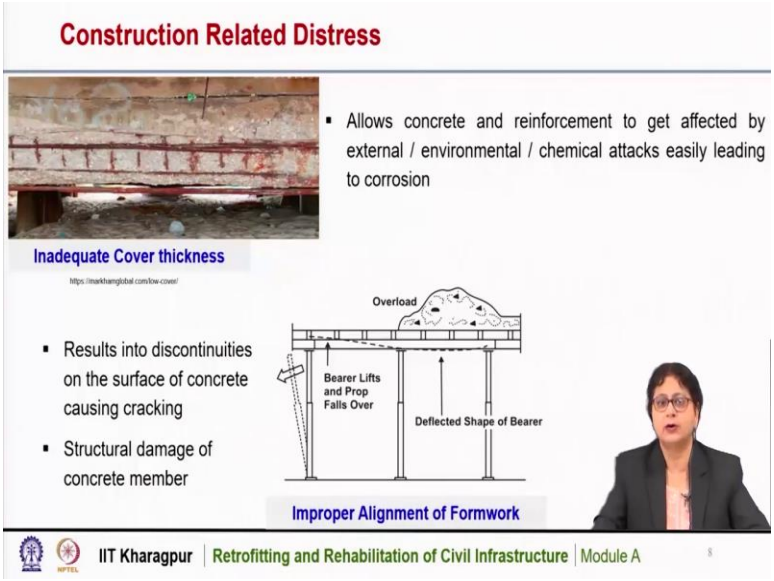

Cover thickness is important for all reinforced concrete structures. Concrete cover actually protects the reinforcement to get adapt due to the effect of environment or chemicals. However, if the cover thickness is not inadequate, then it allows the concrete and reinforcement to get affected by those external agencies that may create other problems.

For example, corrosion, the reinforcement may get exposed to environment due to inadequate cover and that may result into corrosion of reinforcement. Improper alignment of formwork that is also another construction related issue that may damage the infrastructure. If the formwork is not properly aligned, there may be a minor to major cracks in the superstructure, it also results into discontinuities on the surface and that may again cause cracking, this results into structural damage of the concrete member.

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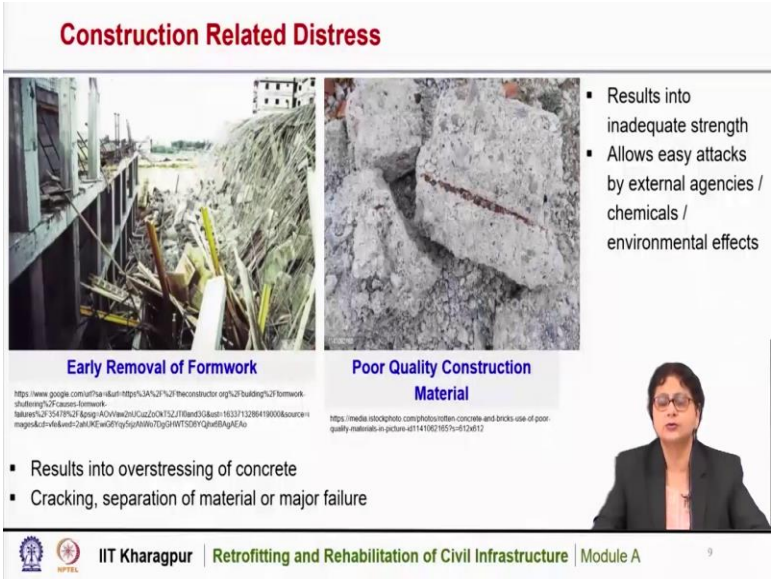

Early removal of formwork is also another construction related issue. Formwork should be placed properly, should be slurry tight, should be aligned and also, they should be provided at the stipulated time. If the formwork is not provided for the required time and it is removed early, then that result into overstressing of the concrete. The concrete may be still in its plastic state or not achieve its full strength, so it may get overstressed.

That may cause cracking separation of the material or even a major failure that may also occur in the member. Poor quality construction material is also another construction related issue. Poor quality construction material may result into inadequate strength of the member and inadequate strength may also lead to allowance of the easy attack by the external agencies due to environmental effects.

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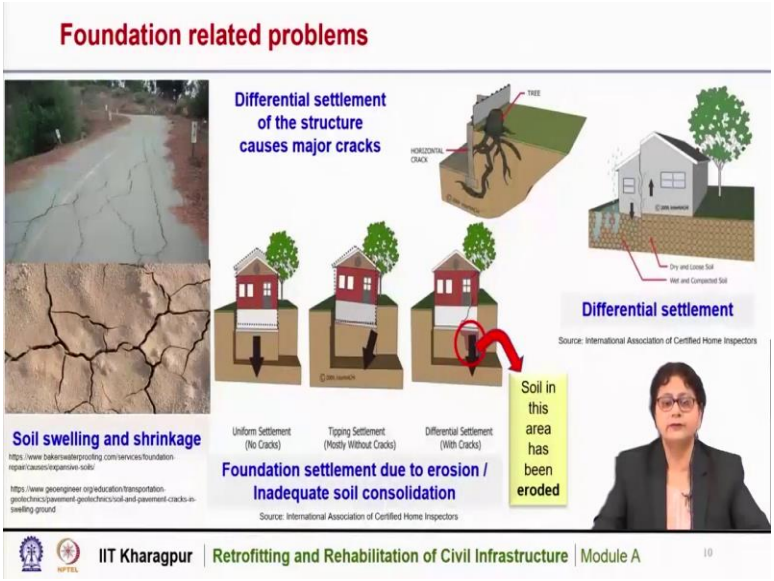

So, we have discussed several construction related issues that may cause damage to the structures. Distresses may also be due to several foundation related problems. Here in this picture, you can see that the soil is undergoing swelling and shrinkage, all structures are supported on soil, but if the soil is not properly consolidated there may be soil swelling and shrinkage and you can see here that this road which is supported on this soil is badly cracked due to soil swelling and shrinkage.

There may be differential settlement of the structure due to improper soil consolidation and compaction. If the soil is not properly compacted, there may be settlement of the structure. However, if they are not compacted properly, but it is uniform there may be uniform settlement of the structure as we can see in this picture, this structure is settled but the settlement is uniform. However, if the soil is not compacted uniformly there may be differential settlement.

You can see here that this building is tilted because of the differential settlement, but cracks may not have been developed. But if the differential settlement is significant due to the erosion of soil at some portion, there may be major cracks on the superstructure, you can see here that there are major cracks developed on the superstructure due to inadequate soil consolidation.

Differential settlement may also occur due to the effect of water that may cause cracks on the superstructure or due to the development of some tree roots, this has happened particularly in very old buildings in urban areas where large banyan trees are growing and the roots of those

trees may cause damage to the foundation. So, cracks are being developed and that may cause damage to the overall structure also.

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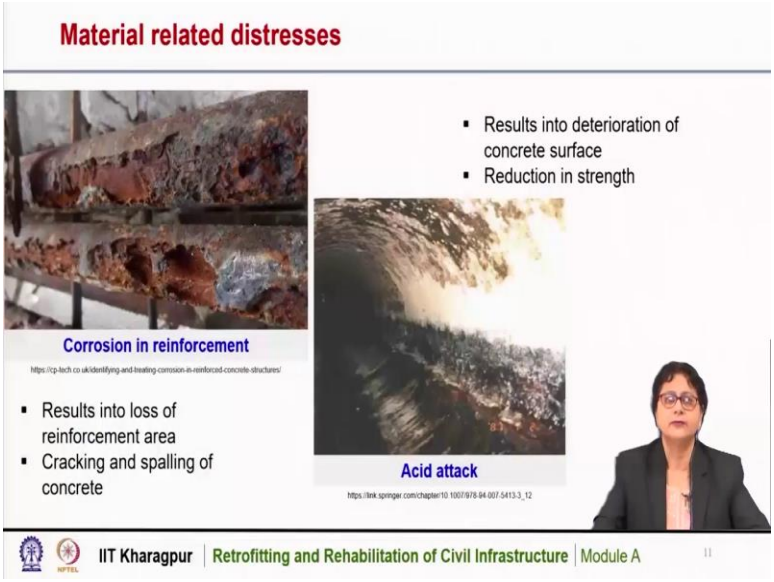

There are several material related issues that may cause damage to the overall structure. Corrosion is a one of the major material related distress that affects the performance of a reinforced concrete structure. Look at this picture, the reinforcements are badly corroded. Corrosion is a chemical reaction of steel in presence of water and oxygen.

As a result, there is loss of material, loss of the reinforcement area which also results into cracking and spalling of concrete. If there is loss of reinforcement area, the flexural or tensile capacity of the member is reduced significantly and because of this corrosion the concrete also is cracked, delaminated and some portions are also spalled out.

This picture shows that there is a significant loss of material of the reinforcement bars and due to the spalling of concrete, the reinforcements are also exposed which further aggravates the distress. This is another distress in concrete structure due to acid attack. This is also a material related distress, sometimes the structures, which are constructed in industrial areas where the byproducts are some acids.

For example, food industries or so where lactic acid or acetic acid are produced as a byproduct and if concrete structure is in contact with those byproducts, the surface may get damaged. You

can see here that this is a sewer pipe, this also is subjected to acidic solution and this causes the structure damaged. Due to the effect of acids, there is deterioration of the concrete surface, the surface is disintegrated, thickness is reduced and the strength is also decreased.

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Another material related distress is sulfate attack, when concrete is in contact with several sulphate salts that may cause damage to the concrete surface. Sulphate salts may be present in some groundwater or seawater and when it is in contact with the concrete, there is leaching of the calcium hydroxide, which is present in concrete and due to that there is chemical reaction and carbonates are formed, which is deposited on the surface.

Thus, a whitish appearance of those depositions, you can see here in this picture, this whitish appearance is due to the sulphate attack as a result of the deposition of salts that results into loss of mass and reduction in strength of the member. Alkali aggregate reaction is also another material related distress observed in concrete.

In concrete, aggregates are used as an ingredient and aggregates are generally very inert. However, if the aggregate used in the mix is not so inert, they may be reactive and these react aggregates sometimes react with the alkalis present in cement and react and the reactive products are expansive due to which the concrete also experiences an expansive pressure, thus it cracks.

So, here look at this picture, it is due to the action of alkali aggregate reaction. The cracks have been developed on the structure due to the reactive aggregates reacting with alkalis present in concrete and causes this type of map cracking on the entire structure.

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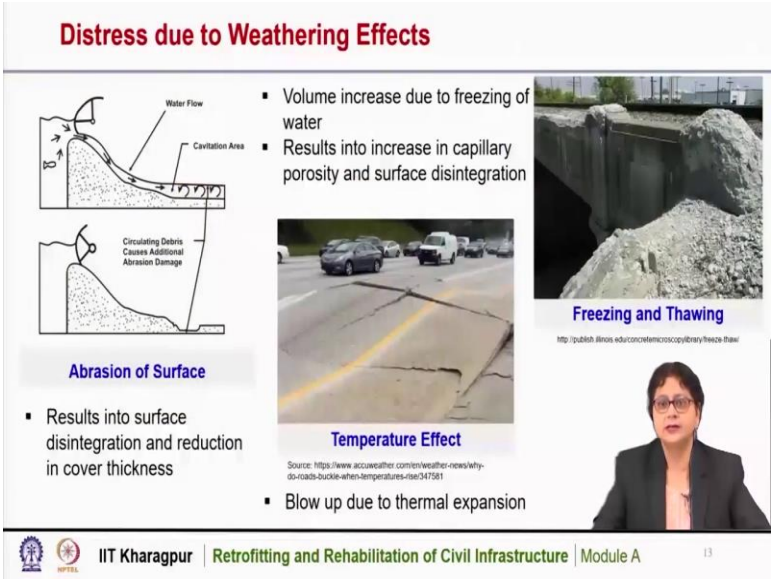

All infrastructures are exposed to environment. So, there are several weathering effects that may cause damage to the structures. Weathering effects may be due to abrasion of surface, temperature effect, freezing and thawing, etcetera. This type of abrasion of surface may occur when the concrete structure is situated, where there is flow of water.

Particularly in the area near the rivers or streams or dams, where there is significant flow of water and that may cause abrasion of the surface. That results into surface disintegration, loss of mass reduction in thickness and also the cover depth. Temperature is another weathering effect that may damage concrete structures.

The effect of temperature is actually twofold: one is due to the variation of temperature, due to daily variation of temperature and one is due to seasonal variation of temperature. Due to seasonal variation of temperature, concrete structure tends to expand or contract with increase in temperature or decrease in temperature. And that is why for large structures, we need to provide contraction joints or expansion joints.

However, if the width of these joints are not sufficient, then concrete is unable to expand and there may be a collition of the two members. Here look at this picture, this is a picture of concrete pavement, where two slabs are separated by this joint, but the joint spacing, the width of the joint is not sufficient for the slabs to accommodate its expansion. So, as a result, there is a collision of the two slabs and a blow-up type of distress happened.

You can see here at the joint of these two slabs, there is severe damage to the pavement. Freezing and thawing is another type of distress, which is due to the effect of weathering actions. This type of distress is found in structures which are situated in very cold region, where there is snow fall and temperature goes below zero degrees centigrade. When the temperature goes below zero degrees centigrade, water freezes into ice and that results into an increase in the volume.

This happens also in the water, which are present in the capillary pores and due to the increase in the volume, there is a thermodynamic imbalance between the water in the gel pores and the capillary pores that result into increase in capillary porosity of the member, which results into surface disintegration.

Here we can see in this picture that this is due to the effect of freezing and thawing type of distress, the surface is disintegrated badly and the structure is damaged significantly.

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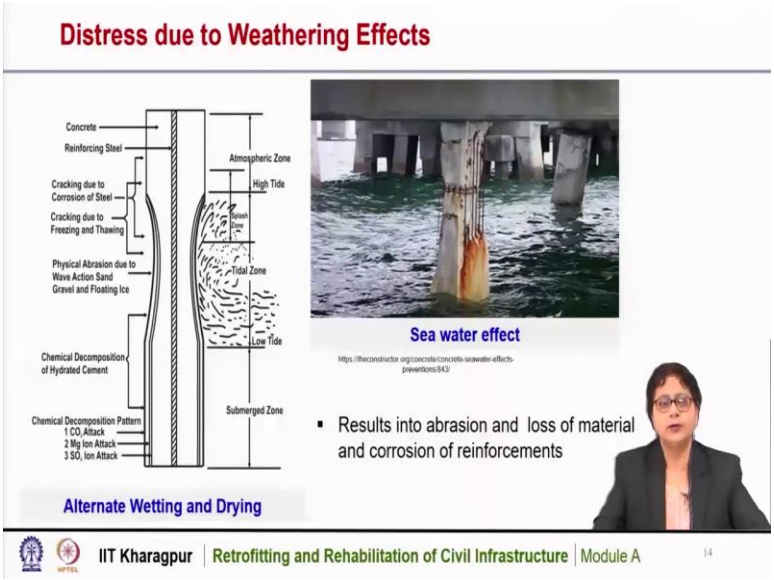

Another weathering effect is due to alternate wetting and drying. This type of distress is observed particularly in the areas where there is tidal action, maybe in the areas near rivers or seaside. So, here we can see that due to the action of this alternate wetting and drying, the structure is damaged. The portion which is completely submerged or which is completely dry, these portions are not affected that much.

But the portion which is undergoing alternate waiting and drying there the distress is more. So here also we can see in this picture that the portion which is under the tidal zone and this area there is distress in the form of abrasion of material, loss of material and with that the reinforcements are exposed, leading to corrosion of reinforcement.

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Distresses may occur due to several natural calamities. Natural calamities are also quite frequent nowadays, there are earthquakes, floods, storm or tsunami and due to which there may be major to severe distresses on the structures.

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Distresses on the structure may also be due to the effect of several man-made accidents, for example, fire or blast, shock, etcetera. Due to the fire, there is very high temperature suddenly coming onto the structure and that may cause disintegration of the concrete.

It also results into the damage to the steel reinforcement; the steel may get yielded and there is an overall decrease in the strength of the member. Due to blast or shock the structures may get damaged severely and that may cause further deterioration of the overall structure.

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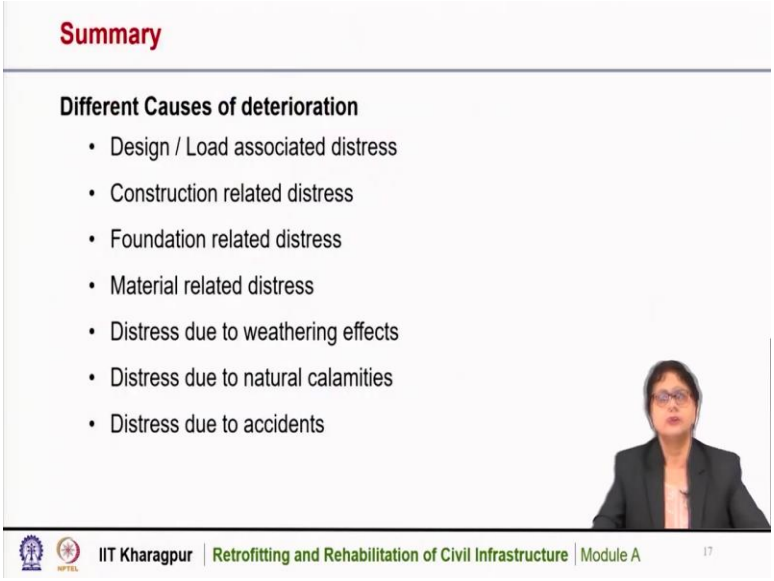

So, we can summarize that we have discussed several causes of deterioration of concrete structures. The distresses may be due to several design or load associated distress. There are several construction related distress. Foundation related problems may also create damage to the structure. Several material related distresses may affect the overall performance of the structures and their durability.

Distresses of structures may also be due to several weathering effects, like alternate wetting and drying, freezing and thawing, etcetera. Natural calamities like earthquake, wind, storm, etcetera may also damage the structures severely. And distresses due to manmade accidents like fire or blast may also affect the performance and durability of the structure significantly.

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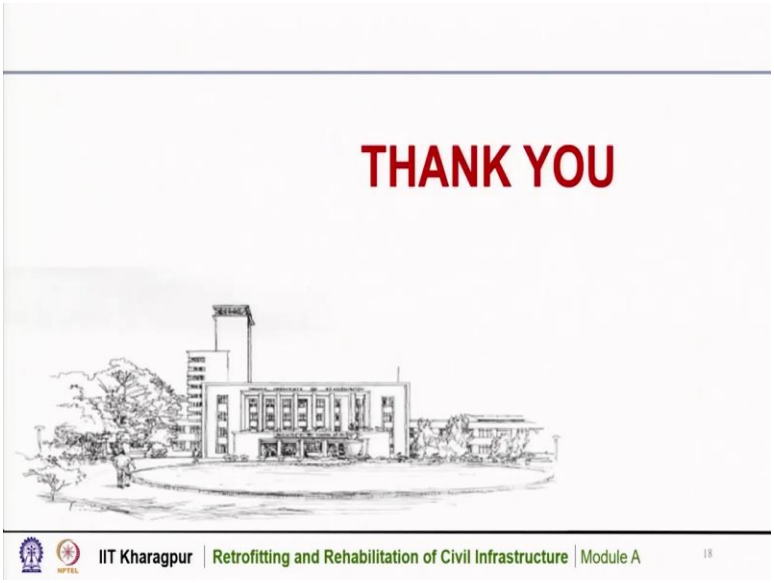

Thank you.