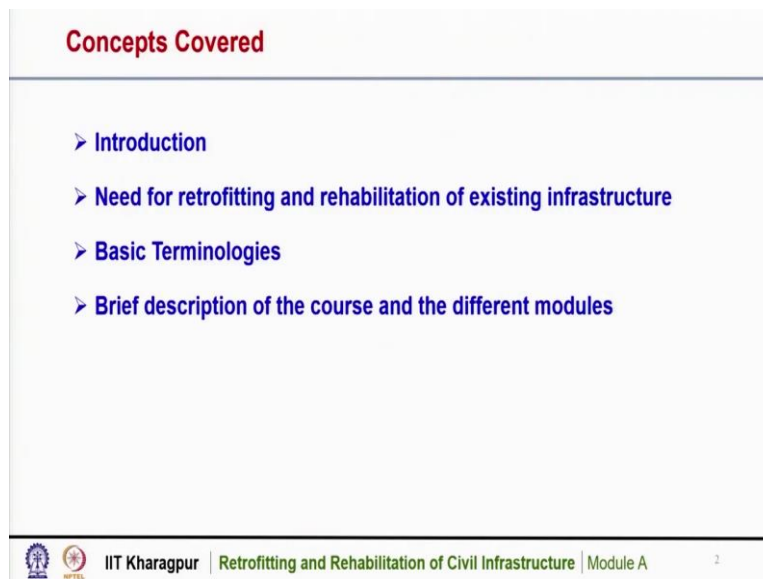


Retrofitting and Rehabilitation of Civil Infrastructure
Professor Swati Maitra
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Indian Institute of Technology, Kharagpur
Lecture 01
Introduction



Hello friends, welcome to the NPTEL online certification course 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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Concepts Covered

- Introduction
- Need for retrofitting and rehabilitation of existing infrastructure
- Basic Terminologies
- Brief description of the course and the different modules

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In this introductory lecture, we will discuss the importance of retrofitting and rehabilitation of existing structures. We will discuss the benefits and needs for retrofitting and rehabilitation and how it is important in today's infrastructure development. We will also discuss several basic terminologies that are used in the study of retrofitting and rehabilitation of existing structures. And in this lecture, we will also give you a brief description of the course with its different modules.

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Construction of New Infrastructure

Construction of new infrastructure is happening in full swing

Business Standard

Gati Shakti Yojana to give tech push for quicker delivery of infra projects

Hyderabad's new skyscraper: 44 floors; more highrises to break new ground

Big target in India's high-rises: A present-day requisite

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In recent years, the construction of new infrastructure is happening in full swing in India. There are several large-scale projects, ambitious projects are being taken up by the government of India like NHTP project, Bharath Mala project or Gati Shakti projects for the development of infrastructure in the country.

So, India is developing its infrastructure from highways to expressways, bridges and tunnels, high rises and skyscrapers throughout the country. Along with this, a number of smart cities are also coming up in several places in the country. Several state governments are also developing new infrastructures in their states.

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Deterioration of Existing Civil Infrastructures

Uttarakhand rains: Portion of bridge collapses in Haldwani; overflowing Nainital Lake floods streets | WATCH

Now, a bridge collapses near Siliguri

THE HINDU

Along with the development of new infrastructures, it is our duty to maintain the new infrastructures as well as the existing infrastructure in a proper way so that they can perform and last longer. All the infrastructures are exposed to environment. So the infrastructures are subjected to deterioration due to several reasons and because of this deteriorations they suffer distresses and in some cases, there may be collapse or loss of lives even.

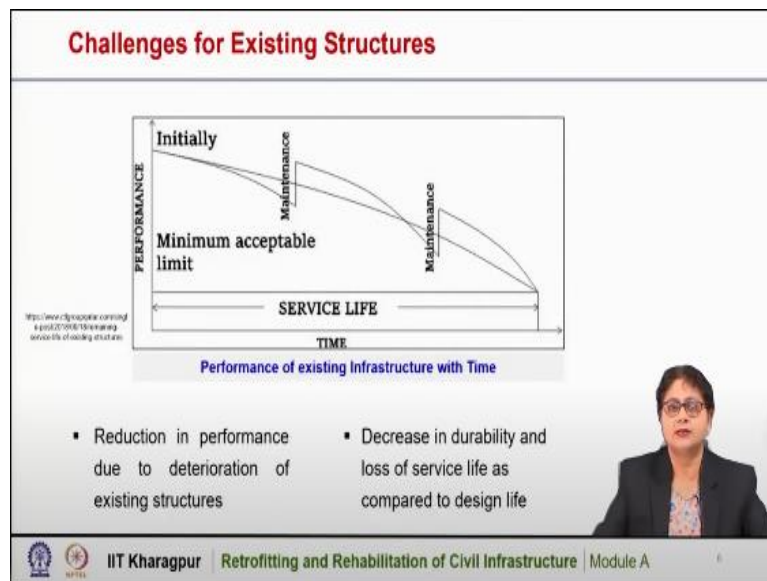
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The existing structures are deteriorated due to several reasons. So, they are facing a challenge of their performance and durability over time. The reasons for deterioration could be several, it could be due to material related degradation, like corrosion of steel reinforcement, or due to faulty design or due to construction related deficiencies.

Overloading is also another issue particularly in our country, which affects the performance of our infrastructure largely. The vehicles are overloaded so the roads and flyovers or bridges are damaged due to this overloading vehicles. There could be natural calamities like earthquake or manmade accidents, that may also damage our infrastructure.

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As a result, the service life of the existing infrastructures is reduced and they are facing the challenge of performance and durability. Look at this diagram, this is the performance with time variation of the existing infrastructure. When the infrastructure is constructed, the performance is maximum, but over a period of time the performance is reduced.

Now, if we do not care about its maintenance or so, then the infrastructure may get deteriorated faster and their service life may reduce. Because of the several reasons of material related degradation or overloading, the deterioration may be faster and that may cause even a reduced service life much before its designed life. So, it is very much important to maintain and proper repair of our structures, so that the performance can be enhanced.

You can see here that if we do a timely maintenance at some point of service life, the performance is improved. Again, after some time the performance is reduced with time, then another maintenance may also improve its performance and then the infrastructure may serve to its purpose. So, it is very important that we should maintain our structures, so that they can perform in a proper way and can serve till its design life.

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Retrofitting and Rehabilitation of Existing Civil Infrastructure

The Telegraph online

State focus on repair of 200 bridges

400 bridges across Bengal identified as distressed, half need urgent attention

Rehabilitation of dams on with World Bank funds

THE TIMES OF INDIA

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As a result, it is important to carry out proper repair, retrofitting and rehabilitation of our existing infrastructures. Several states are now focusing on the repair of several of its infrastructures and new materials are also used for this purpose. In general, high strength concrete or steel is used not only for the construction, but also for the repair and retrofitting of structures.

In recent years, new materials are coming up like fiber reinforced polymer composites are used widely for the retrofitting of several civil infrastructures. And several projects are also being taken up for the rehabilitation of our infrastructures in the country.

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Need for Retrofitting and Rehabilitation

- To improve the structural integrity and performance of an existing structure
- To upgrade the functionality of a new structure
- To upgrade an existing structure commensurate with the latest codal provisions
- To restore the heritage value of a structure
- To improve the durability and extend the service life of a structure
- To improve the appearance of a structure

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Therefore, the need for retrofitting and rehabilitation of existing infrastructures can be summarized as to improve the structural integrity and performance of an existing infrastructure, as we have seen that the performance deteriorates over time. And therefore, the strength is also reduced.

So, to improve the structural strength and integrity of the member, we need to retrofit our existing infrastructure to upgrade the functionality of a new structure. For example, a structure which may not be that old, but its function is changed, for example, residential buildings has been constructed. But after a few years it has been transformed into a commercial building. So, it has to carry a high load.

So, the functionality of the structure has been changed. So, in order to take up the higher load, we can upgrade the structure by retrofitting it. So, to upgrade the functionality of a comparatively new structure, we can do retrofitting and rehabilitation. To upgrade an existing structure commensurate with the latest codal provisions.

For example, the old structures which are already built, maybe 50 years back or so that has been constructed and designed as per the codes at that time. Now the codes have been revised, sometimes the old structure is not as par the present design codes. So, in that case, to commensurate with the latest codal provisions, we can upgrade the existing structure by retrofitting and proper rehabilitation.

So, to upgrade an existing structure commensurate with the latest codal provisions, we can upgrade or we can retrofit the existing infrastructure to restore the heritage value of a structure. There are several structures, existing structures which are old and which has a significant heritage value, for example, a temple or an old building, or mosque etcetera.

So, to maintain our heritage structures in a proper way, we can retrofit the structure, it is important to restore the heritage value of a structure because those structures sometimes give us the identity of that place, the identity of that city. So, it is important to restore the heritage structures in the country.

To improve the durability and extend the service life of a structure, for all repair and retrofitting work, it is important to upgrade the performance and the durability and service life. So, to extend the service life and to improve its durability we need to retrofit and rehabilitate our existing infrastructure and to improve the appearance of a structure. So, all

repair and retrofitting work has to consider the improvement of the appearance of the structure.

So, for the retrofitting and rehabilitation, it is important to carry out proper measures so as to improve the structural integrity and performance of the structure, to upgrade the functionality of the structure, to upgrade an existing structure commensurate with the latest codal provisions, to restore the heritage value of a structure, to improve the durability and extend the service life of a structure and also to improve the appearance of the existing structures.

So, these are the needs for retrofitting and rehabilitation. So, for all existing structures, we have to carry out retrofitting and rehabilitation to meet these needs.

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Benefits of Retrofitting and Rehabilitation

- Saving in financial resources
- Saving in natural resources
- Saving in equipment and manpower resources
- Saving in user cost like delay, extra fuel cost, wear and tear of vehicles, inconvenience, due to demolition of deteriorated structure and its reconstruction
- Environmentally beneficial due to less dust and debris, waste disposal and land filling, resulting from demolition of deteriorated structures

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The benefits of retrofitting and rehabilitation are significant. The first thing is the saving in the financial resources. For any infrastructure, if we want to construct a new structure, huge amount of financial resources are needed. Now, if we repair and retrofit an existing infrastructure, we can save a large amount of financial resources.

So, it is important to save the financial resources. Saving in natural resources, for any new construction, we have to consume large amounts of natural resources. And with this new construction the natural resources are reducing day by day. If it is a reinforced concrete structure, we have to use cement, which is manufactured but the raw materials, our natural resources, the sand or water or aggregates, they are all natural resources and large amount of these resources are required.

Or even if it is reinforced steel or any other material, we have to use the natural resources. So, if we can retrofit a damaged structure, we can save the precious natural resources, saving equipment and manpower resources. For any new construction we require a large amount of equipment and manpower. So, if we can retrofit it, we can save these equipment and manpower to some extent.

And saving in user cost, that is also a very important component for retrofitting and rehabilitation. User cost involves the delay, the extra fuel cost, wear and tear of vehicles, inconvenience due to the demolition of deteriorated structures and its reconstruction. For example, if a bridge is damaged, and it has to be demolished and then reconstructed, then the users, the road users need to follow another route, which of course will be longer route because bridges are always the shortest route.

So, the road users have to follow a longer route that causes delay to the road users. It will consume extra fuel that will again involve some cost, the wear and tear of the vehicles, vehicle has to travel that extra mileage. So, wear and tear of vehicle will also be increased. All this causes inconvenience to the users.

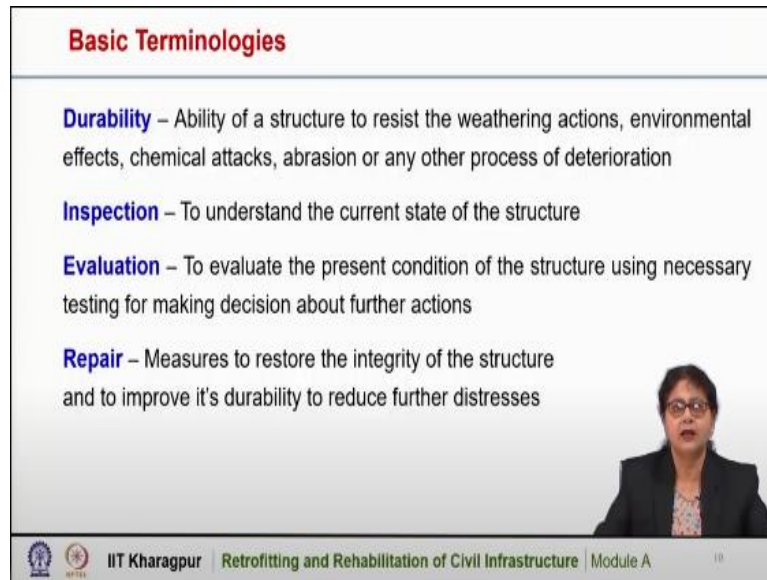
If it is a building, or it has to be demolished and then reconstructed then the users of that building have to be shifted. So, that also involve a lot of inconvenience, cost and other things. So, it is always beneficial if we can retrofit a structure. And in most cases, the retrofitting can be done by when it is in operation. So, saving in the user cost is one of the major benefits of retrofitting and rehabilitation of an existing structure as compared to demolition and its reconstruction.

Environmentally beneficial – The retrofitting and rehabilitation is environmentally beneficial due to the less dust and debris, if we demolish the structure, it will involve a lot of dust and debris and then there is a problem of waste disposal and landfilling. So, all these are results from demolition of a deteriorated structure, which involves environmental pollution. So, retrofitting and rehabilitation is environmentally beneficial if we can do it in a proper way.

So as compared to a new construction, and demolition of a deteriorated structure and then new construction, retrofitting and rehabilitation is a more sustainable option in terms of saving in the financial resources, saving in the natural resources, saving equipment and manpower resources. It also saves the user costs, significant inconvenience. So, it is much more beneficial in that way. And it is also environmentally beneficial.

So, retrofitting and rehabilitation is a sustainable option for a deteriorated structure to enhance its service life and improve its performance.

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Basic Terminologies

Durability – Ability of a structure to resist the weathering actions, environmental effects, chemical attacks, abrasion or any other process of deterioration

Inspection – To understand the current state of the structure

Evaluation – To evaluate the present condition of the structure using necessary testing for making decision about further actions

Repair – Measures to restore the integrity of the structure and to improve its durability to reduce further distresses

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Now, we will discuss some of the basic terminologies that are used in the study of retrofitting and rehabilitation. Durability, durability is the ability of a structure to resist the weathering actions, the environmental effects, the chemical attacks, the abrasion or any type of distress or deterioration. So, how the structure is capable of resisting all these weathering actions or chemical attacks etcetera, and it can last long.

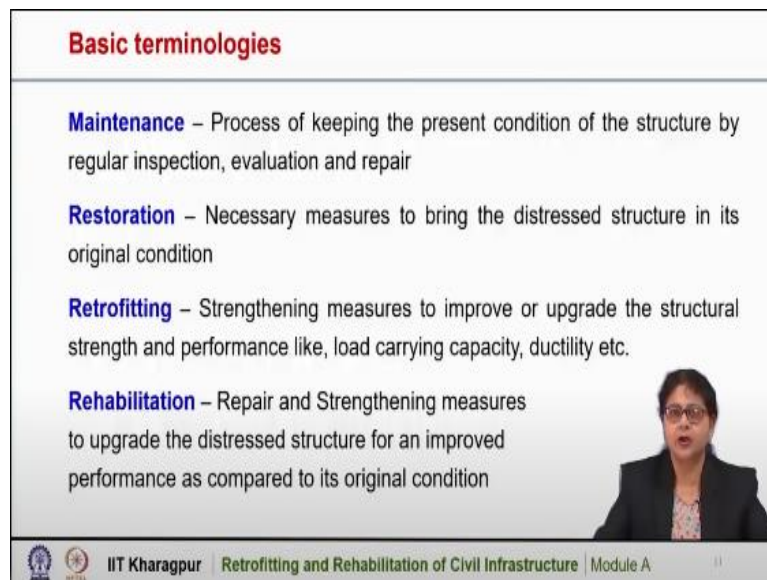
So, this is called durability of the structure. Now, inspection, inspection is to understand the current state of the structure. All structures, after it is constructed and it is in operation, it requires inspection and it may be a regular inspection, most of the time it may be visual and this helps us to understand the current state of the structure. Whether any particular action is needed or not that is important and that we can do by inspecting the structure on a regular basis to understand the current state of the structure.

Then evaluation is to evaluate the present condition of the structure using necessary testing for making decision about further actions. So, by evaluation we can assess the present state of the structure, the present condition of the structure, the in-situ condition of the structure by carrying out several tests that may be semi destructive or non-destructive testing, so that we can make decision for further action.

What repair work to be taken or retrofitting work to be taken, that we can assess by proper evaluation of the structure. Repair is the measure to restore the integrity of the structure and

to improve its durability to reduce further distresses. So, repair is to restore the integrity of the structure. So, the process by which we can restore its integrity like its original condition that is termed as repair so that its durability is improved and further distress is restricted.

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Basic terminologies

Maintenance – Process of keeping the present condition of the structure by regular inspection, evaluation and repair

Restoration – Necessary measures to bring the distressed structure in its original condition

Retrofitting – Strengthening measures to improve or upgrade the structural strength and performance like, load carrying capacity, ductility etc.

Rehabilitation – Repair and Strengthening measures to upgrade the distressed structure for an improved performance as compared to its original condition

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Maintenance is the process of keeping the present condition of the structure by regular inspection, evaluation and repair. So, we have discussed inspection, evaluation and repair and maintenance is the process by which we can keep any structure at its present condition using regular inspection by carrying out regular and timely evaluation and necessary repair.

So, it is the process of keeping the structure at its present condition by regular inspection, evaluation and repair measures. Restoration is the necessary measure to bring the distressed structure in its original condition. Restoration is to bring the distressed structure in its original condition so that further distress is restricted, but we are not enhancing its strength, but it is to restore its original condition.

Most of the Heritage structure we are restoring it, so that its durability is enhanced, durability is increased and the structure can perform. So, it is the measure to bring the distress structure in its original condition; that is called restoration. Retrofitting is the strengthening measure to improve or upgrade the structural strength and performance, like load carrying capacity and ductility, etcetera.

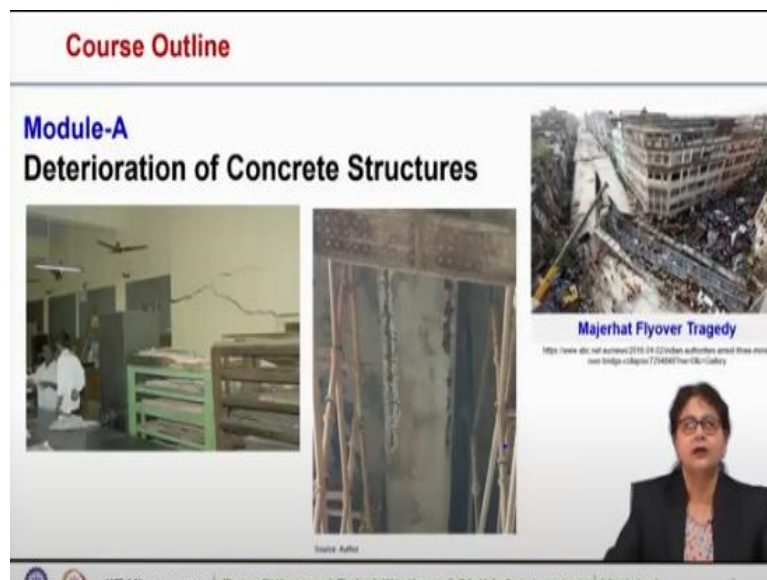
So, retrofitting or strengthening is the measure by which we can enhance or upgrade the structural strength and performance of the structure and of course the durability of the structure like the performance, like the load carrying capacity or the strength or the ductility

etcetera. So, retrofitting is the strengthening measure to improve or upgrade the structural strength and performance like load carrying capacity ductility, strength, etcetera.

Rehabilitation is the repair and strengthening measure to upgrade the distressed structure for an improved performance as compared to its original condition. So, in rehabilitation, we are not only upgrading the distressed structure, but we are improving its performance much better as compared to its original condition.

So, it is the strengthening or retrofitting measure to upgrade the distressed structure for an improved performance, so that it can last long and perform in a better way as compared to its original structures. So, these are the basic terminologies that are generally used for the study of retrofitting and rehabilitation and we will come across all these terminologies in the subsequent lectures, when we will discuss in detail.

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Now, we will give you an outline of the present course, the course will give you an in depth understanding of the various measures of repair and retrofitting of existing structures. And for that we had to follow certain steps, we have to evaluate the structure properly, we have to inspect the structure, we need to know how the deterioration occurs and we have to follow certain steps for that, for the repair and retrofitting of structures.

So, there are 10 modules and that 10 module covers all these aspects. In module one, it is the deterioration of concrete structures, we will discuss, in how many different ways an existing structure may get distressed or deteriorated and that we will discuss in detail.

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Course Outline

Module-B
Condition Evaluation and Testing

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In Module B, we will discuss the condition evaluation and testing. There are several semi-destructive and non-destructive tests that are used to evaluate the in-situ condition of infrastructure. And we will discuss all these tests in detail and how we can use the test result to assess the present condition of the structure. So, in module B, we will discuss the condition evaluation and testing part.

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Course Outline

Module-C
General Repair and Retrofitting of Concrete Structures

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Now, in Module C we will discuss the general repair and retrofitting of concrete structures. There are several ways by which we can repair an existing structure to improve its durability by several crack repair techniques and also, we will discuss the several strengthening

measures using conventional methods. So, here in this module C, we will discuss several repair techniques as well as the conventional retrofitting techniques of concrete structures.

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Course Outline

Module-D
Fiber Reinforced Polymer (FRP) Composites and its Characteristics

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Fiber reinforced polymer composites have been used in retrofitting of several civil infrastructures, the material is comparatively new material and its behavior is different from the conventional steel or concrete material. So, in Module D, we will give you an in depth understanding of fiber reinforced polymer composites and its characteristics and properties. So, different types of fibers and fiber reinforced polymer composites will be discussed and their properties will be analysed and discussed in Module D.

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Course Outline

Module-E
Retrofitting of Existing Structures using FRP Composites

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In Module E, we will cover the retrofitting measures of existing structures using FRP composites. So, here in this module, we will discuss, how we can retrofit an existing structural component using fiber reinforced polymer composites and what are the analysis and design methods for this retrofitting. So, in Module E, we will discuss the retrofitting measures of existing structures using FRP composites.

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The slide is titled "Course Outline" in red text at the top. It features two main sections: "Module-F Concrete Overlay for Pavement Rehabilitation" and "Module-G Retrofitting of Masonry Structures".

- Module-F:** Includes a photograph of a road with a concrete overlay and a yellow line. Below the photo is the text: "Guide to Concrete Overlay Sustainable Solutions for Strengthening and Rehabilitating Existing Pavements, Third Edition, May 2014".
- Module-G:** Includes a photograph of a masonry structure with FRP reinforcement. Below the photo is the text: "www.civil.iitkgp".

At the bottom of the slide, there is a footer with the IIT Kharagpur logo, the text "IIT Kharagpur | Retrofitting and Rehabilitation of Civil Infrastructure | Module A", and a small number "17". A woman's head and shoulders are visible in the bottom right corner of the slide.

In Module F, we will discuss the concrete overlay for pavement rehabilitation. For retrofitting or rehabilitate an existing deteriorated pavement concrete overlay is an effective measure, that we will discuss in Module F. Module G will cover the retrofitting of masonry structures, both brick masonry and stone masonry structures will be covered in this module. The restoration of heritage structures will also be covered in Module G.

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Course Outline

Module-H
Retrofitting of Building Structures
damaged due to Seismic events

Module-I
Retrofitting of
Special Structures
damaged due to
Seismic events

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Module H will cover the retrofitting of building structures damaged due to seismic events. Seismic events or earthquake actually deteriorate several of the existing infrastructure, so it is important to retrofit the structures which are damaged, particularly due to seismic events. So, module H will cover the retrofitting measures of building structures damaged due to seismic events.

Module I will cover the retrofitting of spatial structures damaged due to seismic events, the spatial structures, maybe bridges and water tanks and that retrofitting measures will be discussed in module I.

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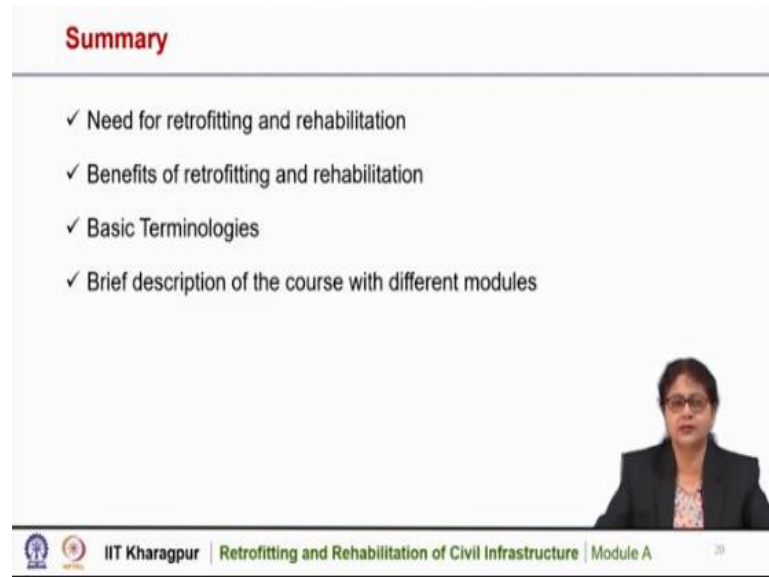
Course Outline

Module-J
Retrofitting of Steel Structures

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In Module J, we will discuss the retrofitting of deteriorated steel structures. So, these are the 10 modules for this course and we will discuss these 10 modules in much detail in the subsequent lectures.

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Summary

- ✓ Need for retrofitting and rehabilitation
- ✓ Benefits of retrofitting and rehabilitation
- ✓ Basic Terminologies
- ✓ Brief description of the course with different modules

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So, to summarize, in this introductory lecture, we have discussed the importance of retrofitting and rehabilitation of existing structures, what are the needs for retrofitting and rehabilitation? And what are the benefits of retrofitting and rehabilitation of existing structures that has been covered today.

What are the basic terminologies and these basic terminologies are used in the analysis and design of retrofitted structures and these terminologies we have discussed and a brief description of the present course with its different modules have also been discussed today. So, these we will discuss the different modules in much detail in the subsequent lectures. Thank you.