Principles of Construction Management
Prof. Sudhir Misra
Department of Civil Engineering
Indian Institute of Technology, Kanpur

Lecture - 29
Epoxy Coated Bars

[FL] and welcome once again to this series of lectures on Principles of Construction Management. And today in this series where we are talking about issues relating to quality control, we will talk about quality control related issues in epoxy coated bars.

I must acknowledge that the outside today, that the material used in the presentation is based on the recommendations for design and construction of concrete structures using epoxy coated reinforcing bars, which is a publication of the Japan society of civil engineers. And I would like to also express my sincere thanks to Professor Taketo Uomoto, formerly chief executive of the public works research institute and professor of Department of Civil Engineering at the University of Tokyo and also chairman of the concrete committee of the JSCE, for his kind permission to use the photographs that I am going to use in the presentation.

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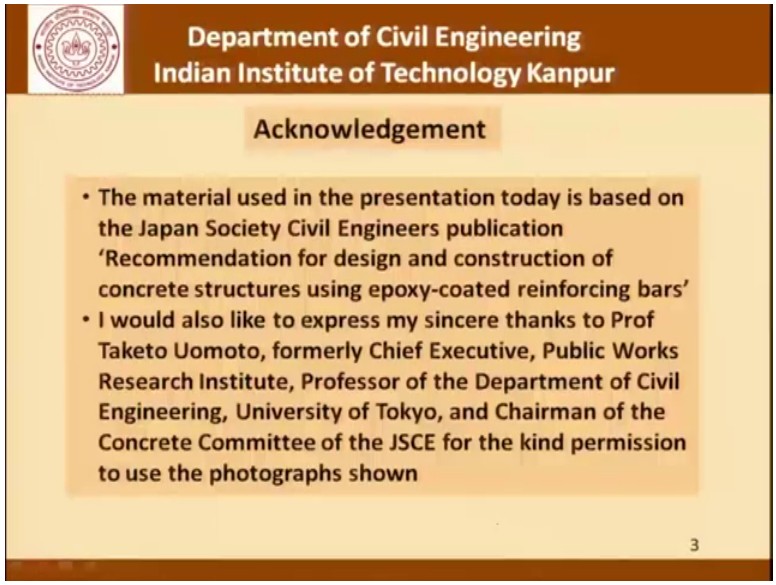

We have talked about the fact that the thought process of quality control is closely linked to that of standardized test methods and specifications.

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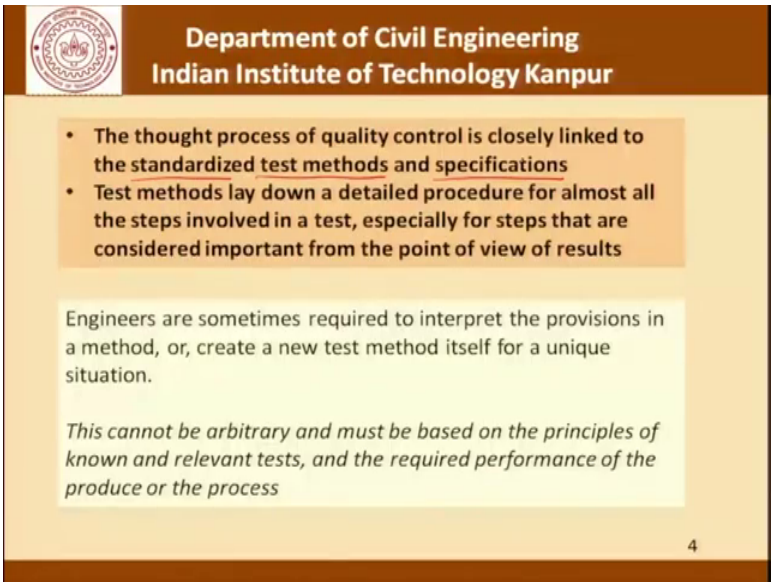

We have talked about the fact that test methods or standardized test methods they give us a clear direction a step by step procedure for how a particular test has to be carried out. Now based on their test we get a certain number, it could be strength, it could be length, it could be temperature whatever it is. Now whether that is acceptable to us or not in a particular application is what is given in the specification. So, this specifications must specify that such an such a number is acceptable to us for this application if the tests are carried out in accordance by such an such a test method.

So, there is something which we have talked about and I am repeating it only to make it very, very clear and emphasize it is importance. And this is what is listed here the test methods lay down a detailed procedure for almost all the steps involved in a test especially for steps that are considered important from the point of view of results. And why we are talking about it here is because engineers are sometimes required to interpret the provisions in a method or create a new test method itself for a unique situation.

This cannot be arbitrary and must be based on principles of known and relevant tests, and the required performance of the produce or the process. So, when the engineer or doctor a test method, they should know what they are doing, why they are doing and how does that modification help them better interpret the results for the kind of situation that exists at the real site.

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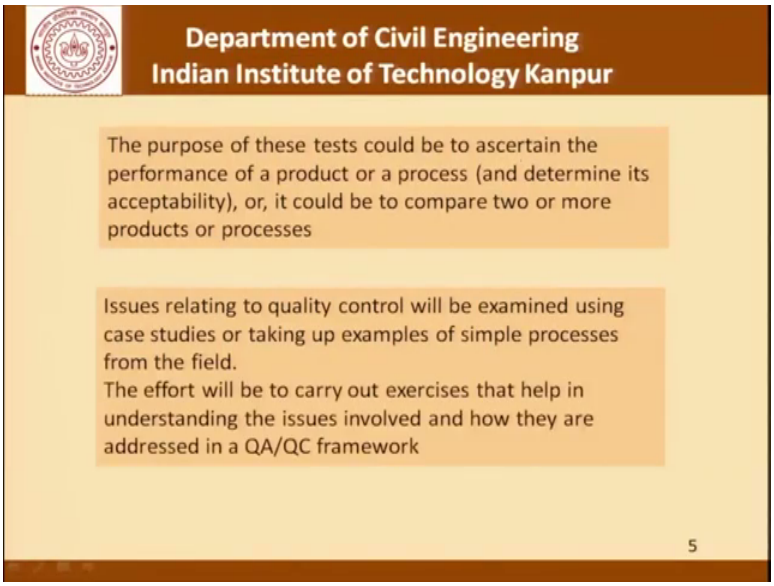

So, the purpose of these tests could be to assert in the performance of a product or a process and therefore, to determine it is acceptability or it could be to compare 2 or more products or processes. Issues relating to quality control will be examined using case studies and taking up examples of simple processes from the field. And it is under this scheme that today we are talking about epoxy coated bars. The effort will be to carry out exercises that help in understanding the issues involved and how they are addressed in a QAQC framework.

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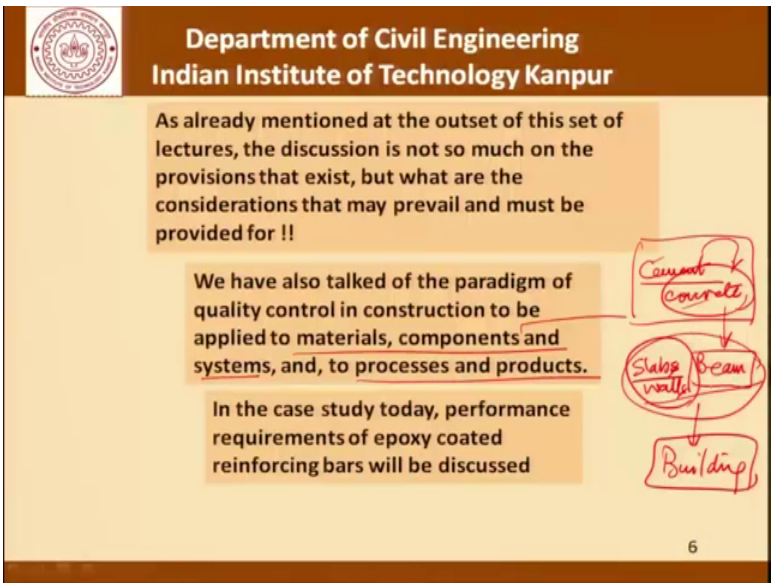

As already mentioned at the outset of this set of lectures, the discussion is not so much on the provisions that exist, but what are the considerations that may prevail and must be provided for in the test method or the specification. We have also talked of a paradigm that quality control in construction is applied to materials components and systems at the one end and to processes and products at the other. So, in the case study today the performance requirements of epoxy coated reinforcing bars is what is taken up for discussion.

Before we get into a detailed discussion on the provisions for testing of epoxy coated bars let me once again give you an example of this freezes which have used materials components and systems. So, cement is definitely a construction material concrete; however, is another material which is having cement as an essential and a very important ingredient. So, this together when we do tests for cement when we do tests for concrete we are actually testing the material itself, whether that material is acceptable not acceptable meets the requirements not requirement and so on.

So; that means, that the specifications have to be there for cement and for concrete for their fitness to be used at a particular site, but that does not ensure good quality construction. So, if we move to the component level this material is being used in structural elements like beams slabs walls and so on. So, these are basically components which are made out of concrete, but the quality of the beams slabs and walls is not related or is not depending only on the properties of the concrete.

There are so many other things that go into it there is shuttering that goes into it there is the workmanship compaction that goes into it curing that goes into it and besides all this reinforcement work. All these elements most of the time are reinforced concrete elements which means that the reinforcement work and the quality of the reinforcement work is an important determinant as far as the quality of these beams slabs and walls is concerned; however, we must understand and appreciate that the story does not end there these beams slabs and walls are part of our building. And this building is not only a structural elements. There are so many other systems (Refer Time: 06:04) there is electrical systems there are the air conditioning systems there is plumbing systems sanitary systems, all these systems constitute the building.

So, a good quality building or an acceptable building is not only acceptable structural components. So, as a quality control engineer or as a project manager, you cannot say or one cannot say that I am going to be bothered only about the quality control issues relating to a structural engineering. Of course, to begin with that is what will happen the inherit assumption or the thought process is that so long as the quality of each of these systems is ensured by ensuring the quality of each of the components used therein, but the point that I am trying to make is that there has to be a conscious decision that meeting all requirements at the material level or the component level or even perhaps the system level for a particular system does not ensure or guarantee that the overall system meets the requirements, what we have to develop as far as our thought process and test methods acceptance quality control and quality assurance is concerned is to keep this in mind and develop the right kind of test methods.

So obviously, it is the professional community comprising of you and me and other people who have to come up with these standards. So, with this kind of a backdrop we are approaching the different aspects of quality control and that is why we are picking up these smaller examples nuts and bolts examples. From the field and trying to go through quality control and quality assurance kind of discussion.

So now (Refer Time: 07:45) let us move forward and try to talk about epoxy coated bars.

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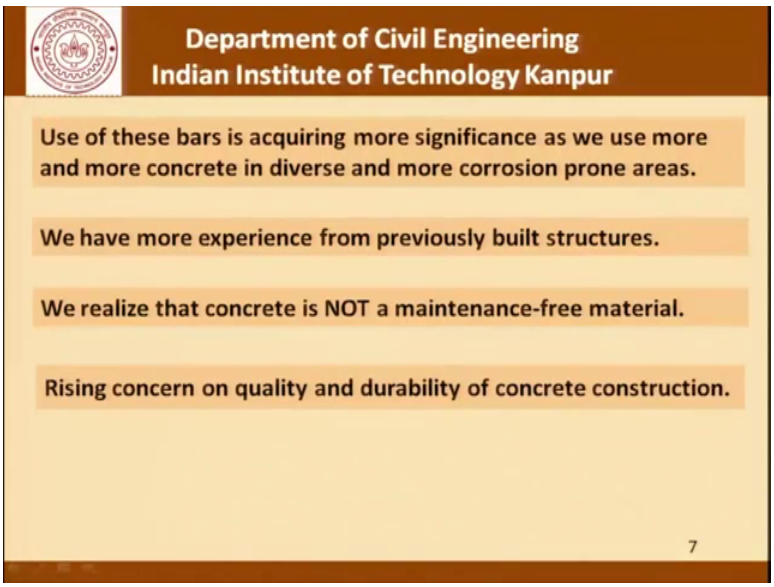

The use of these bars is acquiring more significance as we use more and more concrete and diverse and more corrosion prone areas, basically the idea of using epoxy coated bars is to provide additional protection in environments where the reinforcement is subjected to accelerated or faster corrosion. We have more experience from previously built structures and we know how to handle this problem and epoxy coated bars have emerged as one of the solutions and we have realized through experience that concrete is not a maintenance free material. And rising concerns on quality and durability of concrete construction have only added to the use of epoxy coated bars.

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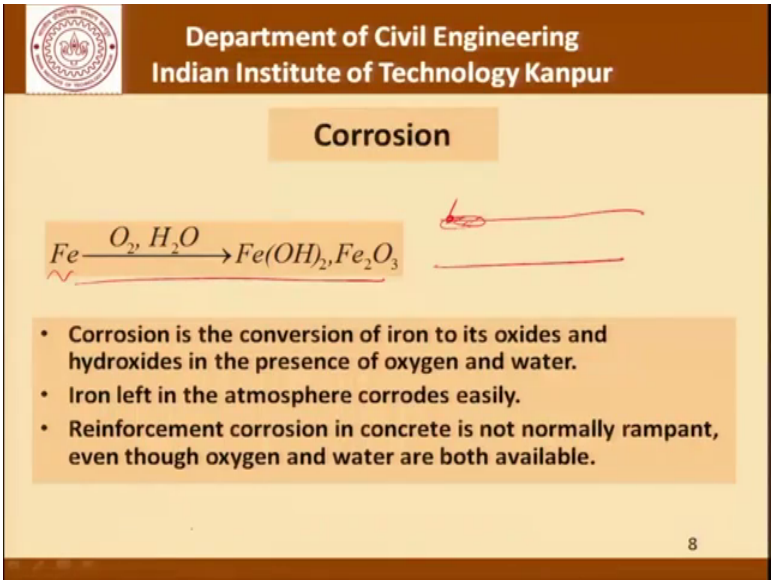

A work about corrosion basically iron going to oxides and hydroxides in the presence of oxygen and water is what corrosion is, and this process has to happen on the surface of the steel. So, if we have a steel bar in order that this bar corrode at the surface somehow this process of iron going to it is oxides and hydroxides should happen. Having said that we must note that reinforcement corrosion in concrete is not normally rampant even though oxygen and water are both available.

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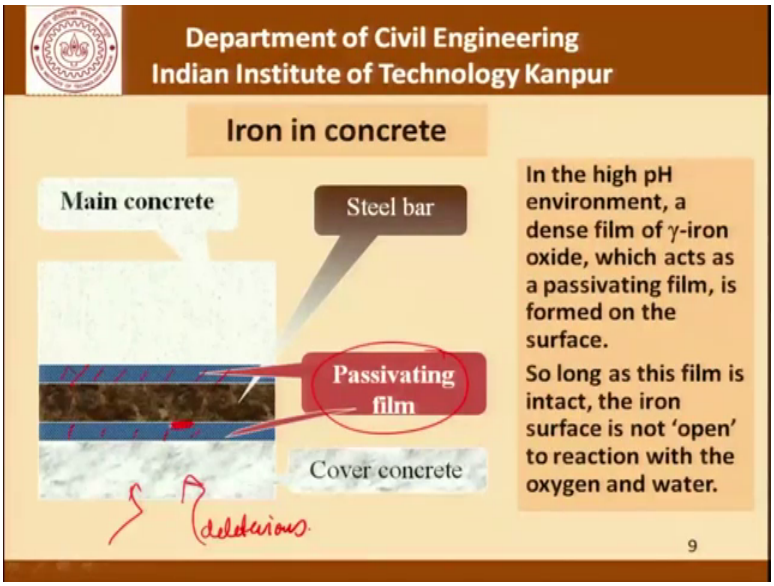

And the reason for that is that there is this passivating film that forms on the reinforcing bar. And this acts as a barrier for any kind of deleterious material that may enter from the outside in reaching this surface.

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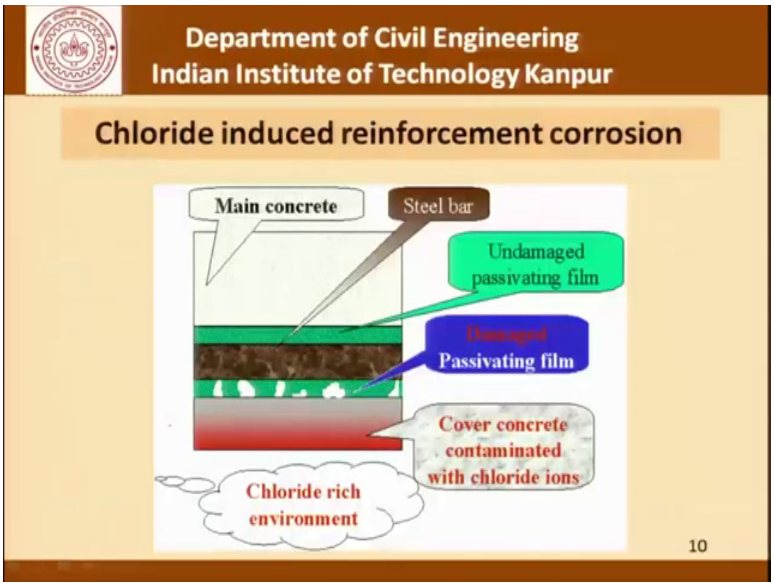

So now, this passivating film can be damaged; however, if what is getting into the concrete is something like chlorides. Now these chlorides have the property of attacking this passivating film kind of eating it away making this part let us say here or this part somewhere here vulnerable to corrosion and that is where corrosion gets initiated.

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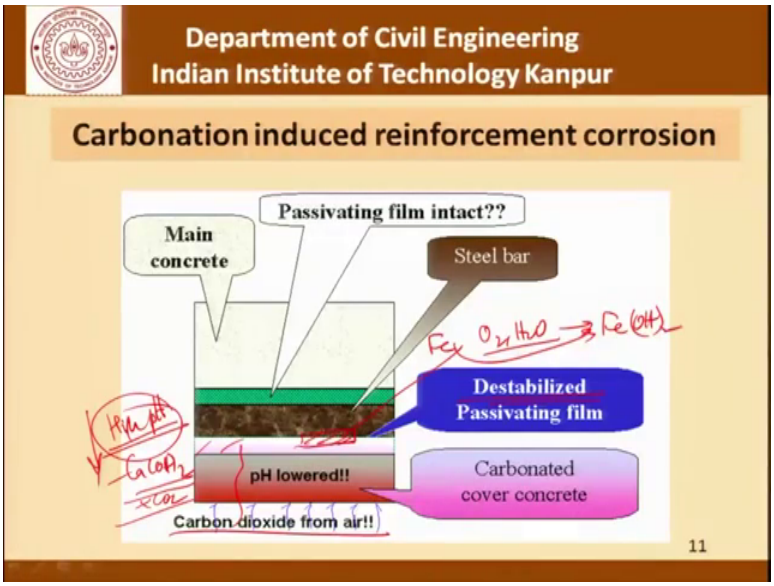

Another environment in which reinforcement Corrosion happens is what is called carbonation and that basically is when carbon dioxide from the air enters into concrete eats up the calcium hydroxide which is primarily responsible for the formation of this passivating film. It is only the high pH that actually causes this passivating film to be formed. In fact, I should have possibly mentioned this fact earlier in the previous slide that this passivating film is formed on account of thermodynamical considerations when iron is immersed in a high pH solution. Now because of the consumption of calcium hydroxide by carbon dioxide this pH goes down and this film becomes unstable. So, this is the principally these happens only the 2 reasons, how and why the reinforcing bar becomes vulnerable to corrosion. In either case it is the surface which becomes susceptible to corrosion, that is at the surface now if oxygen and water are available iron will go to the oxides and hydroxides.

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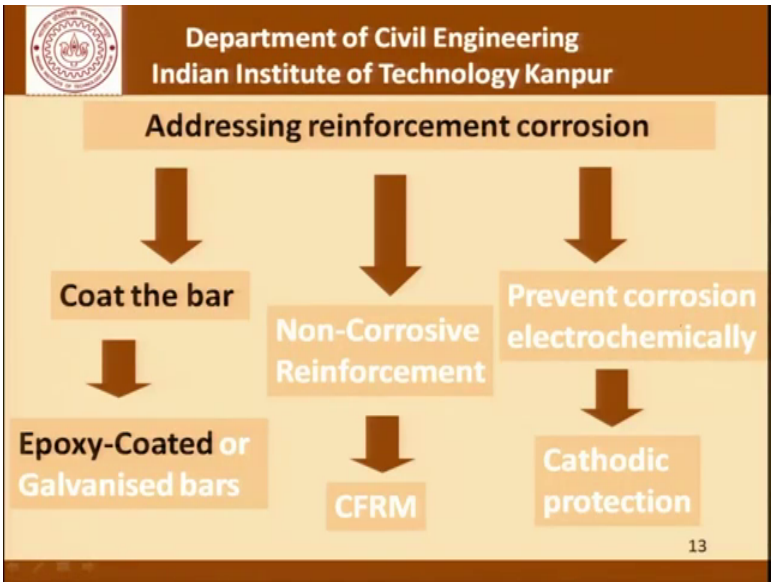

Now, having said that how can this problem be addressed. So, there are different ways of doing it one is coat the bar that is physically provide a barrier between the deleterious material moving in and their iron surface. It is to use non corrosive reinforcement and prevent corrosion electrochemically. Now as far as coating the bars is concerned that is what epoxy coated bars or the galvanised bars are as far as non corrosive reinforcement is concerned we have continuous fiber reinforce materials CFRM it could be carbon fibers it could be (Refer Time: 11:45) So on, which is FRP is a fiber reinforce plastics being used as a replacement for steel. And as far as electrochemical prevention is concerned we could be talking of cathodic protection.

So, now epoxy coated bars is what is the discussion today. So, before we get into the properties of epoxy coated bars that need to be tested from a quality control perspective, let us quickly take a look at what epoxy coated bars physically stand for.

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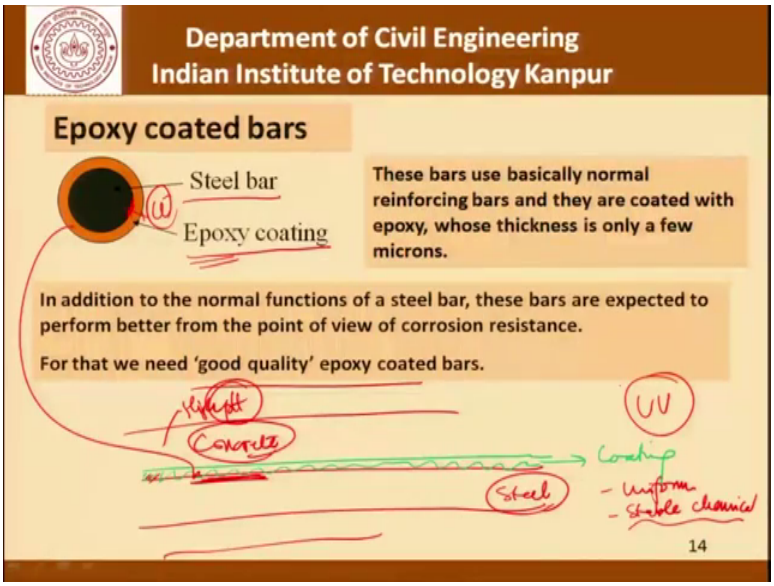

Epoxy coated bars are basically the good old steel bar that is traditional steel bar or the normal reinforcing steel bar with a coating of epoxy which is only a few microns thick. This coating is what protects the reinforcing bar from the attack as far as chlorides are concerned oxygen and water. So therefore, in addition to performing the normal functions of a steal bar these bars are expected to perform better from the point of view of corrosion resistance, but for that we need to have good quality epoxy coated bars. So, basically what we are talking about is a reinforcing bar like this with a coating of epoxy here which is uniformly coated. So, this is what we are talking of the coating and this is where we have our steel and it is expected that this coating will protect my steel surface.

So, there are some very obvious tests that need to be carried out, this coating should be uniform, it should be stable chemically what does chemical stability require as far as epoxy coated bars are concerned. These bars are going to be embedded in high pH environment. They are going to be finally, surrounded by or surrounded with concrete. And this concrete environment is basically a high pH environment. So, we should not have a coating which dissolves when there is high pH. Because then the whole purpose of putting that coating will be lost.

Please also remember that epoxy coats are sometimes vulnerable to ultra violet radiation, but in this case it is not directly relevant because epoxy coated bars are embedded in concrete. And the chances of they are being exposed to ultraviolet radiation for a long

period of time are very, very small. Of course, that does not mean that the epoxy coated bars being used do not have any ultraviolet resistance at all. That is because these bars are going to be exposed or stored in the environment and that are going to be stored in air and for some time before they are being actually used or before they are actually put inside the concrete there will be exposure to ultraviolet radiation.

So, they must have a certain level of UV protection or performance under UV radiation, but not to the extent in cases where you are doing epoxy coatings on steel structures. So, that is where we need to understand the difference between setting their specification at one level or another depending on the actual environment in which the material is going to be used.

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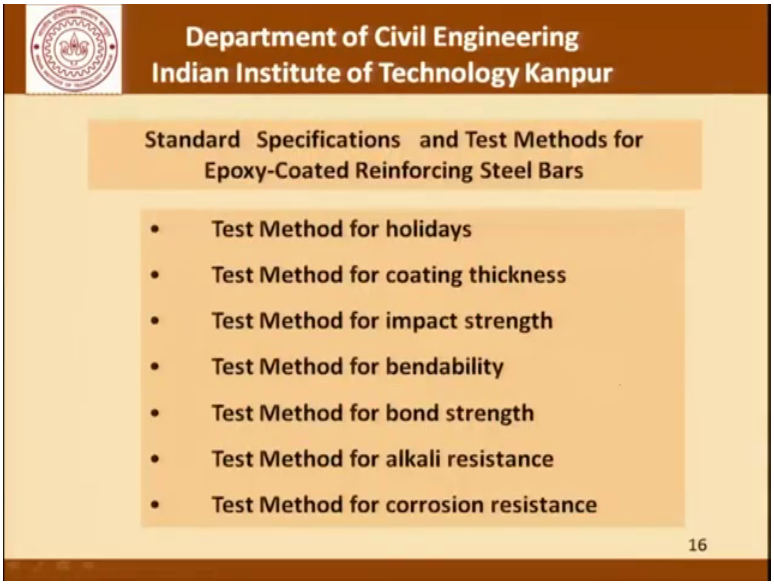

So, moving forward as far as testing is concerned for quality these are some of the methods or some of the tests that are required. Testing for holidays, coating thickness, impact resistance, bendability, bond strength, alkali resistance and corrosion resistance. Now obviously, for each of these tests or each of these properties we need to have a specific test methods.

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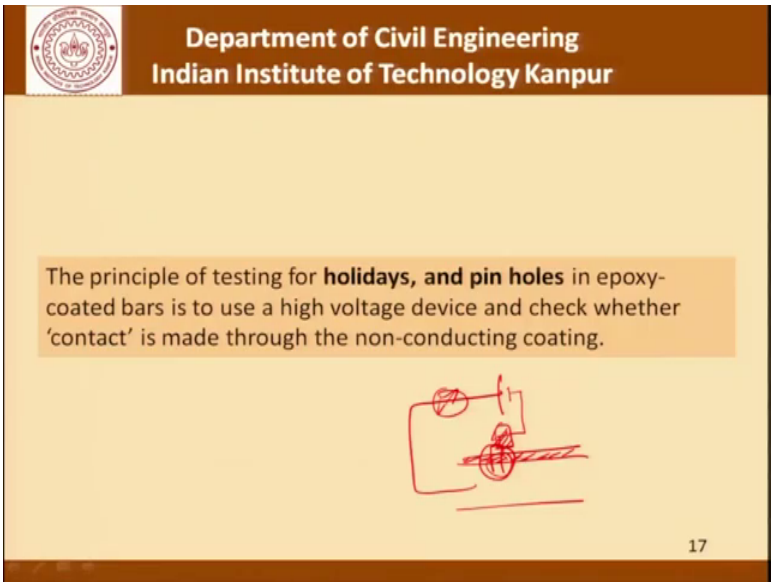

The principle of testing for holidays and pin holes in epoxy coated bars is to use a high voltage device and check. Whether the contact is made through the non conducting coating or not. So, the principle is that we have a bar we have a coating on the bar and in case there is a pin hole here, if we apply voltage through this circuit if this hole is there the contact will be made. So, if we put a device in the circuit, we will immediately see a deflection so obviously, the questions will be what is the kind of voltage to be used. So, those are the kind of details which have to be left to the specific test method that we talk about.

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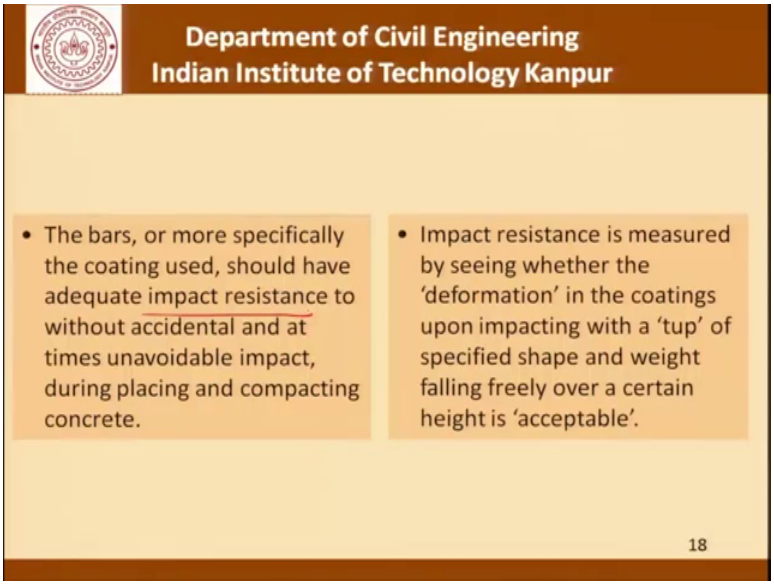

Moving forward as far as impact resistance is concerned the bars are indeed exposed to impact resistance it could be during the handling or it could be even during placement of concrete when we are using vibrators which will; obviously, hit sometimes the reinforcing bars inside. And the impact resistance is measured by seeing whether the deformation in the coatings upon impacting with a tup of a specified shape and weight falling freely over a certain height is acceptable.

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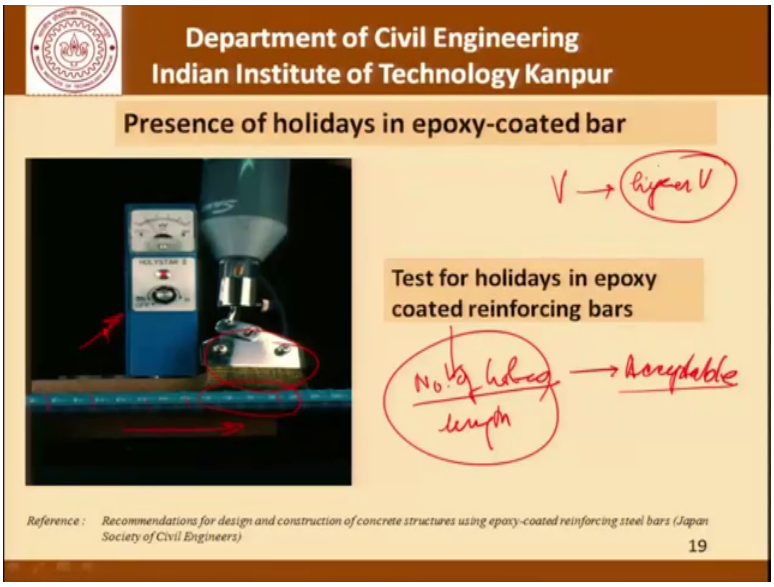

This here is a picture showing the testing for holidays and this is the device this is our meter that we talked about and we are trying to determine if there are pin holes or holidays in this region. It is obviously, to detect the holes at different locations. So, this hand held device is moved along the length of the bar and we try to find out if there are any holes anywhere.

The next step would be to find out or to check if the number of holes that we find is acceptable or not. So, the test method will tell us what is the number of holes per unit length which is available or which occurs on a particular bar. And the second part will be whether it is acceptable or not and this acceptable (Refer Time: 17:32) part can depend upon the criticality of application. In certain applications a certain number may be acceptable, but in certain other applications which are more stringent more stringent the specification need to be used. If stringents can also be introduced in the test method itself

that instead of testing at a voltage of v, you would test it at a voltage which is higher than v.

So, these are methods which are available and this is the kind of discussion we have when we try to engineer, doctor or modify the existing provisions in a given test which says that well. This is the standard test and the engineers are free to modify the test.

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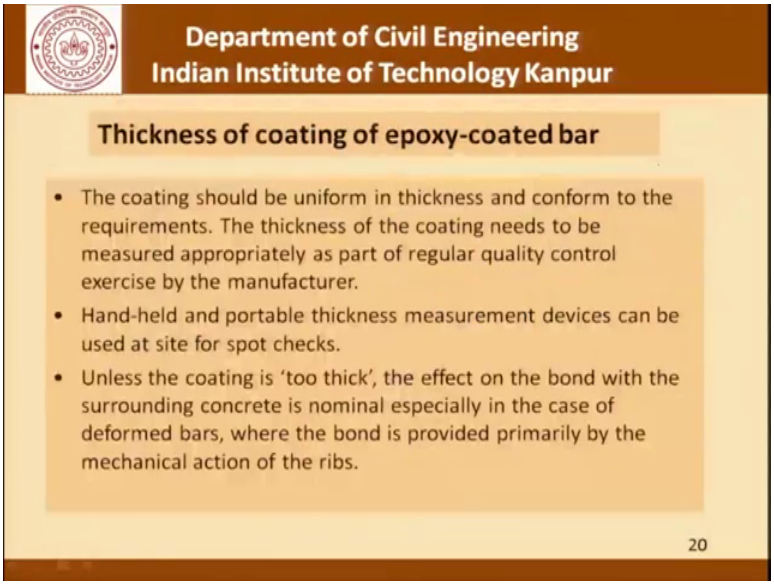

Moving forward we must know the thickness of coating of the epoxy coated bar, they should be a bend test which needs to be carried out because reinforcing bars are often required to be bent in their applications in beams columns and so on.

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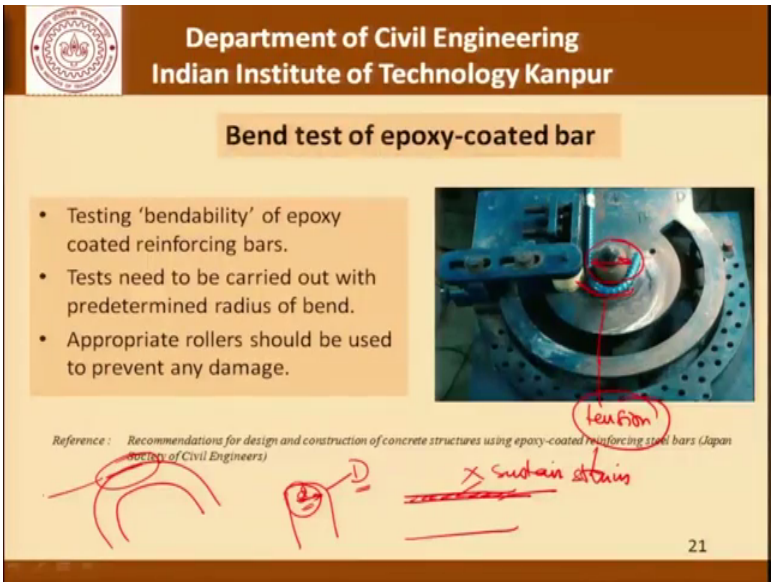

And this bendability of bars is an important test because once we bend these bars the outer surface here is subjected to tension. And if the coating which is there on the bar is not able to sustain the tension or the tensile strains, what we will have is what is shown here.

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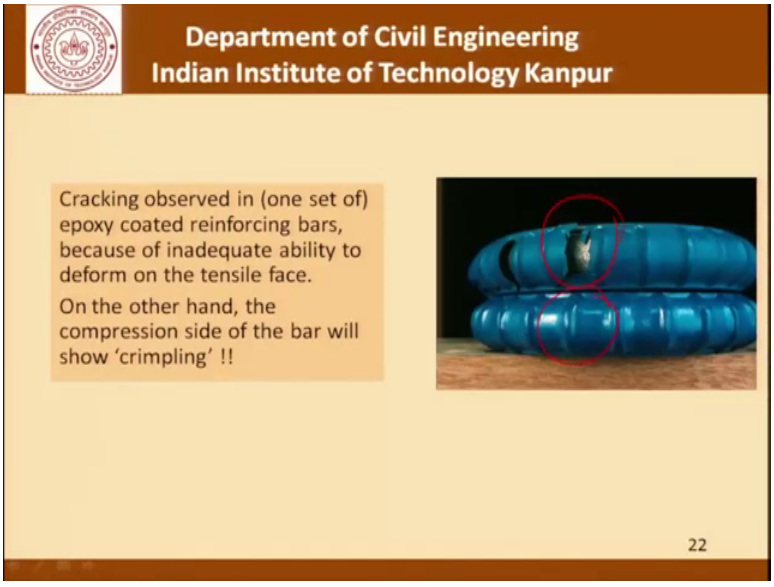

So, this is the kind of breaking or cracking in the coating that is going to be formed whereas, in a good bar that will not happen. So now, this testing; obviously, has it is own set of parameters including the diameter of this ruler about which the bend is to be made.

And I am leaving it to you to find out how the diameter of the ruler would affect the strains on the bar.

What I am basically saying is that if I am bending the bar like this about a certain diameter d and diameter of the bar is capital D, how what is the relationship between this small d and this capital D as far as the strains developed on the outer surface of the reinforcing bar is concerned. So, that is something which you can do as a home assignment, and we move forward. We must also remember as a corollary to what is going to happen on the tension side that is these tracks, on the compression side which is the inside of the bars. We will see some amount of crimpling of the epoxy coating.

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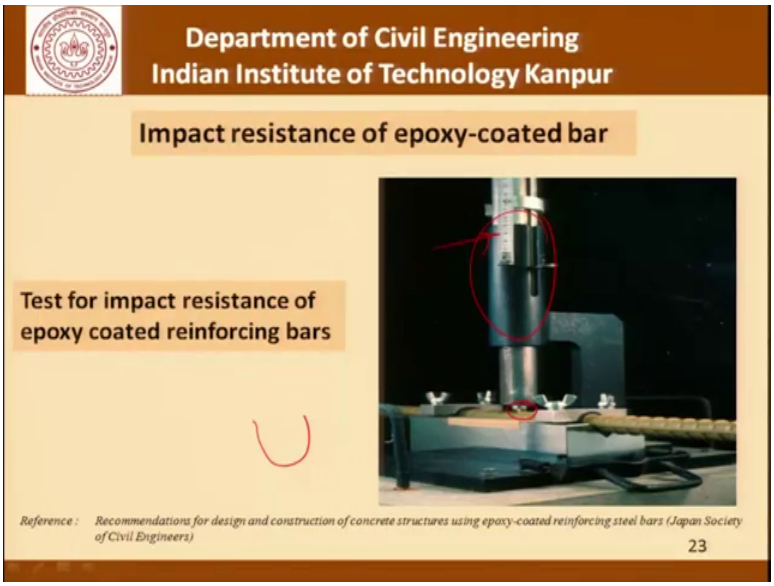

Now, as far as impact resistance is concerned we have discussed it before. This is the semispherical tup and it is mounted on this vertical support with a graduated scale and as it falls on the reinforcing bar what we get is a situation like this where the coating has been damaged.

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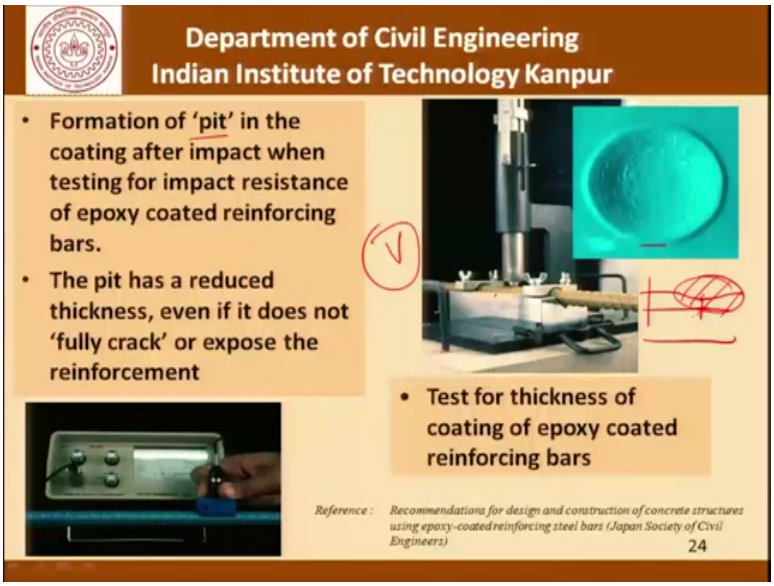

So, this is that kind of cup that forms and what we are interested to know is if this deformation or the damage is such that if we use this kind of a device, which is similar to that which is used for detection of pin holes will that device cause or detect a contact. So, of course, the voltage that we are using need not be exactly the same as we use for the case of pin hole detection.

So, those are the kind of things the details which are given in the test method and if there is a requirement the engineer should familiarize themselves with it and modify it. So, what will happen as a result of the impact of the tup is the formation of a pit which is shown here. So, what we are really interested to know here is that this coating which is deformed like this as shown here.

The damage here is such that it can be detected using a similar device or the same principle as we used in the case of the pin hole detection. Of course, in that case the voltage and so on may be different the principle is essentially the same that is this coating thickness locally would have become a smaller, and whether or not the impact that has been caused or effected onto the bar or the coated bar such that the damage to the coating is still acceptable. As far as thickness is concerned yes, we need to ensure that the thickness of the coating across the bar or along the bar is both uniform.

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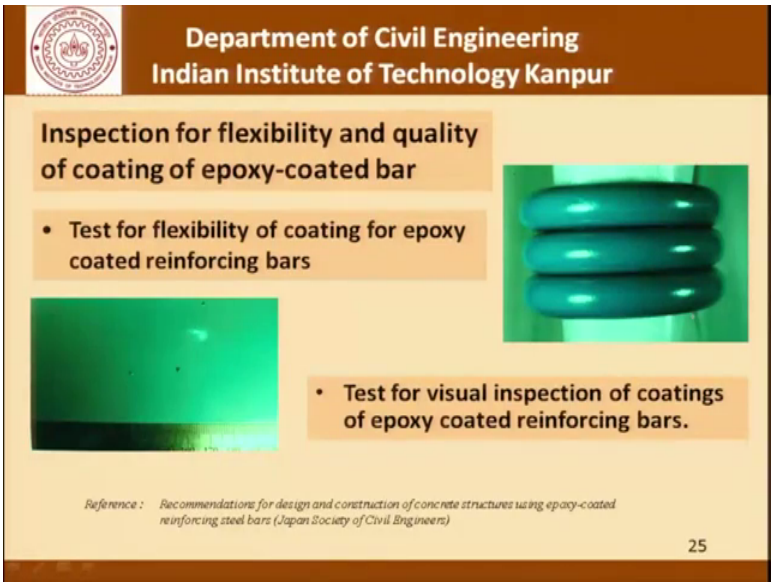

As far as flexibility and quality control of the coated bar is concerned that has also to be a flexibility test of the coating for the coated bars. And visual inspection for the coatings of epoxy coated reinforcing bars. So, these extra deposits of epoxy should also be avoided to the extent possible. And depending on the severity or the frequency of occurrence of these defects the bars may be accepted or not accepted for a particular application.

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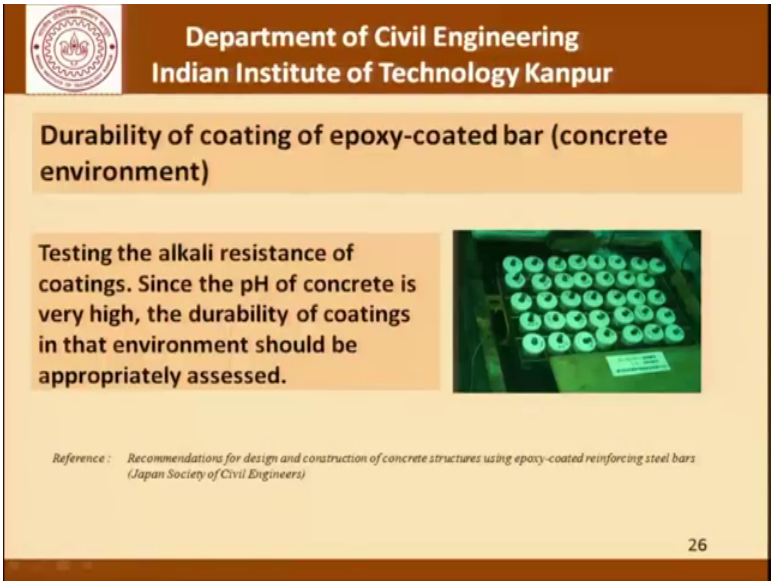

So, this here is a view of the epoxy coated bars being tested in actual concrete they are embedded cured and tested as far as their durability and their suitability for a particular concrete environment is concerned.

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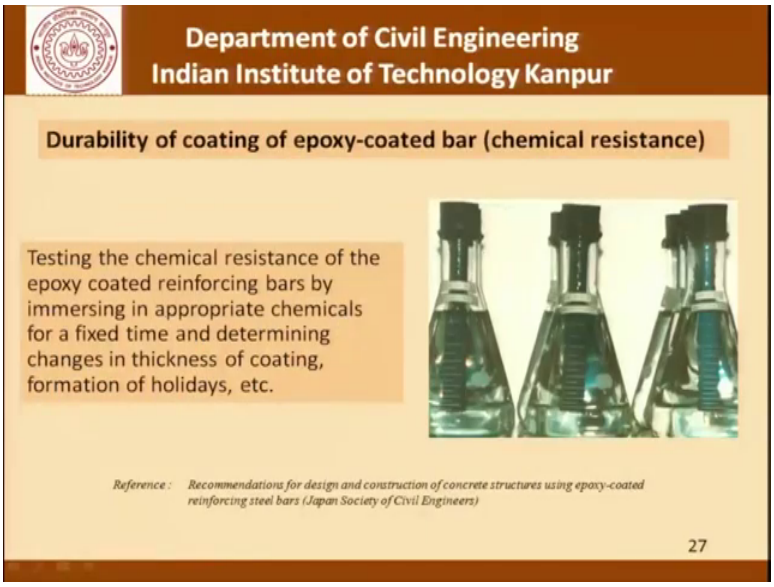

The chemical resistance is to be tested by using high pH and possibly solutions having some amount of chloride to ensure that the epoxy coated bars are such that they can withstand the kind of chemical environment that they are likely to encounter once they are inside concrete.

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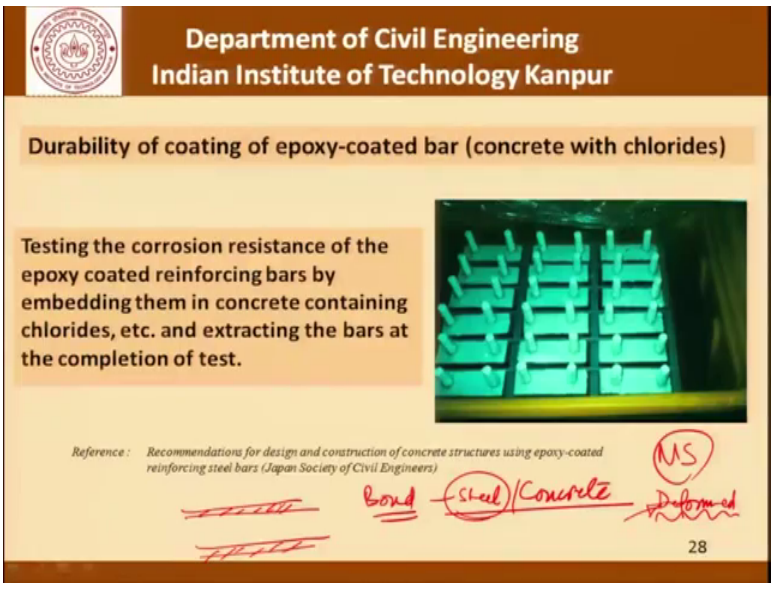

Continuing if required there has to be standard method or a way of testing bars in concrete with chlorides. So, that is the kind of test that is shown here, what we have not talked about is the bond test. We must remember that by putting a coating on the reinforcing bar we may compromise the bond as far as the bond between the steal and the concrete is concerned. What one must remember is that depending on the kind of steel being used, MS rounds are not used now a days in reinforced concrete construction and therefore, if you are talking of deformed bars most of the bond stress or the most of the bond strength is derived as a result of the surface deformations.

And therefore, it is very unlikely that because of the presence of this very thin coating as far as the reinforcing bar is concerned that will make the bond unacceptable. Or that will cause a reduction in bond strength which will be unacceptable. Nonetheless for the sake of completeness it is important that there is information that is collected and (Refer Time: 24:11).

One of the very important parts of quality control and that is something which we have talked about earlier is keeping records. Records must ensure for later inspections that the material used was all acceptable from all points of view. So, if there is a reason to say that yes bond can be affected test should be carried out to ensure that bond strength was not compromised when we used a certain type of epoxy coated bars. We did not discuss the bond test because that is more of a mechanical test as far as steel is concerned and along with the bond test we must also remember that these epoxy coated bars should meet all the other requirements as far as tensile strength yield strength proof stress and so on is concerned. That part cannot be compromised simply because they are epoxy coated. Now moving forward we come to an end of the discussion today and let me just leave you with some questions to think.

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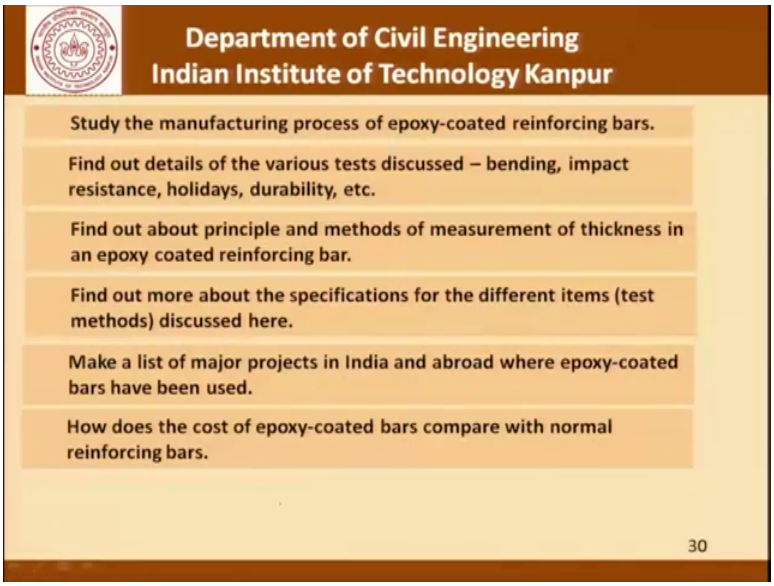

You study the manufacturing process of epoxy coated reinforcing bars, find out the details of the various tests discussed bending impact resistance, holidays, durability. Find out the voltage which is used in that device find out the number of holes acceptable in a particular length for a particular application. Find out about the principle and methods of measurement of thickness in epoxy coated bars. Find out more about the specifications for acceptability for the different items which are discussed here for example, in this case the impact strength would be given to you in centimeters or in meters. That is the length through which the tup can fall acceptably without causing unacceptable damage to the reinforcing bar.

So, you must understand that we are trying to get impact resistance of the bars, but what we are doing and what we are getting out of the test is a unit of centimeters. And what is acceptable to us could possibly depend on the kind of application whether at times it may also happen that if we take certain precautions we may still be able to use bars which were otherwise not acceptable. For example, if we use epoxy coated needle vibrators then we may say that well because the degree of impact or the kind of impact is going to be different therefore, we can lower the bar as far as acceptance is concerned from the point of view of impact resistance, but then that has to be again tested under a different regime.

Make a list of major projects in India and abroad where epoxy coated bars have been used and finally, what is the cost of epoxy coated bars compared to normal reinforcement.

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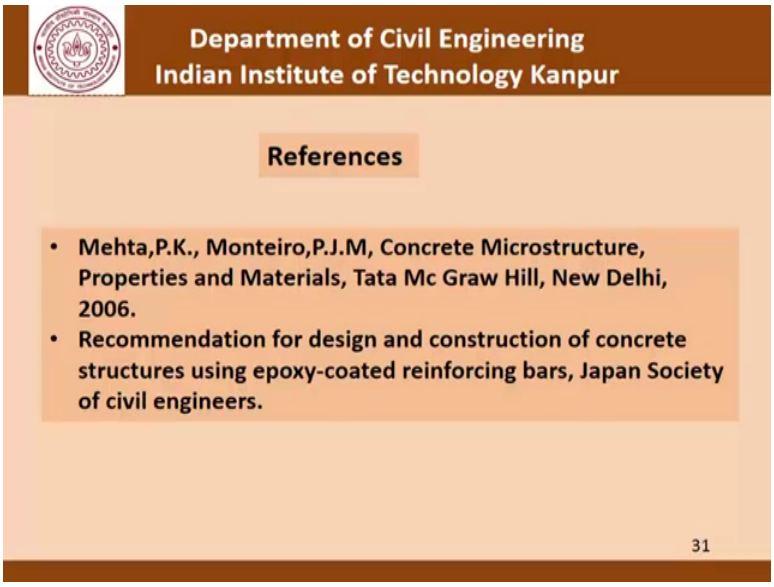

And as is the practice this is the list of preferences which you may like to use and get more information about using epoxy coated bars. And I look forward to see you in a subsequent discussion on quality control later.

Thank you.