Principles of Construction Management
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Lecture - 27
Quality Control in Construction

[FL] and welcome to this series of lectures once again on Principles of Construction Management. And today we begin a new module as for as we are concern in this series on quality control in construction.

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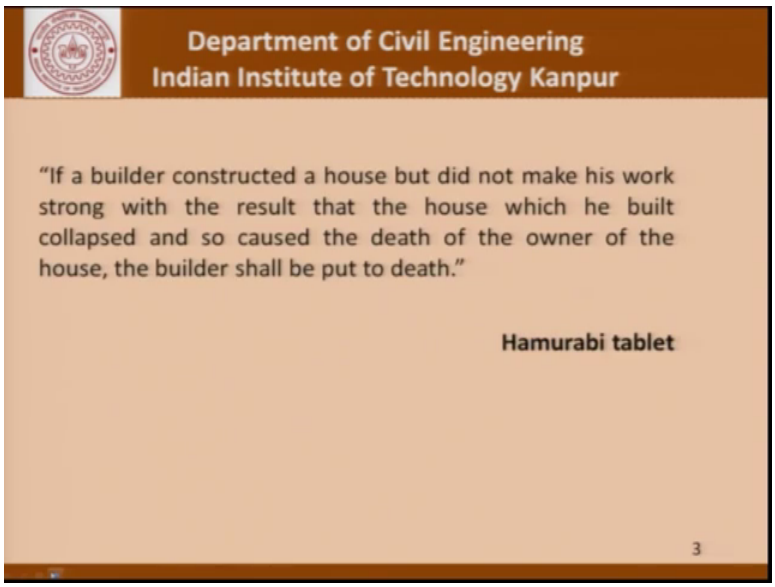

Now, since times in memorial quality of construction has attracted a lot of attention. And different people have looked at a differently for example, from here Hamurabi who lived thousands of years ago, said that if a builder constructed a house, but did not make it strong enough with the result with the house which he built collapsed. And so, caused the death of the owner of the house the builder shall be put to death.

So, this we have seen in the context of safety as well, but it is equally relevant as for as quality is concerned. So, if the construction is of poor quality the person of the company which does the construction is to be held responsible whether the builder should be put death or not is a different story, but the fact of it remains that yes, there is an issue that

there is a certain amount of responsibility that has to be borned by builder. Now when it comes to quality as for as construction is concerned it can be related to fitness for purpose.

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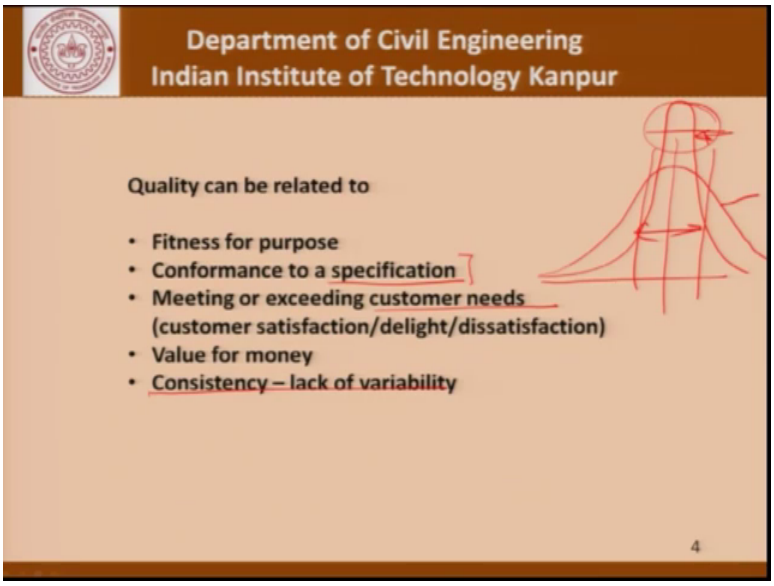

And this is true not only with construction, but perhaps with lot of other things in general fitness for purpose. So, whether a thing or a process is fit for the purpose for which it is designed or it suppose to serve.

Conformance to a specification. We have a specification we decide that this is what the specification the product or the process must meet. And whether it meets it or not is a parameter for quality. Meeting or exceeding the customer needs customer satisfaction delight or dissatisfaction. Now this is a slightly different way of putting the specification because the customer needs are often quantified in given in terms of this specifications. Value for money consistency and lack of variability. This is very, very important as for as construction is concerned.

We cannot get one strength today and another strength tomorrow or ostensibly the same concrete. So, if we are getting a certain strength we must keep getting the same strength. So, basically what we are saying is if we look at it from a quality control prospective, if

this is the normal distribution of the strengths or any parameter that we take. This spread that we have should be as narrow as possible. If it is like this where the peak is very well defined, this shows a much better quality control than this one. The amount of variation that exist in the values of the data is represented by the spread. One of the very important parameter as for as quality is concerned is this spread, continuing in quality control and management.

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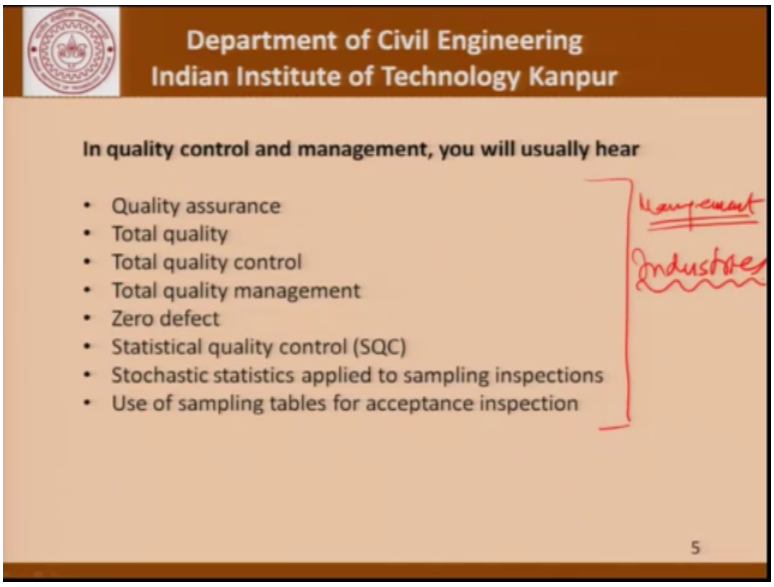

We often hear terms like quality assurance total quality total quality control TQC total quality management TQM, zero defect statistical quality control, stochastic statistics applied to sampling inspections. Use of sampling tables for acceptance inspection and so on. These are some of the keywords that come to mind when we come to talk about quality from a management perspective. Typically all this is applicable and valid in the case of industries. That is when we are talking about industrial production.

Now, in the case of construction projects there is very little industrial production that happens. A lot of our construction work in fact, most of our construction work happens at site. And it is very difficult sometimes to apply some of these principles at least the way they are given in most of the books and texts to construction projects but having said that we must be aware of these issues so that we can adopt them and move forward.

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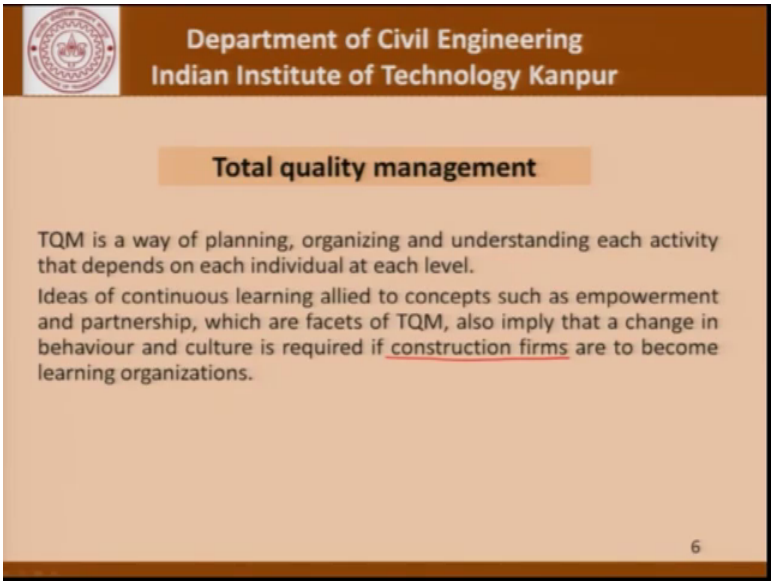

When it comes to total quality management TQM, is a way of planning organizing and understanding each activity that depends on each individual at each levels. So, quality is something which is governed by the performance of an individual worker. And different individuals are all involved in construction work at a particular site, they all contribute to the quality of the work being done at that site. And that is something which you see in a subsequent slide where workers are working at different processes in the construction site.

So, TQM is a way of planning organizing and understanding each activity that depends on each individual at each level. And ideas of continuous learning allied to concepts such as empowerment and partnership which are facets of TQM also imply that a change in behavior and culture is required if construction firms are to become learning organizations. Construction companies have to learn have to understand that quality control awareness towards quality is something which workers often need to be educated about. It is an awareness that has to be created much as in the case of awareness towards safety. Quality assurance programs encompass the following.

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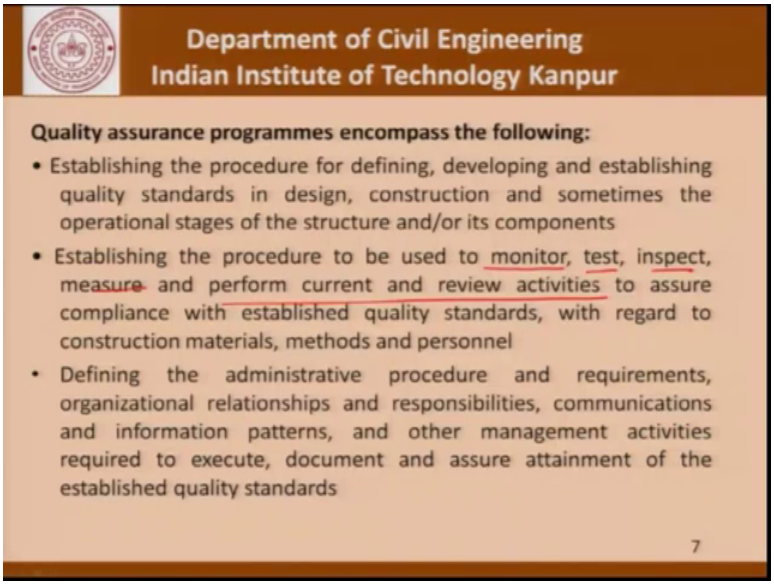

Establishing the procedure for defining developing and establishing quality standards in design construction and sometimes the operational stages of the structure and or it is components. Establishing the procedure to be used to monitor test inspect measure and perform current and review activities to assure compliance with established quality standards with regard to construction materials, methods and personal.

Defining the administrative procedures and requirements organizational relationships and responsibilities communication and information patterns and other management activities required to execute. Document and assure attainment of the established quality standards. If you read this document on your own you will realize that each term here is a very odd term and has a lot of meaning to it. When we say that establishing the procedure to monitor test inspect measure and perform current and review activities. This is something which is very important monitoring testing inspections measurement and actually determining the performance, all these are integral part of a quality assurance plan.

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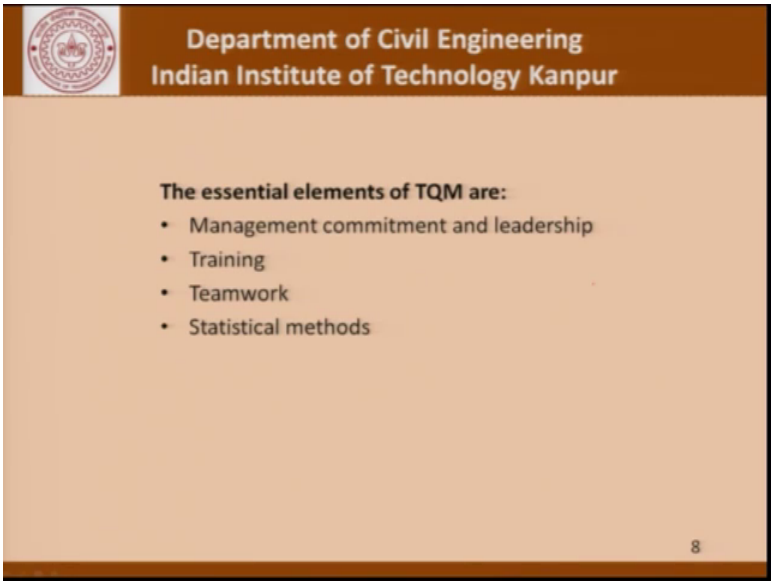

Essential element of TQM are management commitment and leadership, training, team work statistical methods, cost of quality and supplier involvement.

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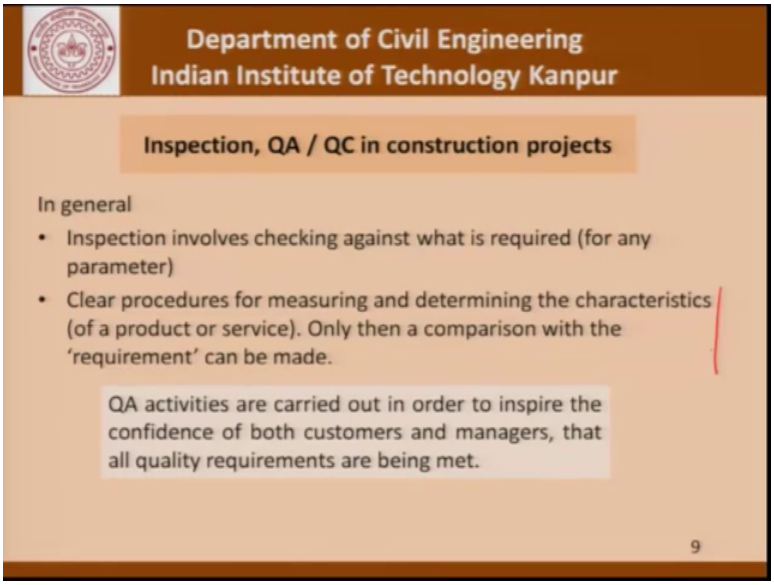

As for as inspection and quality assurance quality control in construction projects is concerned, in General inspection involves checking against what is required for any

parameter. Whether it is strength it could be geometrical tolerance, it could be roughness, it could be setting time of cement or whatever. Clear procedures for measuring and determining the characteristics of a product or service and only then a comparison with the requirement can be made. We must remember that when we are talking of quality control we are also talking of the possibility of rejection of certain products. And once there is a rejection there could be a huge financial implication and that is something which has to be avoided. And therefore, to the extent possible the procedures to be adopted including the details of all this steps that will be followed must be outlined as clearly as possible.

QA activities are carried out in order to inspire confidence of both the customer and the managers, that all quality requirements are being met. It is very important proper QA activities and procedures in still a lot of confidence in third parties in inspectors. If there are procedures in place then people feel confident that yes, the work is being done according to standards. If those procedures are not in place there is always a little bit of jitteriness a little bit of discomfort in accepting the product. And that is true for construction projects mush as it is true with other products which are generally meet in the industry. In fact, the brand value concept is precisely that a product which has a higher rand value typically has better quality control procedures, and this reminds me of the variability issue that we talked about.

If the attention pay towards quality control in the factory made product is high, the variability is likely to be low.

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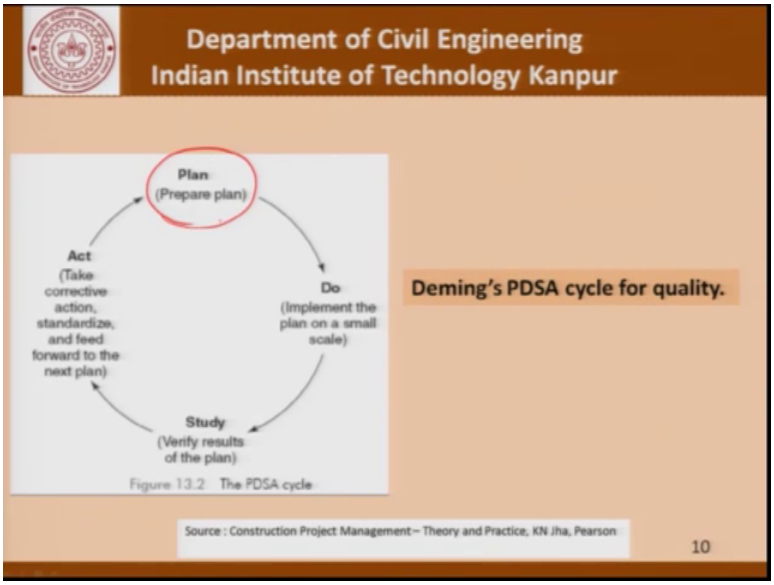

Let us see what some of the important quality gurus or some of the theories that have been put forward as for as normal quality control is concerned, say about quality here we have demings PDSA cycle for quality which says plan, which is prepare a plan do that has been prepared. Study that is verified the results of the plan a which is take corrective action a standardize and feed forward to the next plan. So, this planning is not necessarily a onetime exercise. It can be repeated in fact, it must be repeated depending on the feedback. This feedback is a very important part of a quality control procedure.

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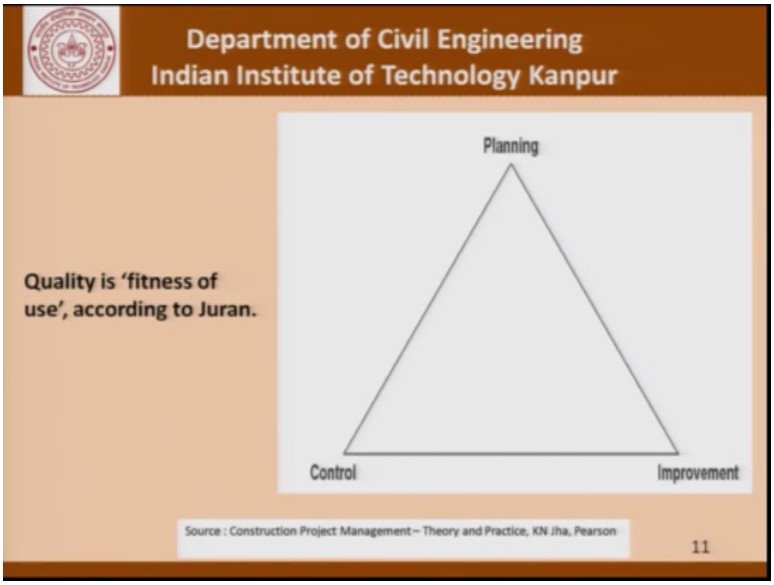

This is the quality triangle suggested by Juran comprising of planning improvement and controlling and then planning once again.

Now, quality according to Juran is fitness to use, these are some of the concepts which have been put forward by people who are well known as for as the theory of quality assurance quality control is concerned. Coming to another set of statements by Philip Crosby quality as conformance with requirements that the company itself has established for it is products based directly on customer needs.

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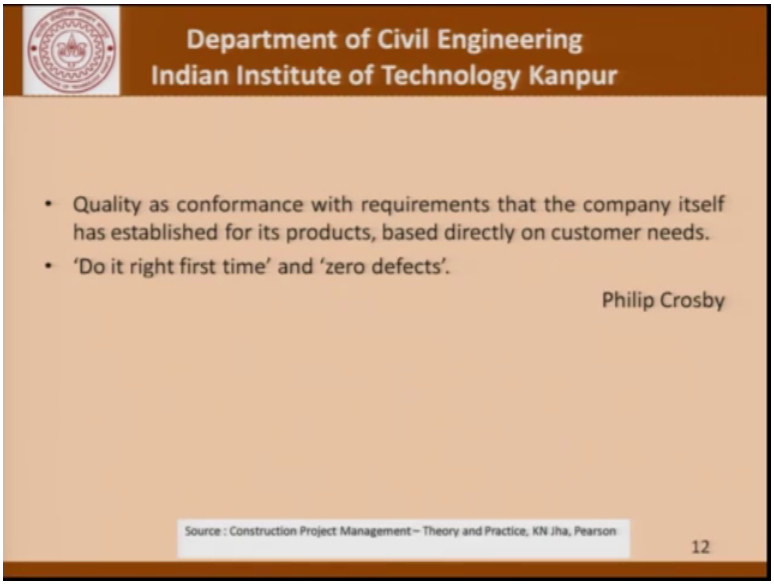

It involves do it right the first time and 0 defects. There is no way that we can say that since it was the first time it did not go well as for as construction is concerned as for as production is concerned anywhere. The first product has to be as good as the last product. It we cannot say that since that was the last product we made people had become tired and therefore, it is not meeting the quality that cannot happen.

Therefore the quality has to be sustained right from the word go right till the time that the production stops.

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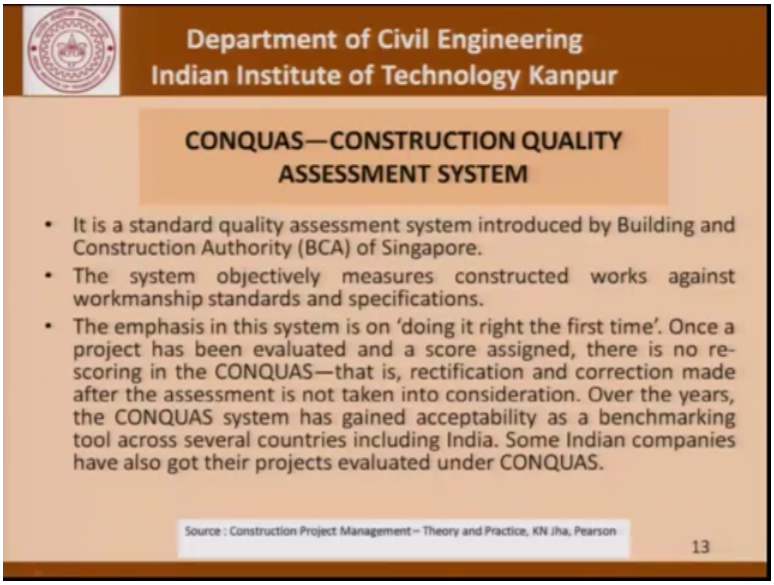

Now, continuing further as for as we are concerned in the construction industry conquas is a construction quality assessment system which is one of the system which I would like to introduce to you. And it is a standard quality assessment system introduced by the building and construction authority of Singapore and has gained popularity in the world. The system objectively measures constructed works against the workmanships standards and specifications.

And the emphasis in this system is doing it right the first time as we just saw. Once the project has been evaluated and a score assigned there is no re scoring in conquas that is rectification and correction made after the assessment is not taken into consideration. Then a over the years this system had gained acceptability as a bench marking tool across several countries including India. Some Indian companies have also got their projects evaluated under this construction quality evaluation or assessment system.

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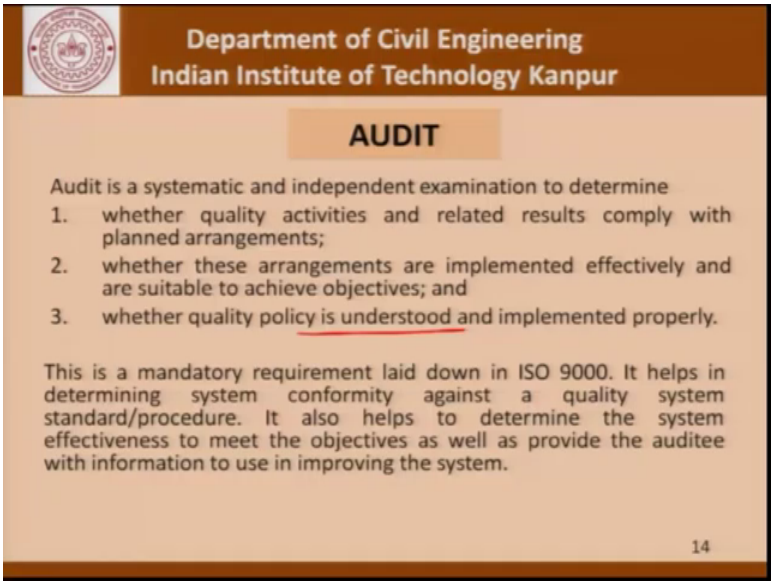

Now, there is another important aspect of quality control and quality assurance and that is audit. Now what is audit? It is a systematic and independent examination to determine whether the quality activities are related results comply with the planned arrangements that is they meet expected values, also whether these arrangements are implemented effectively and are suitable to achieve objectives. And whether understanding of the quality policy basically means that the people the workers who are involved with the execution of the quality policy they must understand the provisions. That is what is important unless that happens is very difficult to assure or ensure that quality in a construction project will be met. This is a mandatory requirement laid down In ISO 9000 it helps in determining system conformity against a quality systems standard or procedure. It also helps to determine the system effectiveness to meet objectives as well as provide the audity with information to use in improving the system.

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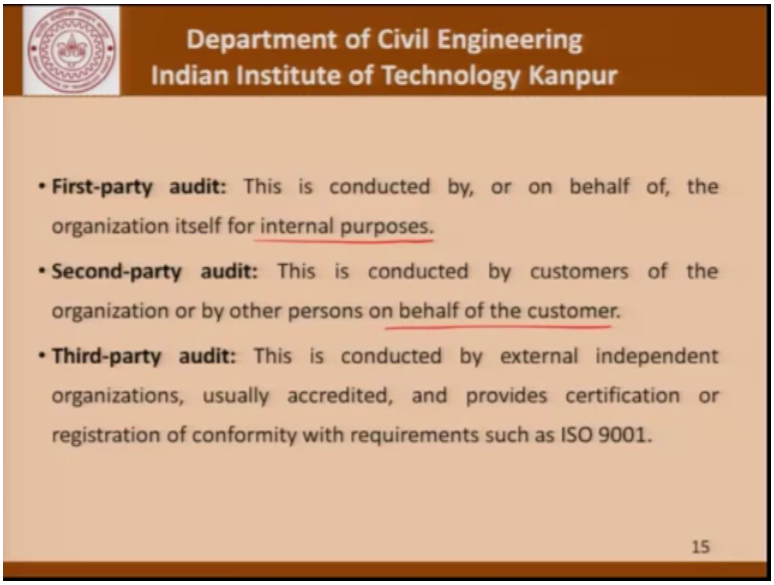

Now, there are different types of audit. A first party audit is conducted by or on behalf of the organization itself for internal purposes then; obviously, there will be a second party audit this has conducted by the customers of the organization or by other persons on behalf of the customer. So, this part is an internal story where the manufacturer or the contractor or the organization actually carrying out the work carries out that audit which is in inspection, on it is own this part which is a second party audit is carried out on behalf of the customer. The customers may hire in independent auditing agency to do this and then there is what is called a third party audit which is conducted by external independent organization usually accredited and provides certification or registration of conformity with requirements such as ISO 9001 and so on.

Very often third party audits and third party checks are becoming more and more common as for as construction projects are concerned. So, the clients and the contractors they agreed that while the work is being executed there will be a mutually agreed third party which will inspect the works regularly submit it is reports and these reports will become the feedback to both of them to improve the quality further as the project progresses.

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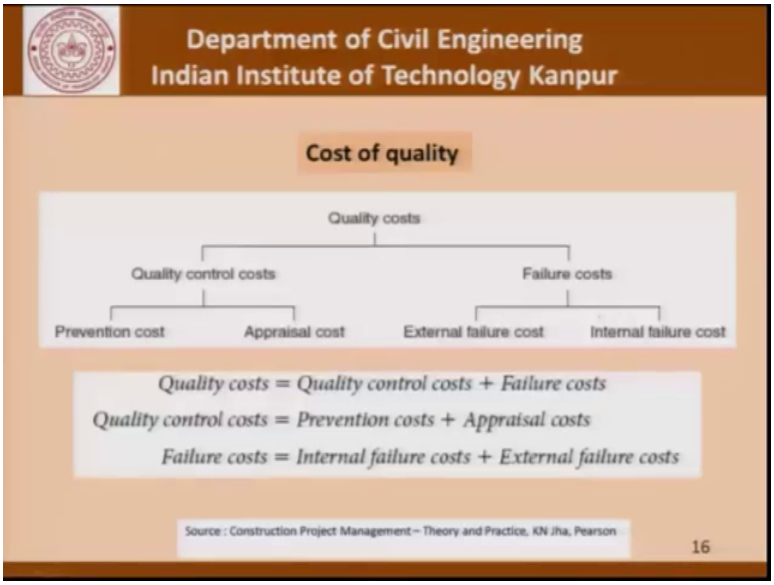

Now, let us come to the cost of quality. The cost could have quality control costs and failure costs. What we have to understand is that this picture is basically coming from the industrial processes. There is a cost involved in the quality control procedures. There will be whole quality department which will have to be given salaries they will have to be given their perks and there is a cost which is involved.

So, that is the direct cost of quality in terms of quality control.

What happens if we do not have quality control would be failures? Now those failures could have an external cost and they could have an internal cost. So, what we have given here is the quality costs is equal to the cost of quality control plus the failure costs and the quality control cost is prevention cost and appraisal cost and the failure cost itself is internal failure and external failure costs.

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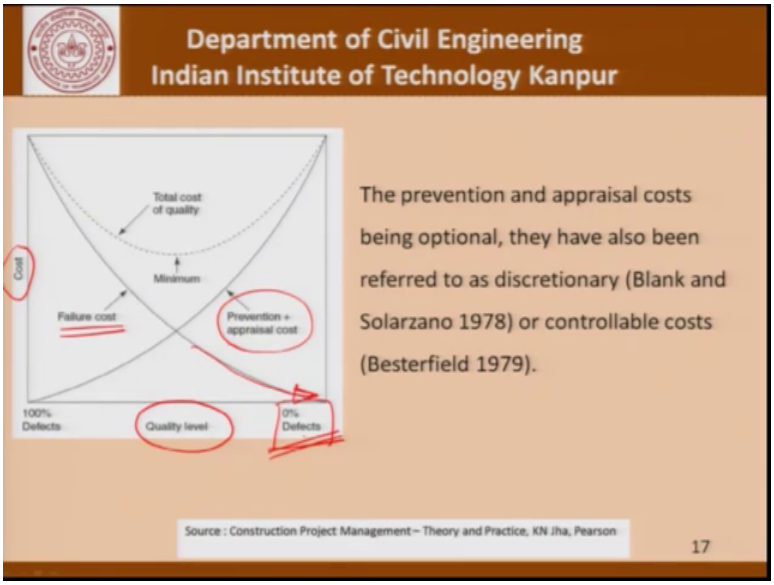

Now, if you look at it diagrammatically, if we have this as our quality level. And we look at the cost on this side, we have something called the failure cost.

The failure cost will keep decreasing as the quality level increases and finally, we will have a situation where we have 0 defects whereas the prevention and appraisal cost will keep increasing as we move towards this goal of 0 defects. Now it is up to us to decide what is the level of quality that we will keep. What is the level of quality that is acceptable to us, because there is a cost involved.

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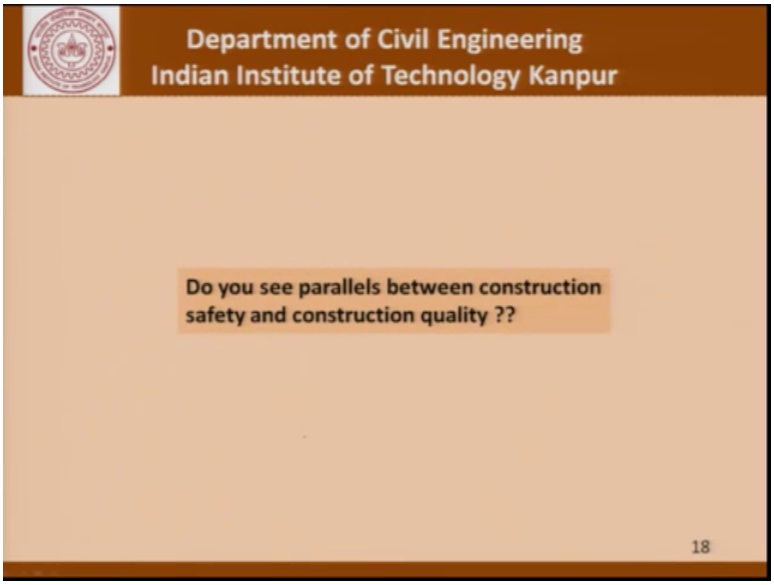

Now, in the discussion so far we have already talked about construction safety. Do you see some parallels between construction safety and construction quality. At least I see several things which are quite in common when we talked of safety we talked of prevention of accidents and we talked of the cost of safety direct cost in direct cost accident having a direct cost in an in direct cost then also there was the whole department of safety.

There also we have talked about a safety. Engineer we talked about a safety audit team and so on. Those people who were also involved in ensuring that the project site is a safe place to work that is there are few accidents. In fact, the target is 0 accidents. Now in order to ensure that there is a cost that is involved, and much like in the case of quality control there will be quality inspectors there will be quality audits there will be quality reports, there will be a feedback mechanism there have to be records both quality and safety inspectors are not main line execution people. They can be looked upon as people who hindered the progress. So, quality control inspector can well say that well product being made or the construction activity that being carried out does not meet quality standards, does not meet acceptable standards and therefore, must be stopped. Much as the safety inspector can say that safe practices are not being followed at site and therefore, work must stop.

But what has to be understood by the top management or the management of the site is that both of them are an integral part of ensuring a good product at the end of the day. They are part of a team that ensures the reputation of the company and the fact that the finally, the project or the constructed facility meets standards. So, that is how we can kind of see the relationship between quality and safety that of course, is in a side.

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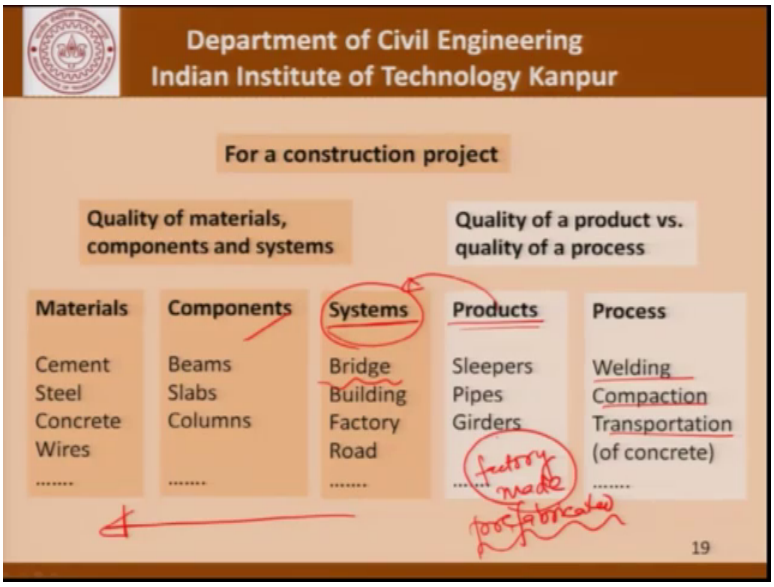

Now let us come to a specific situations for a construction project. In this module we will not be talking so much about total quality control or total quality control managements 0 defects and so on, from a theoretical prospective. But therefore, it will be to identify certain small topics taken from the field of construction taken from the site and discussing them from the point of your safety.

So, what we are trying to look at from a construction project prospective is, quality of materials components and systems. That is one way to look at it. The other way of looking at it is to talk of quality of a product versus quality of a process. Now as for as the first view is concerned where we have talking about materials components and systems, what are the materials that we use at site. It could be cement steel concrete pre stressing tendents and the list goes on and on and on. So, each of these materials must confirm to certain quality standards. And that is what we are talking about when we say that we are talking about quality control of materials that are contributing to a

construction project.

Moving on there are components of a structure it could be beams, slabs, columns, walls all of them as components they are made of materials, but there is also a lot of other things that goes into making them the form work the compaction of concrete the welding if it is involved and so on. Then there is the system. Finally, it is the system that is the target. The bridge, a building, a factory, a road, a sewer line and so on. The system is the final product. Moving this way if we go in order to ensure that the system performs acceptably it is important that the components performs satisfactorily and it is important that the materials perform satisfactorily. So, there have to be bench marks for materials components and systems and that is what is ensured when we talk of quality control and quality assurance in construction projects.

Now, coming to products versus processes as for as construction industry is concerned, products could be sleepers pipes girders and so on, which are largely factory made products. So, in this day and age we are talking about pre fabricated members. Now no matter how much pre fabrication we do we will be able to make certain products, but finally, they will have to be integrated at site to develop a system.

We often seen construction being done with pre cast girders. Now those pre cast girders are factory made products, but they have to be assembled they have to be erected at site and there is a lot of workmanship that goes on, while they are at site in order to ensure that the bridge made with them meets the requirements. Coming to processes there are so many processes there could be welding compaction transportation of concrete, And so the list is endless. Each of these processes has to meet certain requirements only then will the products meet the requirements only then the components will meet the requirements and so on. So, the whole gamut of thought processes as for as construction industry is concerned from the point of view of quality is a very complex situation. And it is important that we understand each and every detail of whatever small bit we are looking at. And that will be the approach that we will adopt as for as this discussion is concerned in this course.

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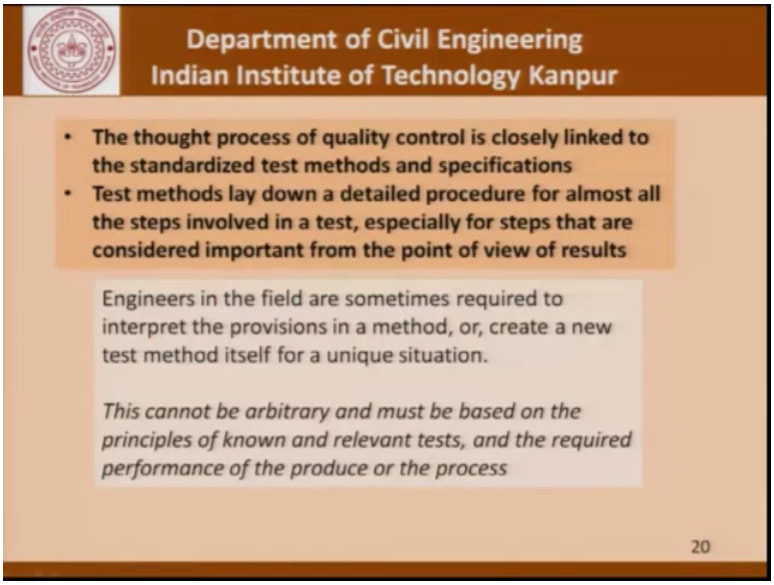

Now, the third process quality control is closely linked to standardize methods and specifications. Test methods lay down a detailed procedure for almost all the steps involved in a test especially for steps that are considered important from the point of view of results. We will see this when we briefly talk about the parameters which are important from the point of your testing, the strength of concrete today and later on in a subsequent discussion greater details engineers in the field are sometimes required to interpret the provisions in a method or create a new test method itself for a unique situation. And this adaptation or modification that an engineer makes cannot be arbitrary and must be based on principles of known and relevant tests, and the required performance of the produce or the process. We will appreciate them port of these statements better when we look at some of the examples.

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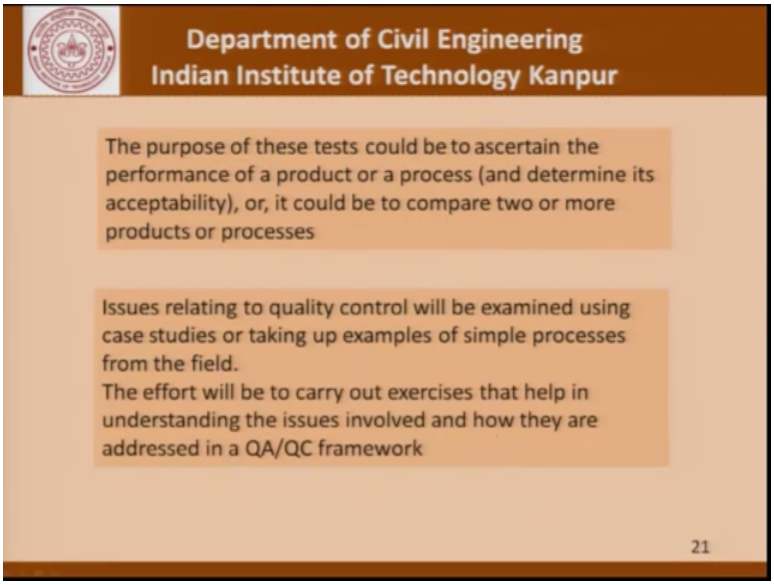

Another purpose of these tests could be to ascertain the performance of product or a process, and determine it is acceptability or it could be simply to compare 2 products or processes. Issues relating to quality control will be examined using case studies or taking up examples of simple processes from the field. And therefore, it will be to carry out exercises that help in understanding the issues involved and how they are addressed in a quality assurance quality control frame work.

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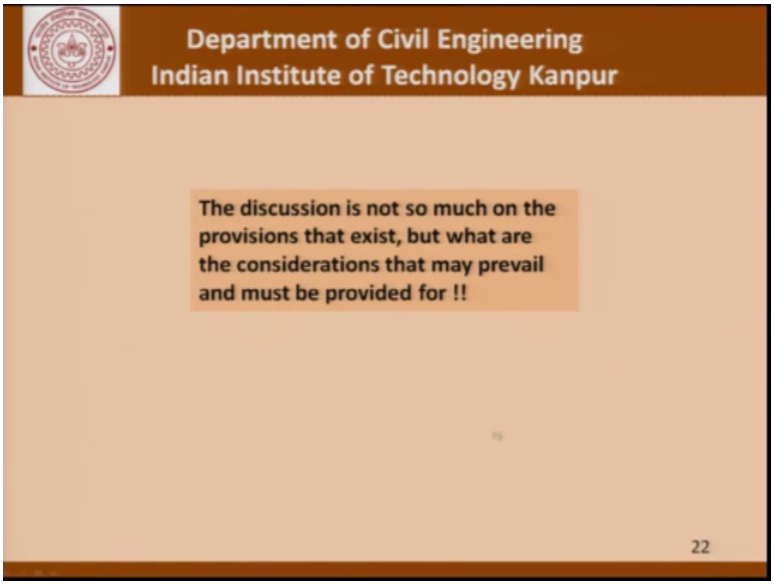

So, the discussion in this course is not so much about the provision that exist, but what considerations must prevail or may have prevailed when we introduced to those provisions in a particular test method or a specification.

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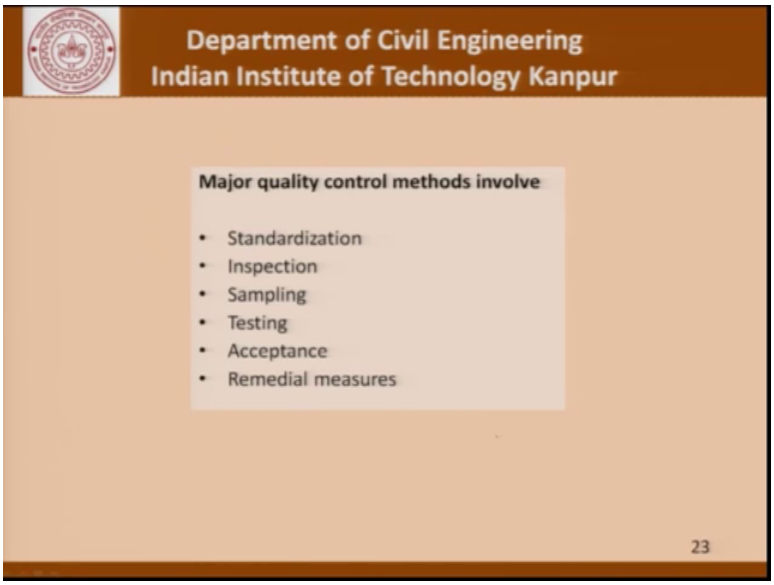

Not to recapitulate major quality control methods involve standardization, inspection, sampling, testing, acceptance and remedial measures in the event that acceptance criteria is not readily met. These are things which should be addressed in our procedures and only then we will be able to talk about a proper quality control quality assurance program and also have fewer deputes and that something which we will talk about later.

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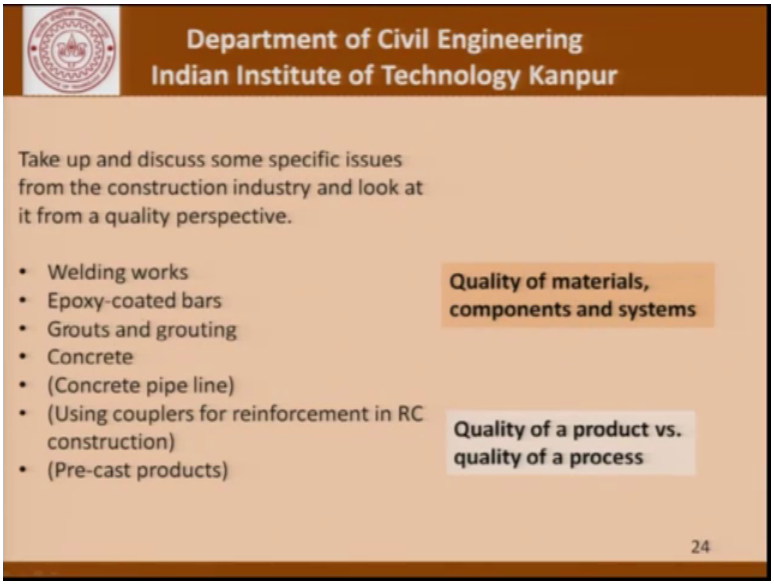

We will take up and discuss some specific issues from the construction industry and look at it from the quality perspective.

Some of the things that I have identified to take up a case studies is welding works epoxy coated bars grouts and grouting concrete, concrete pipe line using couplers for reinforcement in reinforcement concrete construction and pre cast products. The last 3 which are given in brackets we will be taking up later on or possibly I will just upload this material on the website for you to go through in your own. The first 4 parts is something which we will talk about As we move along in this course.

Now we will look at this from the point of view of quality of materials components and systems that we talked about and the quality of product versus the quality of a process. Now can we looked at these 7 things in the frame work that is suggested in the quality of materials components and systems and quality of product and quality of process framework?

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Now, if we look at that way as for as the quality of materials components and systems is concerned these items fall in that category epoxy coated bars is a material grouts is the material.

But grouting is a process. Concrete is a material and concreting is a process. Concrete pipeline is a system using couplers for reinforcement in RC construction is also a material couplers themselves are basically a kind of material. That we use at the construction site. Looking at the other side welding is basically a process, grouting is a process, concreting is a process. Using couplers is the process, but pre cast products and the kind of considerations that go in quality control of pre cast products is basically a matter of quality of a product. So, this is how we are going to divide our discussion.

We are going to focus on bits and pieces of the construction site to better understand the issues involved in the quality control and quality assurance when it comes to a construction project site.

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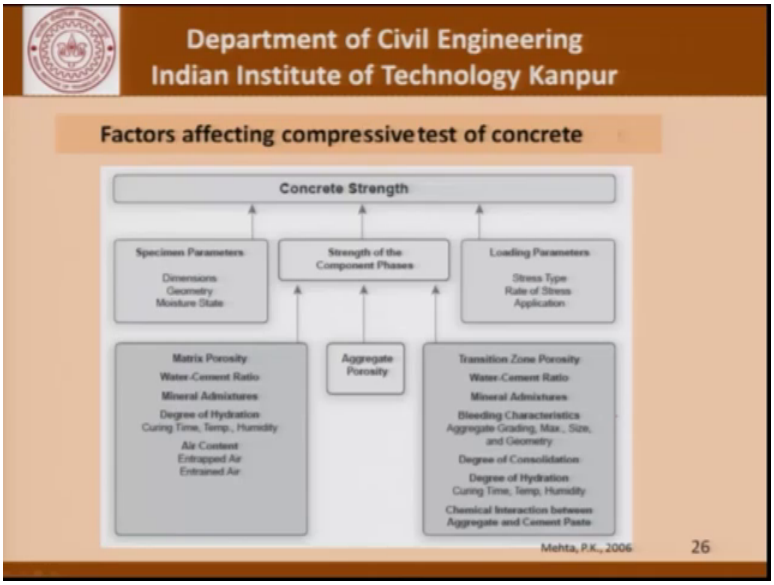

Here is the list of factors effecting the compressive strength of concrete as determined at the compression test. There are issues relating to the specimen parameters which could be dimensions, geometry or moisture state. There are issues relating to this strength of component phases which could be the matrix porosity the water cement ratio mineral add mixtures degree of hydration which in itself is related to curing time temperature in humidity, air content which could be entrapped or entrained. It could be aggregate porosity which is completely different thing. It could also be transition zone porosity water cement ratio and the kind of factors which is listed here and then of course, there are loading parameters which could be stress type rate of stress and application and so on.

So, what I am trying to say through this slide is that even a simple thing like the compressive strength of concrete is having so many small bits in pieces or important parameters, considerations, factors that go into determining that strength. So, one of these parameters changes everything changes. It is important to understand and appreciate this from a point of view of quality control because of the inherent possibility of any of these parameters being taken up for a very fine scrutiny, if it comes to rejection of products.

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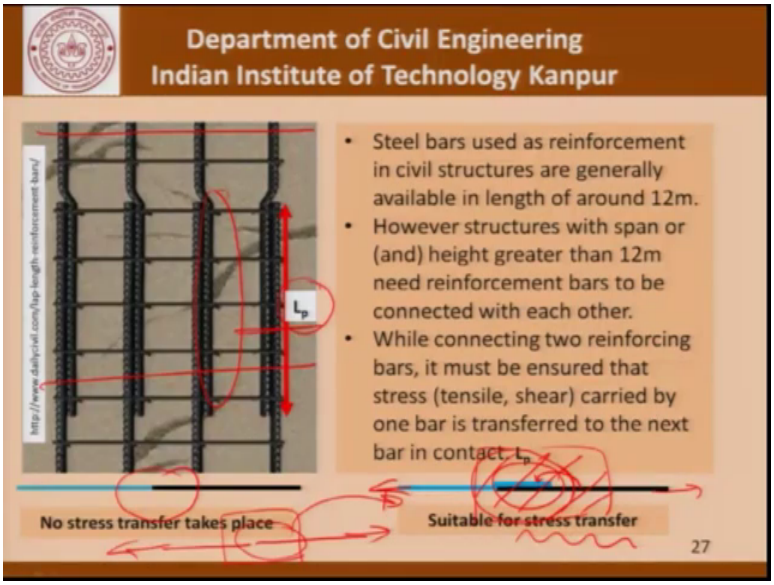

We will continue our discussion today and look at another very simple issue when it comes to concrete construction. That is lapping or splicing of reinforced concrete bars when it comes to RC construction. So, a steel bars used in reinforcement in civil structures are generally available in lengths about 12 meters.

However structures of height or span greater than 12 meters need reinforcement bars to be connected with each other and this connection has to be such that the stresses whether it is tensile or shear or whatever. Carried by one bar is transferred to the next. So, if we have a situation like this that we have a bar here, and we bring a bar here and we put concrete around it. And this bar is pulled out or is subjected to tension there is no way that the whole joint or the whole member is going to behave the way it is designed to behave. So, in order to ensure that we have a mechanism for stress transfer and one of the ways is to have a lap. So, this conc whole joint gets buried in concrete. And whatever forces are acting on the steel are transferred from one bar to another through this lap. Now this is what is shown in the picture here and this lap is the lap length.

So, there is a relationship between how much should the lap length be in terms of the diameter of the bar. Without getting into the details of that it is important to understand that the moment there is a lap at a given cross section there is more congestion as for as reinforcement is concerned we are looking at let say 4 bars, but here we could be looking

at 8 bars. And that makes the concreting process very difficult that is one problem. The second problem is that this lap length is actually something which is being wasted from a material point of view. This is a material which can be avoided if possible. One of the things could be as for as economy is concerned can we get rid of this lap length or can we reduce this lap length and so on.

So, there are different ways which have been tried as for as site is concerned. Now why we are getting into this discussion here in this course is, because of quality control issues as for as the structure is concerned in order that it performs satisfactorily, it has to be ensured that all these laps are proper. Basically what it means that they stresses in this part of the bar are appropriately transferred to this part of the bar. So, with that performance criteria in mind lapping is just one of the ways of doing it. In order to ensure a proper stress transfer checking the lap length is just one of the ways.

Now, let us try to see what are the implications of this kind of a splicing.

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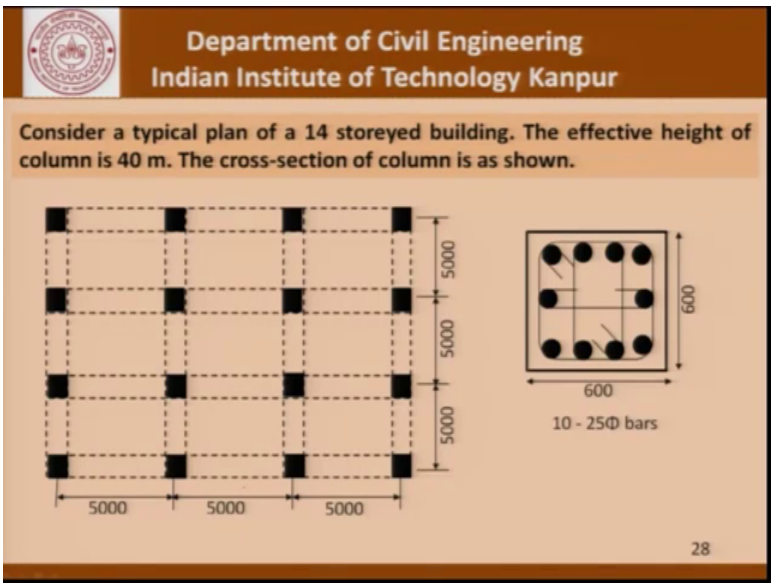

Consider a typical plan of a 14 story building, which gives us an effective height of the column let say a 40 meters. And if the cross section of the column is shown here it 600 by 600 with 10 bars of 25 diameter. We have 16 columns in this plan.

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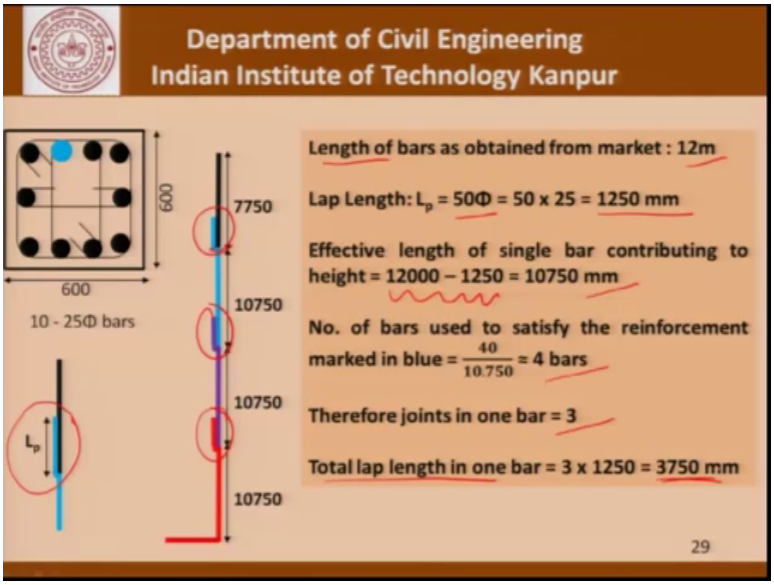

And we find that we have to provide certain lap length for each of these reinforcing bars.

So, if we look at a simple calculation what we find is length of the bars is obtained from the market let say 12 meters, the lap length is taken as 50 times the diameter which is 1.25 meters which means that the effective length for each bar towards the height of the column is only 12 meters minus 1.25 which gives us 10.75 and the number of bars being used is 4 joints in one bar is 3. So, these are the 3 joints that we will have to let say encounter on a minimum. Now the total lap length in one bar therefore, becomes 3.75 meters in a height of 40 meters we are using 3.75 meters of lap length, which is avoidable perhaps provided the performances not compromised.

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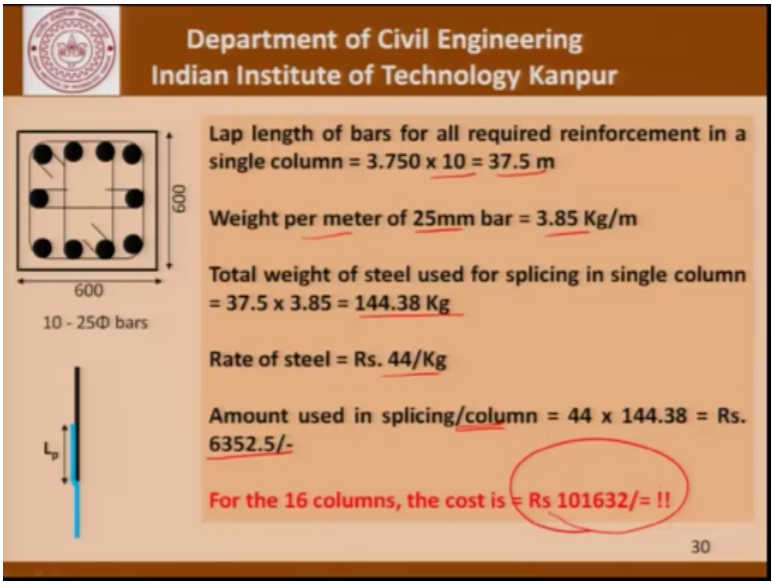

Continuing with this simple calculation the lap length for 10 bars in a single column is 37.5 if we take the weight per meter of a 25 mm bar to be 3.85 kgs a meter. We are wasting or using 144.38 kgs in a single column and taking the rate of steel to be let say 44 rupees a kg. The amount used is splicing per column is as much s 6352. Now this for 16 columns go is going to cost us a 100000 rupees. Now this is the kind of back of the envelope calculation which tells us that there is reason to study this issue a little bit and try to find out what are the alternatives.

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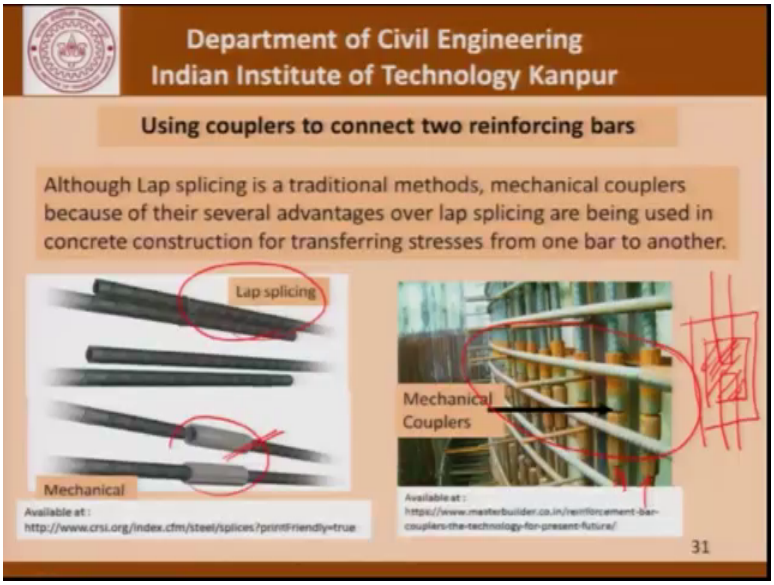

Now, one of the alternatives is the use of couplers. Instead of using lap splicing as I shown here, we can use mechanical couplers the way that is shown here. There is no lapping and what is done is that there is a bar here, there is a bar here and there is a coupler which holds the 2 bars together. Without going in to the details of the mechanical coupler and how they are fixed and so on which becomes a completely different discussion. From a quality control perspective it is important to ensure that this coupler or this joint in the reinforcing bar using couplers the way it is shown here in all the bars they perform in a manner that there is no compromise on the performance of the structure. There is no compromise on the performance of the steel bars.

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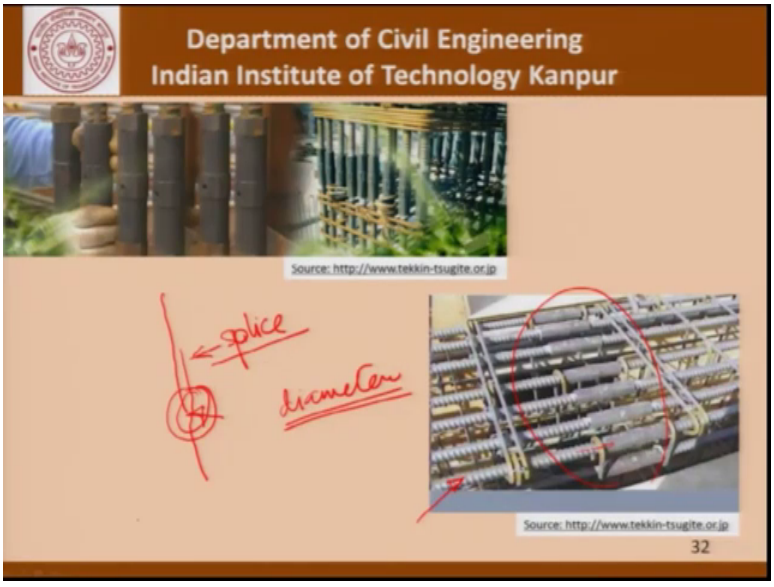

This is another view of couplers being placed at site. And we can see that once we decide to use couplers there will be 100s of such couplers being used at a construction site. And that takes us to this issue of quality control how do we ensure that the couplers being used at site are of a certain quality. How do we ensure that the bars are being properly embedded? This picture here In fact, also tells us what will be the kind of congestion of the bars if we were not using couplers and we were using the regular splices. We must remember that the diameter of the bars plays a very important role when it comes to deciding whether or not we should use couplers, or try to look into the possibility of alternatives to splicing. In a previous figure we had seen that when doing a splice the bar needs to be bent the way it is shown here. Now bending this bar to this extent or in this fashion is not easy when it comes to large diameter bars. For smaller diameter bars yes, it is possible.

But for large diameter bars it is a very difficult proposition. And therefore, I whole manual exercise or even a mechanical exercise of bending the bars to this shape adds to the cost of a splicing which we did not take when we talked about that 100000 rupees which is just an indicative illustrative number. The picture also tell gives us a slightly different view on quality control and that is that this procedure to ensure the couplers are good, the coupling is good, this has to be ensured right across all the thousands of bars which are used. And therefore, it is very, very important that the person who is actually engaged in

that job is the person who is conscious of the responsibility on his shoulders to do a good job. Because we must remember that as for as reinforcement is concerned it is actually going to get embedded in concrete and it will be very difficult to do anything after the concrete has been cast.

And it is equally difficult to ensure that each of these reinforcing bars will be inspected before the casting is done. Of course, in certain very critical structures it may be ensured that may be a procedure that will take that into account, but most of the time it would be simply impossible to do that and that is the importance of quality control that is the importance of educating people to do a good job.

Now, we move forward and try to look at another possibility that is joining bars using gas pressure welding.

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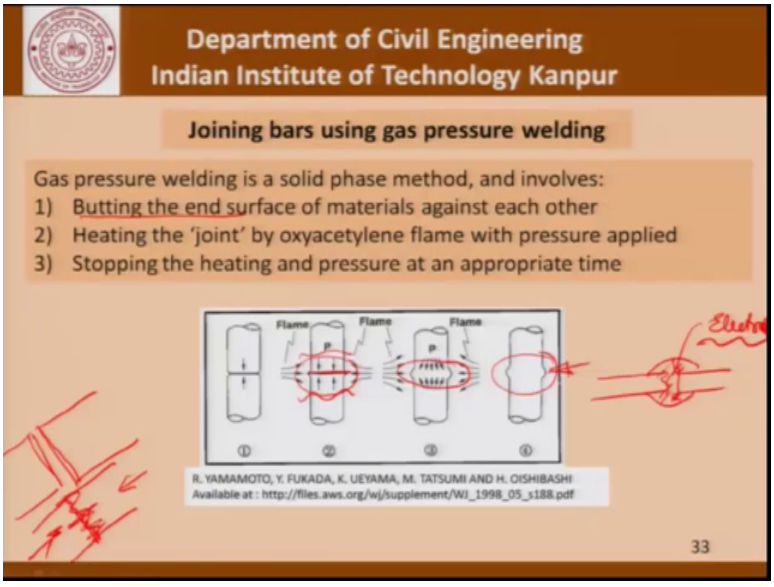

Now, what this method does is not use traditional welding. In traditional welding there is a material here, and there is a material here we do some kind of edge preparation here. We have an electrode that deposits additional material and we get a weld. As far as gas pressure welding is concerned it does not involve deposition of additional material. What it does is that the 2 ends of the bars are butted against each other, we make sure that the

ends of 2 bars are flushed and they are brought together. So, there is a end here and there is an end here, with as little gap as possible here.

Now this is held in position through a certain amount of pressure the next step is to heat the joint by an oxy acetylene flame with the pressure applied. So, what we are doing is we are heating this zone in the neighborhood of this joint using an oxy acetylene flame and as this temperature increases to an extent that the metal becomes more deformable. This pressure leads to a bulging here and once a sufficient amount of bulge has been formed and the metal has actually fused that is these 2 metals have actually fused and we get a joint like this we stop the heating and the pressure.

So, this is the technology involved without getting into the details of the technology the principle here is quality control. What are the issues that go into doing the quality control of gas pressure welding?

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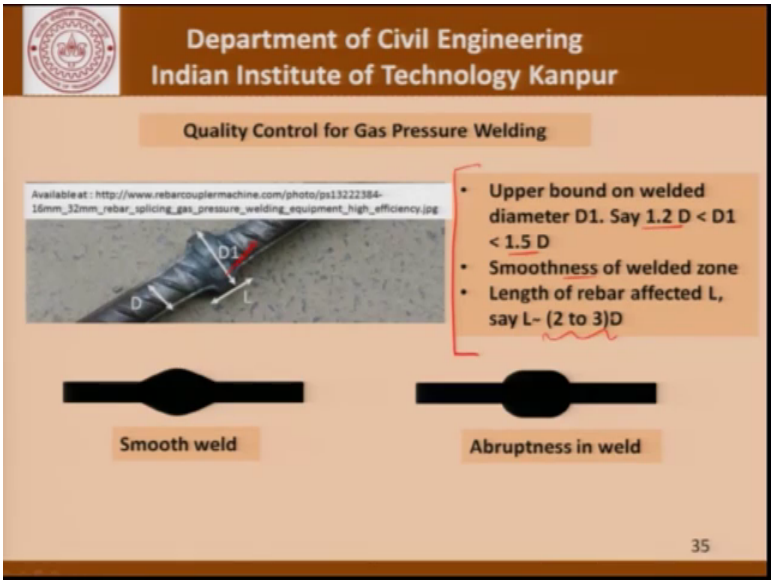

This picture here shows how the gas pressure welding is carried out. You can see this wise here which is there to hold the bar together one end of the bar and the other end of the bar is here. And this is specially designed flame burner which is heating the joint across for a certain length. And finally, what we get is a gas pressure welded joint which would

look like this. This is the bulge that we have here and possibly the length of the effected zone. The effected zone means the zone which has been heated to the extent that the metallurgical composition or the phases in the metal have undergone changes. Now this is something which you understand from theory. In order to ensure that the quality of the reinforcing bar has not been compromised, we must ensure that the welding has been done properly.

Obviously, come to mind one could be what is the change in diameter, whether the change in that diameter is smooth or it is abrupt. So, there could be prescriptions or there could be limits like this which could be that the upper bound on the welded diameter D 1 should be between 1.2 D and 1.5 D there should be a smoothness in the welded zone. And the length of the rebar affected should be let say 2 to 3 D or whatever it is. So, this is something which we can prescribe depending on or based on laboratory tests and the research work on gas pressure welding. When we have these kind of guidelines in place we are better prepared to ensure quality control on gas pressure welding.

So, this discussion here whether it is couplers or it is gas pressure welding is not so much to discuss the technology involved there is a whole lot of things that go into it as for as the technology is concerned. The point is to only introduce to you technologies and talk about them briefly to the extent that you understand what are the issues involved when it comes to quality control in using those technologies.

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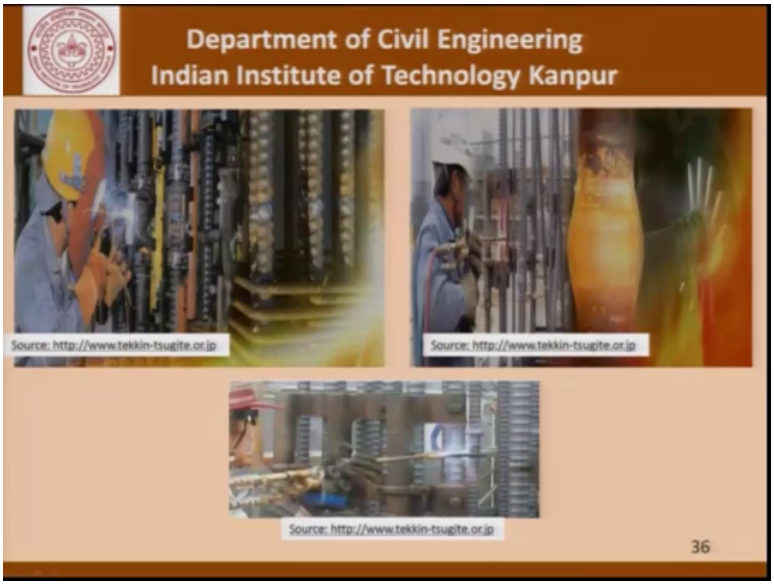

Now, these pictures here show site conditions where this gas pressure welding is been carried out. And again we see the importance of a workman the person who is actually carrying out the work it is the skill which is involved and there are 100s of bars to be welded.

So, this is the very, very large scale operation carried out in situ and that poses tremendous challenges as for as quality control is concerned. And that is something which we must aware in mind when we are trying up the right kind of specifications.

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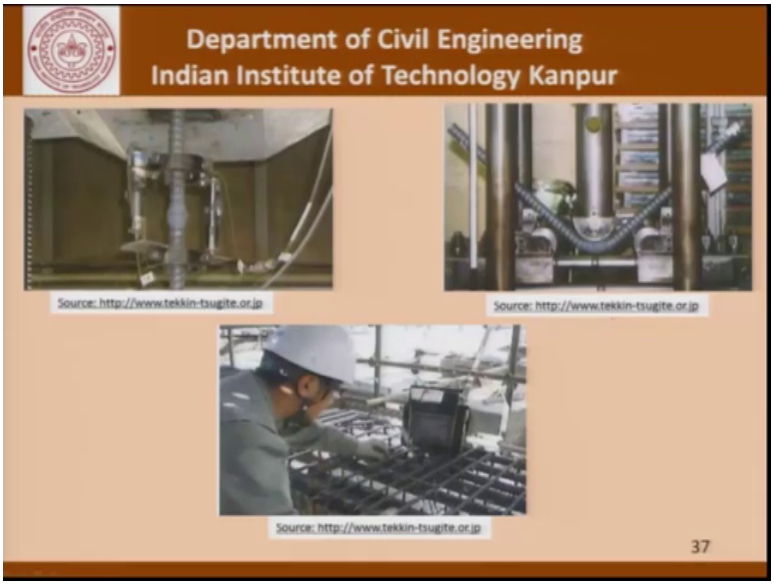

These pictures here show how the testing is done, whether it is let say the tensile test across a gas pressure welded bar or a bending test of a bar, or the testing at site using any of the devices. There are several methods which have been developed to carry out in situ inspection of reinforcing bars if there been joint using couplers or using gas pressure welding or welding whatever is permitted, and these are the tests which must be carried out in order to ensure that the reinforcement work the detailing is acceptable.

Now, with this we come to an end of our discussion today where we have talked about the general issues relating to quality control as for as construction is concerned.

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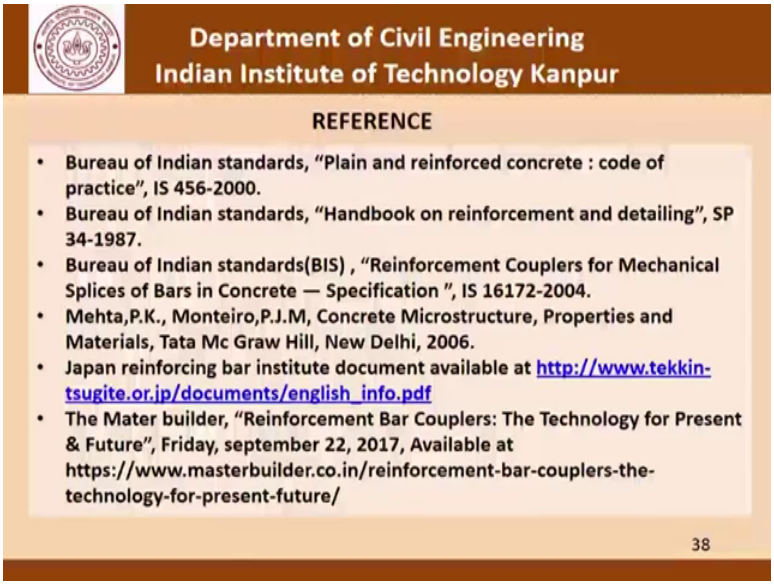

And here is a list of some of the references which you may find useful as for as our subject material today is concerned, and from the next class we look at the 4 or 5 a specific topics that we talked about welding grouts and grouting concrete epoxy coated bars and so on. And possibly I will upload some other material for you and I look forward to seeing you in further discussions.

Thank you.