Principles of Construction Management
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Lecture – 31
QC issues in concrete

[FL] and welcome once again to the series of lectures on Principles of Construction Management.

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And what we have been doing in the previous few lectures is talking about issues relating to quality control.

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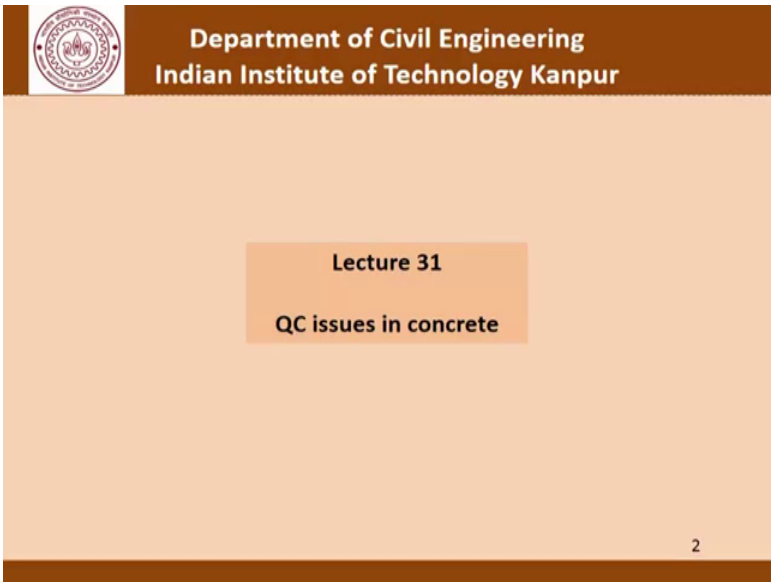

Taking up a specific case studies or situations from the field and trying to analyze them discuss them in the framework of quality control. So now, in that scheme of things today the discussion is focused on quality control issues in concrete.

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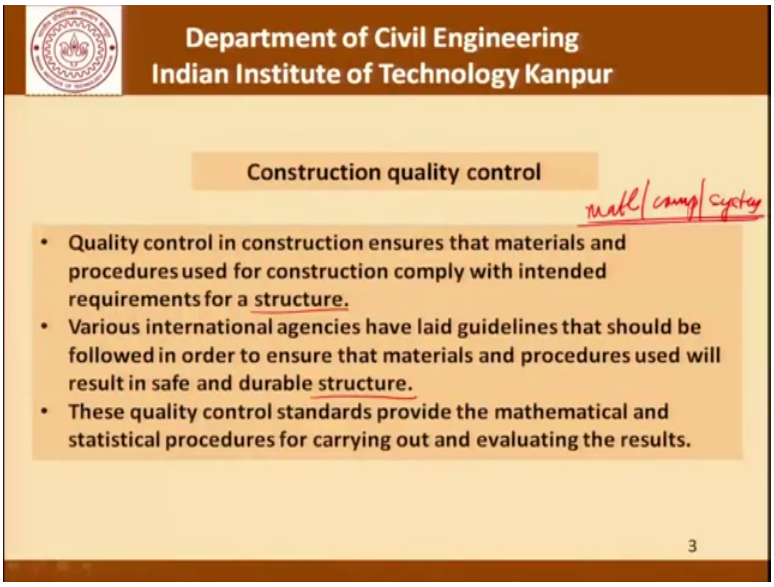

Now, before we get Into concrete per say let us spend some time on repeating or putting in another way general principles of construction quality control. So, quality control in construction ensures that materials and procedures used for construction comply with the intended requirements. Various international agencies have laid guidelines that should be

followed in order to ensure that materials and procedures used result in a safe and durable structure.

So, what we are talked about is finally a structure. Finally, it is the structure which can be broken up and perhaps should be broken up into different systems. And in order to ensure compliance or quality of the structure we must ensure compliance from quality point of view of all the systems. And a part of ensuring compliance for all the systems what we need to ensure is quality of the components, and to ensure quality of components we need to ensure the quality of materials. Nothing brings out this principle of the quality control of materials, components and systems better than discussions in concrete.

Because when concrete is used in the field there are so many processes which are involved which contribute to the final quality of the product. And that is something which we will look at and discuss a little bit today. These quality control standards provide the mathematical and statistical procedures for carrying out and evaluating the results.

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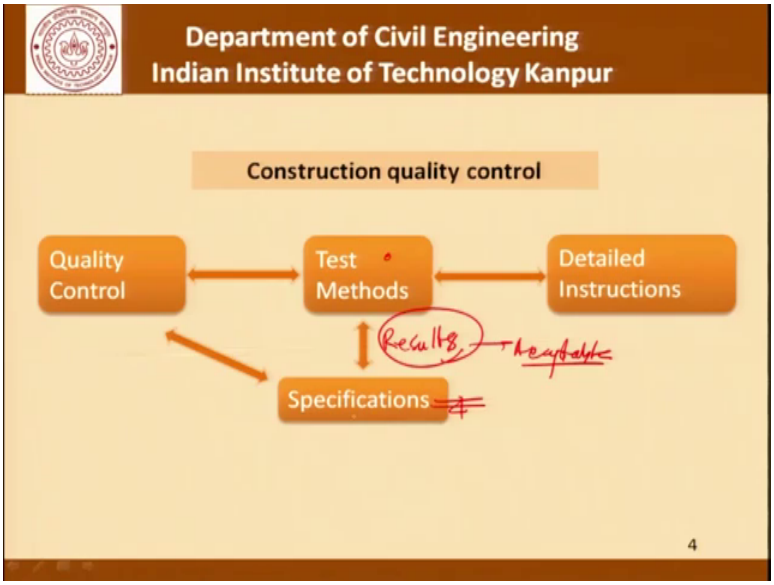

Quality control we have see before is basically Linked, it cannot be d linked from what is called test methods and specifications. Test methods as we have repeatedly pointed out lay down the step by step procedure exact details what temperature to carry out the test, how many times to do the tamping whether a mallet should be used or hammer should be used, what should be the size of the specimen, what should be the conditions of the test.

Those are the details which the test methods specify. Based on the tests which are carried out in accordance with a certain test method we get what we can call results.

Now, whether these results are acceptable or not is something which the specification will tell us. In case it is acceptable so what? And in case it is not acceptable what is the process to be followed? This will be laid out in the specifications. And obviously, the specifications can be different for different structures; they can be different for different clients. They can be different depending on different countries, different environment in which the structure is. And so, also the test methods.

The test method for example, for testing of concrete strength is not a unique method as far as the world is concerned. Different countries have their own codes they have their own shapes of specimens that are tested usually it is cubes or cylinders; the size of those specimens and so on. So, one must specify what method exactly is to be used as far as the testing of a certain parameters concerned.

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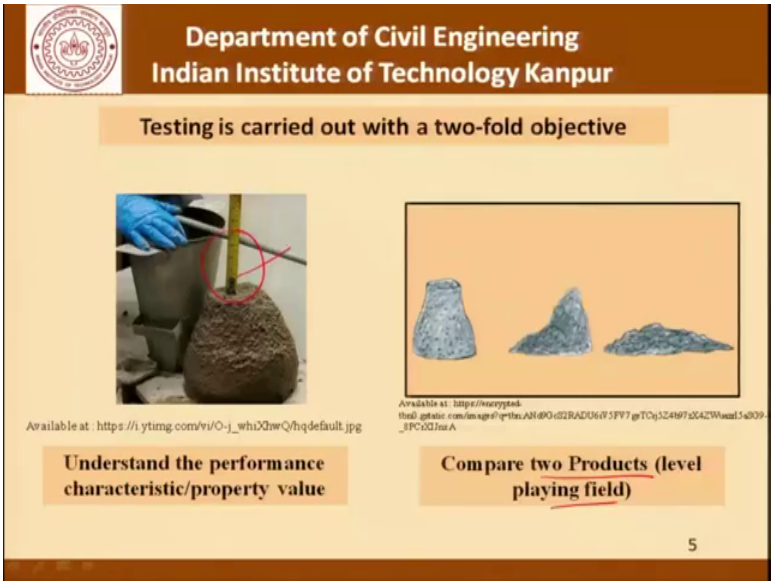

Now, moving forward the tests are carried out with a 2 fold objective. The first is to understand the performance or the characteristic or the property as a quantitative value. For example, this test here shows the slump. So, here the objective is to find out what is the slump of this concrete. Now they will be a specification whether the test carried out in accordance to the certain test method. And there are test methods which are different as far as slump is concerned and I am leaving it to you to find out. As far as that slump is

concerned whether it is acceptable or not for a particular application. If you are putting the concrete in rigid pavement or a place where there is no reinforcement, the requirements of slump will be different compared to a situation where we are trying to pump the concrete. We are not talking so much what concrete and therefore, we will limit our discussion on that. And as far as the same test is concerned apart from finding out the value it can also be used to compare 2 concretes just because we want a level playing field that this concrete has more slump than this.

So, we have to measure this value precisely from the point of view of acceptance or for comparing 2 concretes. As far as the testing for quality control is concerned, there is a property which is involved and the quality control test basically evaluates that property.

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And then there are processes which are involved and the quality control procedure basically test the quality of the process. And this part which is process material and so on, is very well covered as far as theory is concerned in industrial processes.

The quality control test to evaluate the process of construction would necessarily try to look at construction as a whole and then break it down to a set of activities which is different processes.

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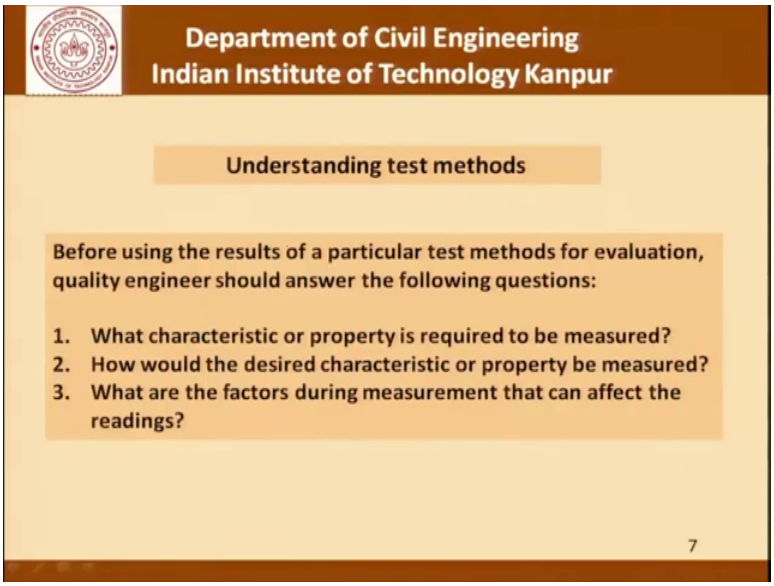

So, if you understand the test methods before using the results of particular test for evaluation the quality control engineer should answer the following questions. What characteristic or property is required to be measured? How would the desired characteristics or property be measured and what are the factors during the measurement that can affect the readings? So, if we are able to answer these questions clearly in our mind we will not be following a particular test method blindly. Usually there is no compromise the test method as prescribed should be followed, but at the same time the engineer can make an exception if there is reason to change one or the other step. But before doing that there has to be a reason for doing it. And the answers to these questions would help the engineer make the decision.

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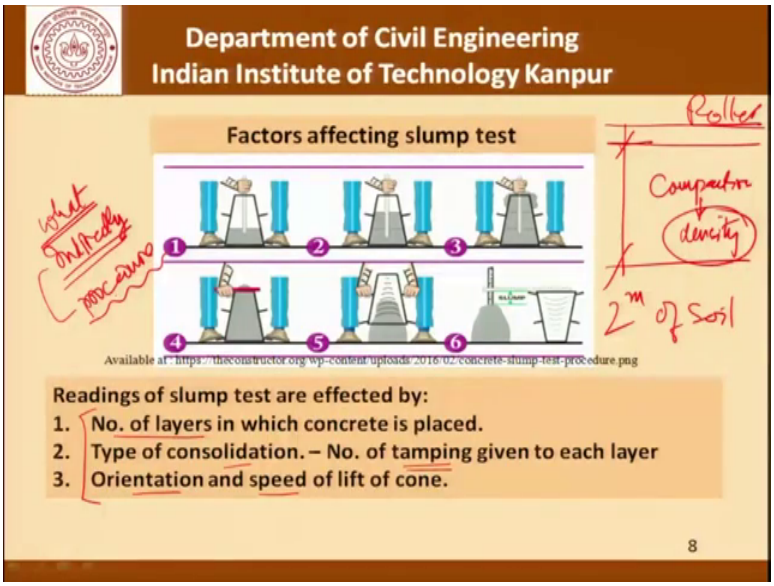

Even If it were the slump test the number of layers in which the concrete is placed the type of consolidation for example, the number of times the tamping is done for each layer and the orientation in the speed of lifting the slump cone, these things could very easily change the value of slumps that is recorded.

So, one must keep in mind and try to follow to the extent possible the exact procedure laid out in a particular situation. Now let me give you another example which is not related to concrete at all. For example, there was a situation where we want to deposit let say 2 meters of soil. And this had to be compacted.

Now, there are ways and means of compacting there are different ways in which it can be compacted. As far as the contract is concerned it could simply say that the contract as responsibilities to place 2 meters of compacted soil. Now one way of doing it is to put the entire 2 meters or may be little more than 2 meters and compact it using some kind of a roller or hand compaction or whatever you want to do So that you have this 2 meters deposit. The issue really would be that how do we measure compaction. Now compaction one of the methods of parameters that is quantifiable perhaps is density.

Now, if we are able to specify that the soil placed here has to have this density, then it becomes a performance based criteria, that we have lay down a performance criteria density that has to be achieved. Now how it is to be achieved is left out of the discussion for all practical purposes. Another way of looking at it is that whether the density

achieved or not it should be placed in a certain number of layers there should be certain number of passes as far as the roller is concerned the soil should have a certain amount of moisture because that will facilitate compaction. If we lay out the procedure in all the steps without is specifying acceptable density then we are only doing a part of the job.

What is important to appreciate is finally, what is the parameter that we are interested in, are we measuring that parameter directly or we are doing it indirectly. And if you are doing it indirectly are we concentrating too much on the procedure, or we have somehow trying to simplify the procedure and the procedure is representative of the actual conditions. So, these are the kind of thought processes which one must go through before adapting and actually using a test method.

So, now coming back to our discussion on concrete.

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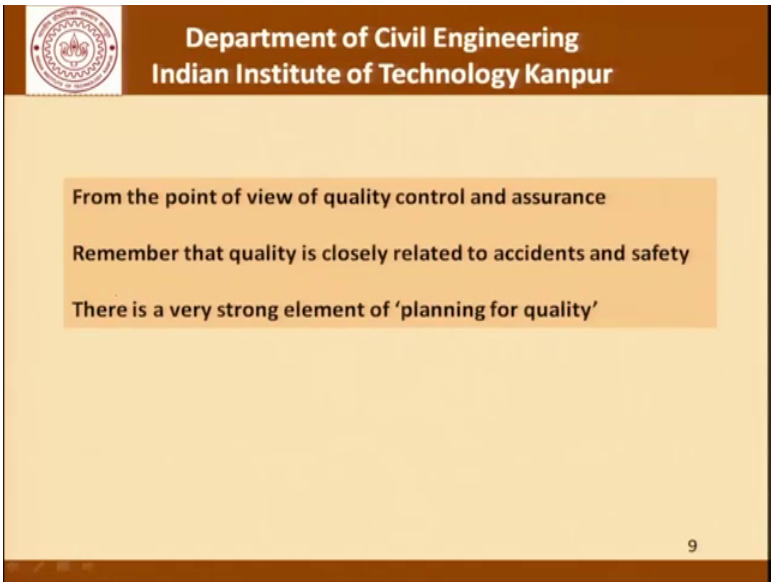

From The point of view of quality control and assurance remember that quality is closely related In fact, to accidents and safety. And there is a very strong element for planning for quality much as we discuss the issue of planning for safety. Now before we take up an example of relation between Quality and safety.

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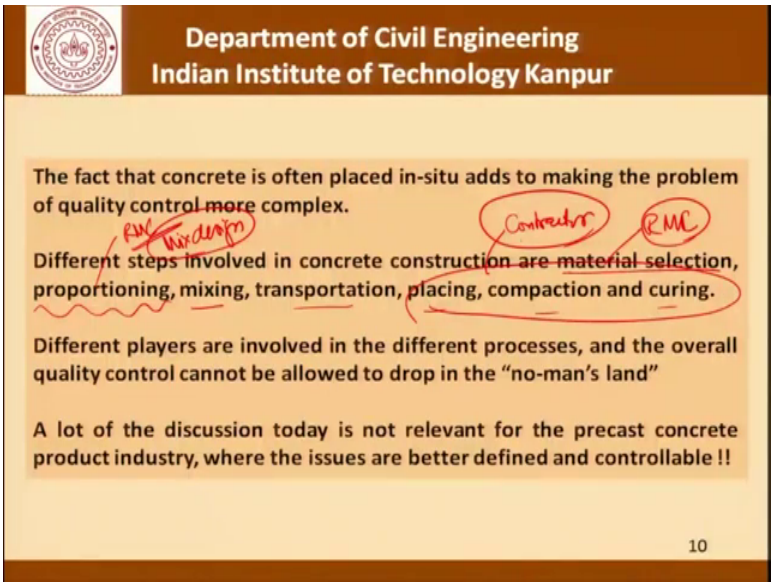

Let us go through this slide which says that the fact that concrete is often placed in situ only adds to making the problem of quality control more complex in concrete.

Different steps involved in concrete construction are material selection, proportioning, mixing, transportation placing compaction and curing. Now each of these processes have to be carried out in an acceptable manner in order to ensure that the final concrete construction is acceptable.

We must also remember that these processes are interdependent. The situation is even more interesting because different players are involved in the different processes and the overall quality control cannot be allowed to drop in the no man's land. Material selection mixing and transportation this is done typically under the control of the ready mix concrete manufacturer.

The proportioning could be done by the RMC or it could be a part of a mix design which is given to the concrete manufacturer with some amount of leave way. The placing compaction and curing this happens directly under the supervision of the contractor. So, at the end of it the contractor is using concrete and carrying out the placing compassion and curing of that concrete which has been delivered to the site from the RMC plant.

So now if at the end of the day the concrete does not perform the weight was supposed to, there is an issue. RMC plant can see that we supplied the right concrete, because the

contractor did not place it properly compacted properly or cure it properly it did not reach acceptable standards and on the contractor side they can say that the concrete was poor as far as the quality of supplies concerned. So, this actually makes the quality control interesting and at the same time of course, challenging.

A lot of discussion today of course, is not relevant to precast concrete products, where the issues are more defined uncontrollable because after all precast concrete elements are factory made.

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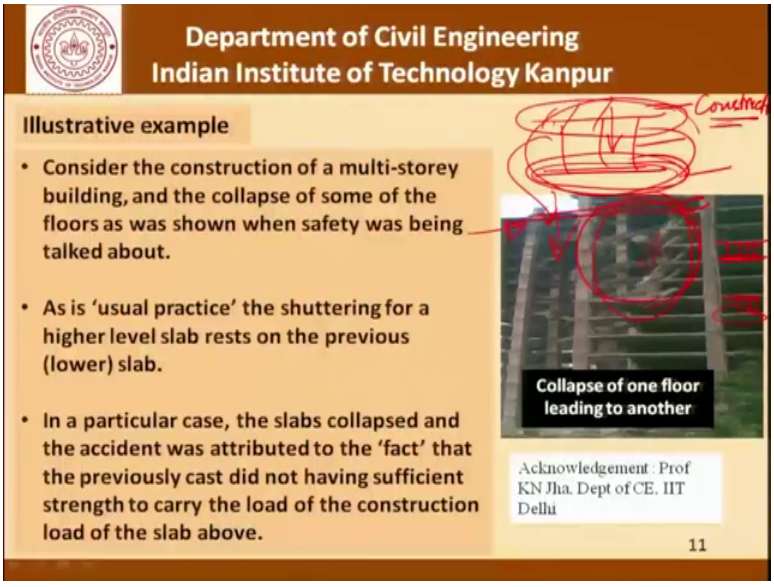

So Now, going back to our discussion on relation of quality and safety we are seen this picture and seen the collapse of these floors while the building was on construction. Now as is usual practice the shuttering for a higher level slab rests on the previous lower slab.

So, when we are casting the slab here this shuttering is resting on the previously cast slab. This slab is cast only after this slab and this slab here supports the shattering. So, something went wrong here and cause this collapse to happen. In this particular case the slabs collapsed and the accident was attributed to the fact that previously cast concrete did not gains sufficient strength to carry the loads of construction of the slab above.

So, what happens is that if this slab which is caused previously does not gain enough strength to be able to support the construction loads of the next slab this slab will give way. Now if this slab gives way; obviously, the shattering is gone and this slab also

collapses during construction. This slab here which is already cast in doing is doing fine is suddenly subjected to the load of both these slab following on this. And therefore, a domino kind of in effect likely to happen and that is what we possibly saw as far as this particular accident is concerned.

So, the quality of construction in terms of strength development is one of the likely problems in this kind of a situation. So, the quality of construction led to an accident and that is what is a very important matter to appreciate investigate and learn lessons from.

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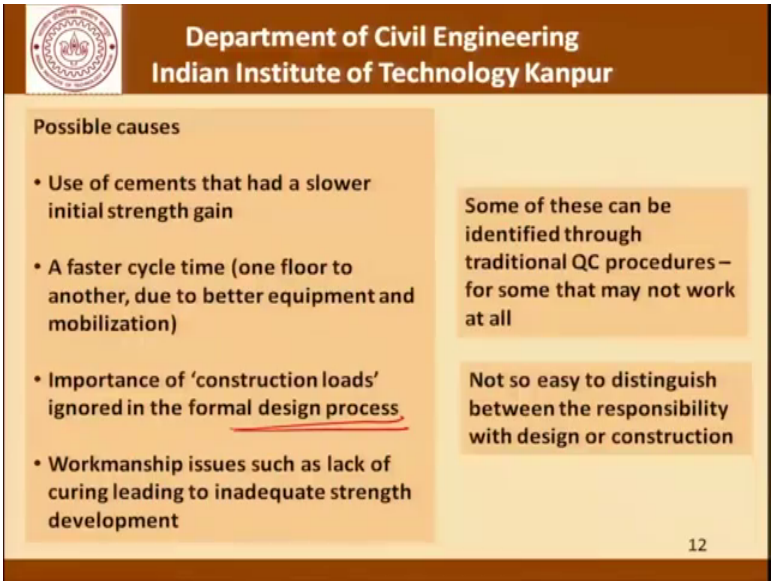

So, the use of cements that had a slower initial strength faster cycle time one floor to another due to better equipment and mobilization, in the good old days from one slab to another the fixing of the reinforcement the fixing of the shattering that would take a certain amount of time. But with mechanization that can be done much faster, we have better and different cements where the strength development is generally faster.

Importance of construction loads which sometimes ignored in the formal design process workmanship issues such as lack of curing leading to inadequate strength development. So, these are some of the possible causes of the situation that the slab on which the shattering was resting did not gain sufficient strength.

Now, if the design process not considering the construction loads is a failure of the design process. Why I am highlighting this is to only draw your attention to the fact that

quality control or quality construction as far as concrete construction is concerned also has a very important part in the design office. So, the design office has also to be able foresee a lot of things. Most of the time they do it is not that it is not done, but it is only a matter of highlighting, it is only a matter of better communication between the site and the design the site it may happen that the temperatures maybe such or the material may be such that the kind of assumption which the designer has male in terms of strength development that is not happening. And if that is the case then the designer has to be flagged that well we have changed the materials here the temperature is different here the kind of strength gain that we are getting is only this much. So, would you like to change or alter some parts of the design process the construction sequence and so on and so forth.

So, moving forward some of these can be identified through traditional quality control procedures for some that may not work at all. So, it is not easy to distinguish between the responsibility with design or constructions. So, those are matters which once an accident happens there is always going to be a tarsal and plane game and that is something which is part of our professional life, but it should be carried out in a manner that we do not repeat accidents.

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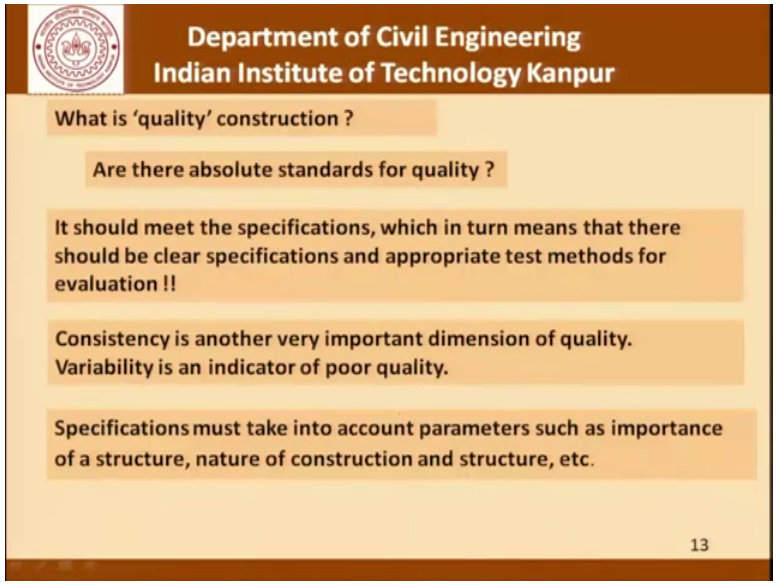

Now what is quality construction? Especially in the context of concrete construction are there absolute standards for quality.

Now, quality means it should meet the specifications which in turn means that there should be clear specifications and appropriate test methods for evaluation we have already talked about this. Consistency is another very important dimension of quality. Variability in quality is a very, very poor indicator as far as quality is concerned. Specifications must take into account parameters such as importance of structure nature of construction and structure and so on.

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Now Issues relating to quality control and assurance in concrete construction cannot be looked in isolation from the stages in construction and the specifications for the job. And these specifications need to address challenges on account of using new materials or different materials which are not traditionally used, mechanization in the construction process and the changes in the professional environment.

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Now as far as quality construction is concerned we have talked about this considerably as far as this discussion today is concerned that quality of concrete construction is affected by the quality of work at each step.

Therefore apart from the narrow view that the requirements at each step are met the larger global picture should also not be lost sight of. And given the far reaching implications quality at each step should be seriously considered and planned for at each step.

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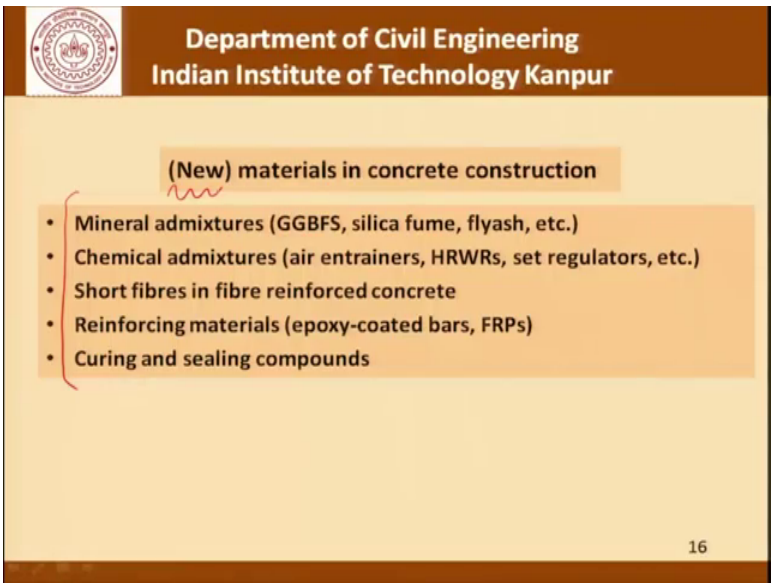

As far as materials are concerned we are routinely using blast furnace slag silica fume fly ash especially fly ash in our cements, in the concrete chemical admixtures are also routinely used whether there air entrainers, water reduces or set regulators the sometimes we use short fibres and that is when we get fibre reinforced concrete. We use different kinds of materials epoxy coated bars fibre reinforced plastics as far as reinforcing material, we have talked about epoxy coated bars and the quality issues related to epoxy coated bars in a previous discussion, and curing and sealing compounds. So, these materials are routinely used, they are not new to that extent anymore and they affect the test methods. They effect this specifications as far as our efforts to ensure good quality concrete construction is concerned.

So, we must remember that whatever quality control standards we have set keeping in mind the materials being used the environment in which the concrete is going to be placed and so on. So, as far as mechanization is concerned that also has it is own implications As far as drawing of the right kind of standards is concerned.

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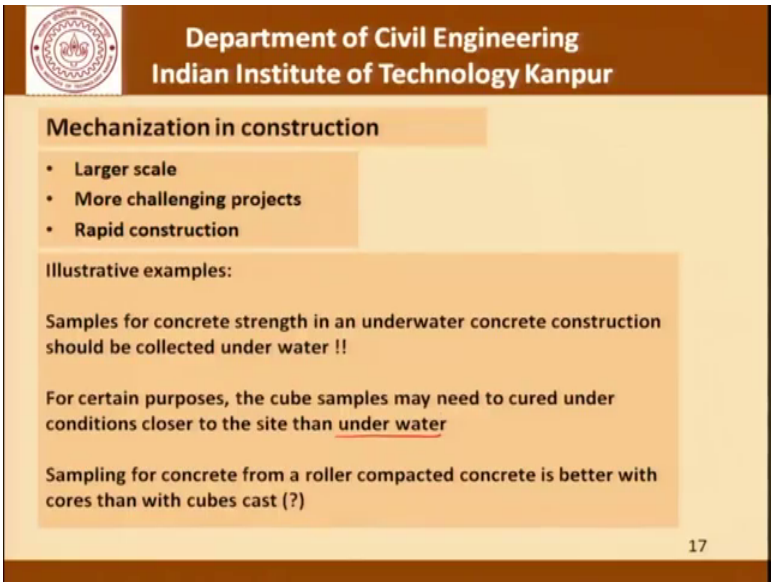

We now are able to do concrete construction at a much larger scale in more challenging projects, we can do construction much faster. Let us also now take a few examples as to how different environments, the construction being carried out in different environments, how does it affect the quality control procedures.

Samples for concrete strength in an underwater concrete construction should be collected underwater. So, it does not make any sense to collect the concrete samples in air even though concrete is being mixed in air, but it is been placed underwater, it is going to remain underwater and has been designed as an underwater concrete.

So, if you want to find out the strength of that concrete because the sampling underwater is likely to be different from sampling in air is more challenging. We must keep in mind that the cubes that we collect should be representative of the kind of construction all the kind of member where the concrete has been placed. And in this case when it is an underwater concrete the concrete has been placed under water. The member where the concrete is underwater and therefore, in order to get it is representative strength it is imperative that the sampling is also done underwater. For certain purposes the cubes samples may need to be cured under conditions which are closer to the site than under water. Indeed underwater curing at a certain temperature is the standard way of curing and determining the strength at 28 days. At times it may be important to also have some tests some cubes which are being cured under conditions which are closer to the site condition if for nothing but for only comparison of the strength gained under those conditions with respect to cubes cured underwater.

Sampling for concrete from a roller compacted concrete is better done with coarse than with the cubes cast. Now this is something which I am not going to answer here a leave it to you to think that if we are casting a roller compacted concrete, how should the sampling first time we done? It is very difficult for that concrete to be cast in cubes we can do it we can vibrate the cubes and so on, but is that the way that the concrete element is in the roller compacted concrete itself. No, the roller compacted concrete element is concrete placed in a certain thickness compacted with a row vibratory roller and left there with curing and so on.

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Moving forward, There is a changing professional environment which has it is own implications as far as quality control is concerned. Traditional client contractor consultant relationships has undergone a major change. Government participation in public in large projects has been redefined in the role of regulatory bodies, and with the increase in the size of projects international participation has increased and private public partnership is a new mantra.

Basically why I am bring the subject of again in this context is that ensuring quality construction is everybody is responsibility. The issue is there is a cost associated with quality because all these tests that are carried out are not free they cannot be carried out for free. And somebody has to bear the cost.

Now, in the traditional system the test for simple and the cost could be worked out people knew exactly what is going to happen and so on, now in the present situation where construction industry has gone through changes and the contractors the clients the regulators they have their own way of looking at a certain project, what happens to quality control. Overriding principal is that yes nobody will subscribe to the belief that quality can be compromised, but who should bear the cost. And that is why it is impotent to understand that element in drawing up the kind of plants that are required for quality assurance in construction.

Decision making is carried out in the framework of the contracting.

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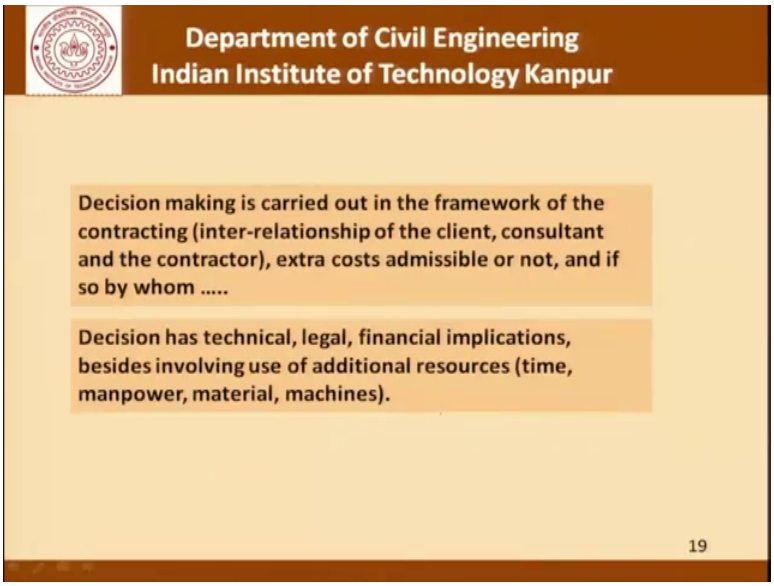

Which is interrelationship between the client consultant and the contractor and extra cost and whether they are admissible or not. And if so by whom? These are questions that need to be built in into the contract documents. For example, sampling underwater taking coarse from a roller compacted concrete these are situations which are extremely simple, but can be taken up as a case where additional cost will be involved in even sampling. And whether or not the contractor who may be charged with the responsibility of ensuring the strength of concrete whether that additional cost should also be borne by them in certain cases yes it is obvious, but in certain cases it is not. So, obvious decisions relating to quality control have technical legal and financial implications beside involvement of additional resources in terms of time manpower materials and machines.

So, these are kind of things which have opened an entirely different dimension to quality control exercises as far as concrete construction is concerned.

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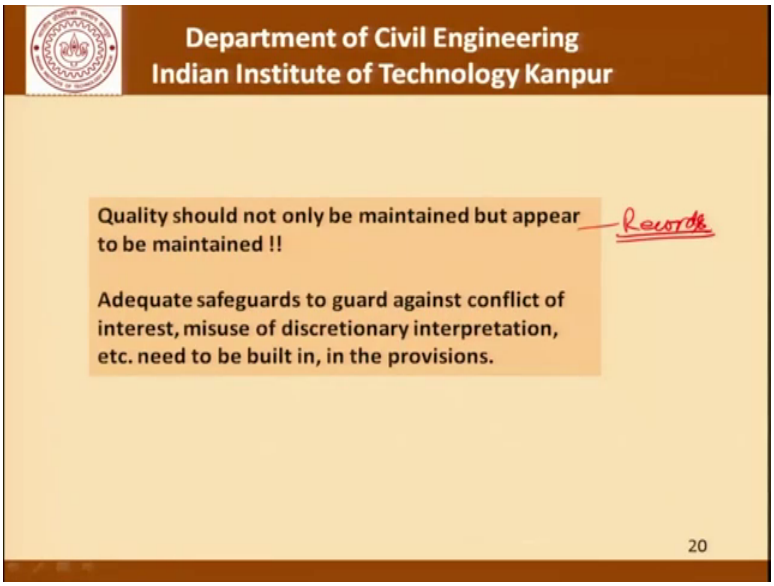

Importantly Quality should not only be maintained, but appear to be maintained which means that they have to be records which have to be systematically maintained So that at a later point and time they can be referred too. Adequate safeguards to guard against conflict of interest misuse of discretionary interpretation need to be built in the provisions.

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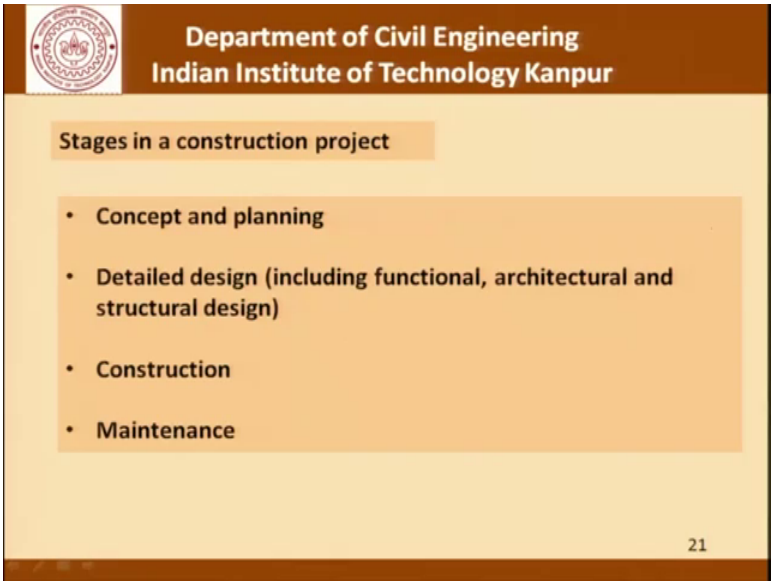

And stages in the construction process could include; obviously, concept and planning, detail design including functional architecture in structural design construction and

finally maintenance. As far as we are concerned in today's discussion, we are talking primarily in detail design and the construction phases and the quality control issues relating or arising.

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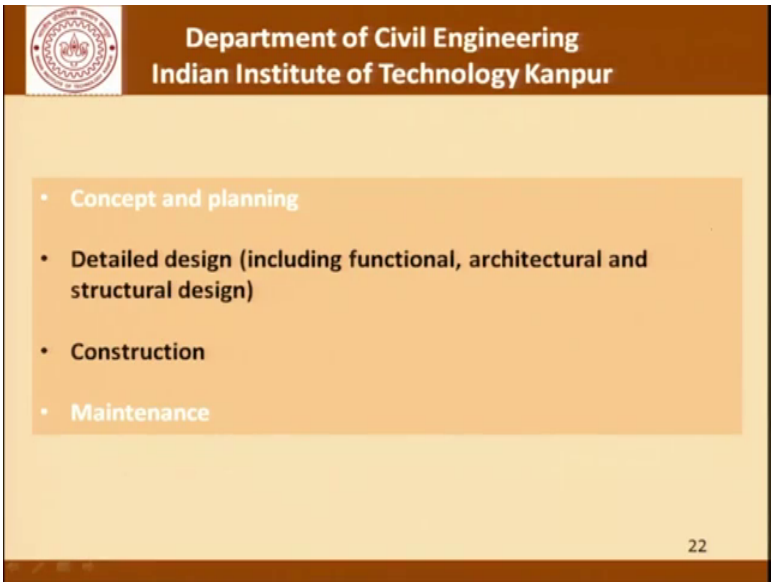

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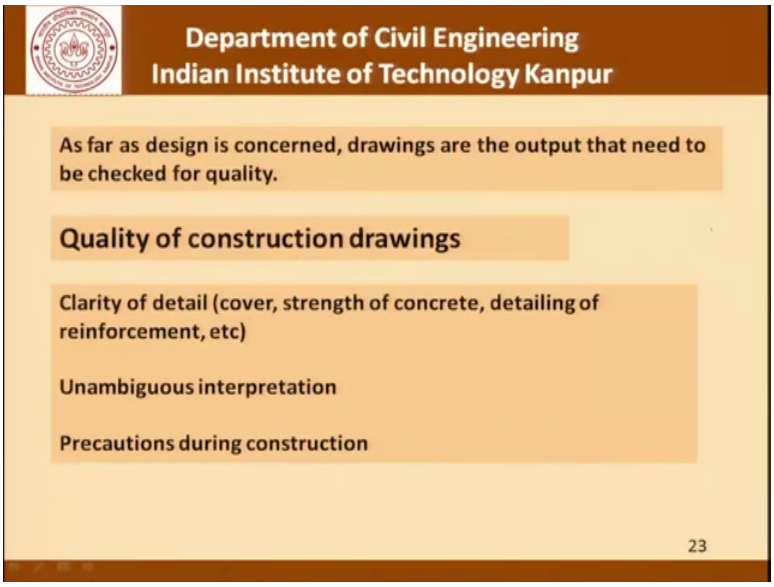

There and as far as the design is concerned drawings are the output that needs to be checked for quality.

Quality of the construction drawings is a very important issue when it comes to ensuring quality of the final construction. There has to be clarity of detail cover strength of

concrete detailing of reinforcement and so on. The drawing should not be ambiguous. And they should also clearly put forward the precautions during construction. We will talk about the issues relating to the collapse of those slabs at the outset of this lecture today. And that is some of the things that can be addressed in the quality of the construction planning construction drawing stage.

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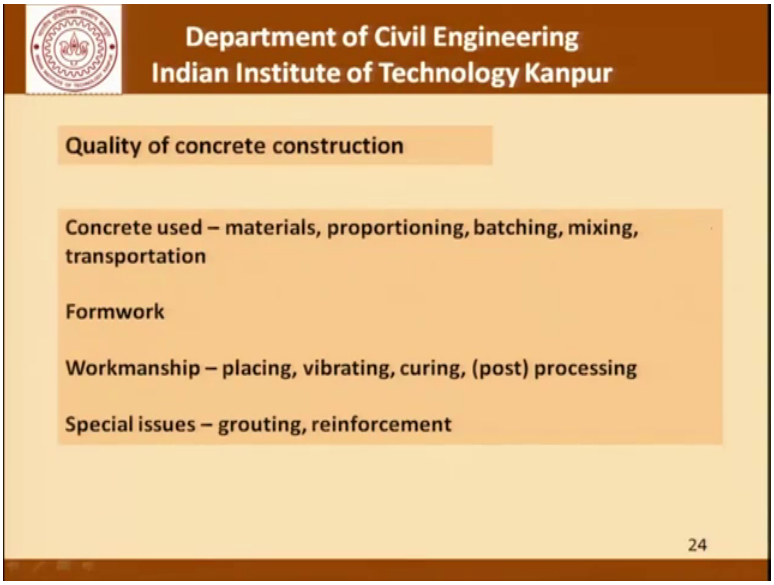

As far as the quality of concrete construction is concerned the concrete used has issues with materials proportioning batching mixing and transportation other than placing curing and compaction. We have talked about that formwork workmanship that is placing vibrating curing and post processing and special issues which will be in grouting in reinforcement.

So, these are some of the things that directly contribute to the quality of concrete construction.

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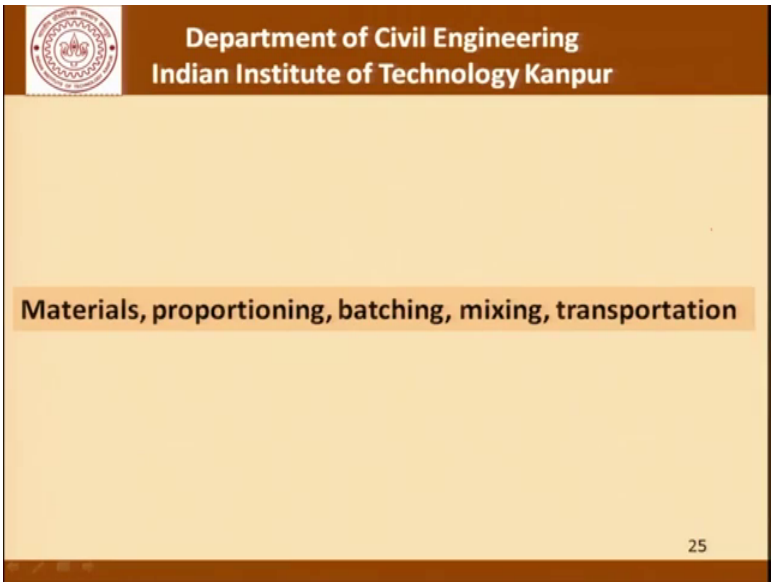

Now coming to materials proposing batching mixing and transportation since it is not a discussion majorly on concrete engineering. I will skip some of the discussion.

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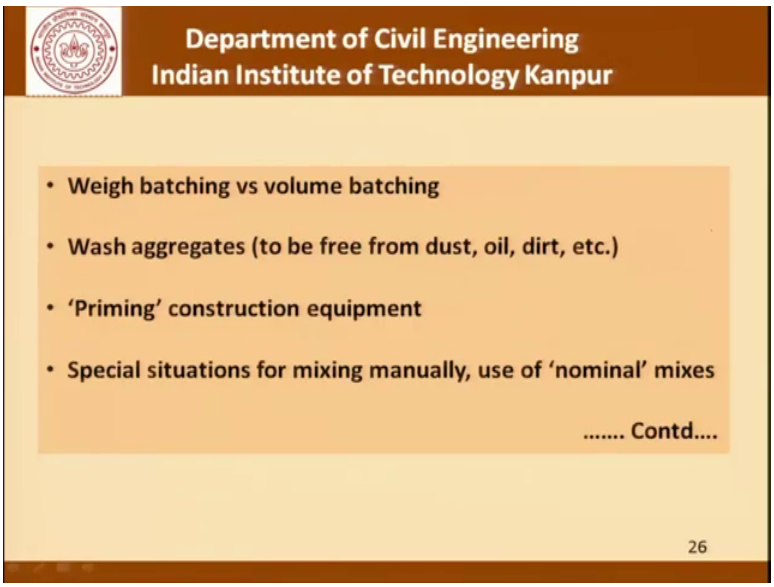

Assuming that you already know about it. There are issues relating to weigh batching and volume batching there is the issue of washing of aggregates to be free from dust oil and dirt. There is the issue of priming construction equipment whether it is the trucks whether it is the mixers. There are special situations where mixing is allowed manually

and has to be carried out and in those cases what should be the kind of mixtures used there is a provision for nominal mixes as far as India is concerned.

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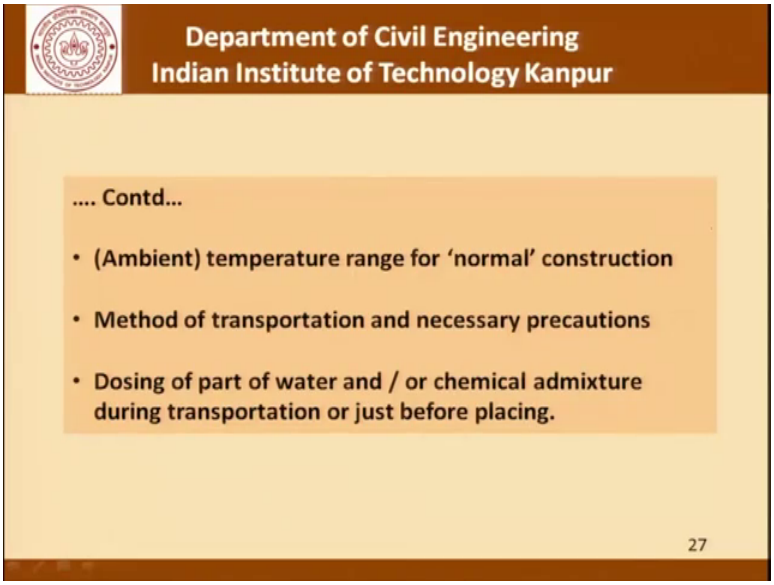

And moving forward there is an issue temperature in the normal construction what should be the ambient temperature or what should not be the ambient temperature there will be a forbidding clause, that is concrete should not be caused if the temperature is below a certain number if it is higher than a certain number. Methods of transportation and necessary precautions dosing of part of water and chemical admixtures during transportation or just before placing, this is a practice which is very often frowned upon by engineers and quality control experts.

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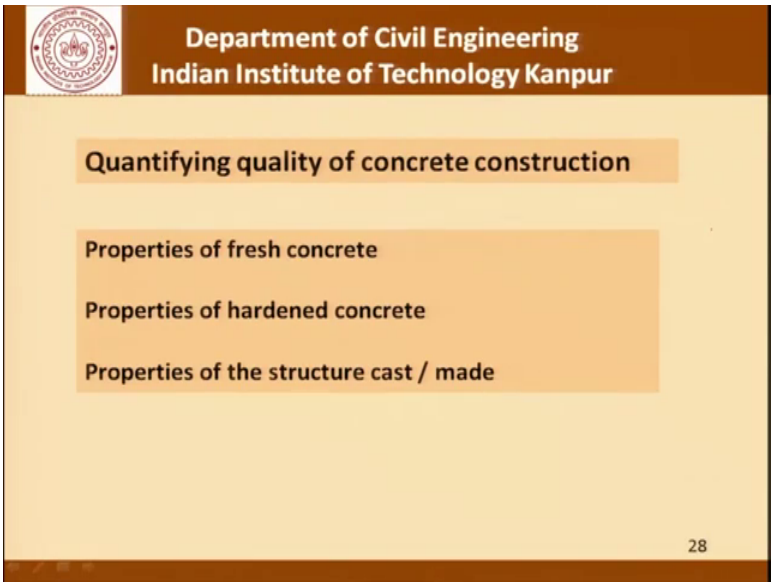

As far as quantifying the quality of concrete construction is concerned, we can do it in terms of properties of fresh concrete. We can do it in terms of properties of hardened concrete and we can do it in terms of properties of the structure cast or made. So, what we are trying to mention here is precisely the issue of material and component. When it comes to concrete as a material we could be talking of properties in the fresh state and we could be talking of properties in the hardened state.

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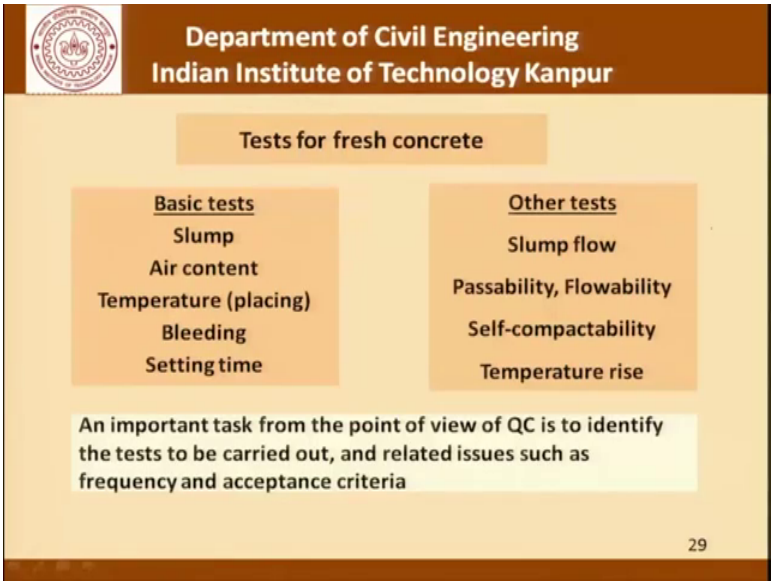

Now, as far as the fresh state is concerned the test could be slump air content temperature at placing bleeding and setting time, there could be other tests such as slump flow possibility, flowability, compatibility, temperature rise. So, the engineer has to make a decision on what and which of these tests are relevant are they relevant and should be carried out in toto following lay down procedure or there should be changes made.

So, it is an important task from the point of view of quality control to identify the tests that need to be carried out and related issues such as frequency and acceptance criteria.

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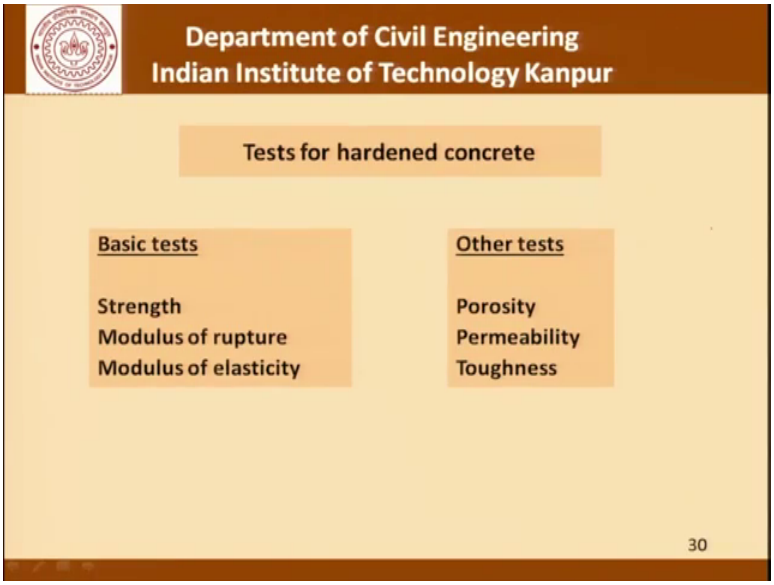

As far as hardened concrete is concerned strength modulus of rupture and modulus of elasticity are is known in standard test. To that list porosity permeability toughness are additional test which are gradually creeping into our framework for quality control in concrete construction and again here also the engineer whether it is a design engineer or the field engineer they have to decide they have to lay down the standards which are required. The test method should be followed and the specifications which would be use to accept or reject the concrete.

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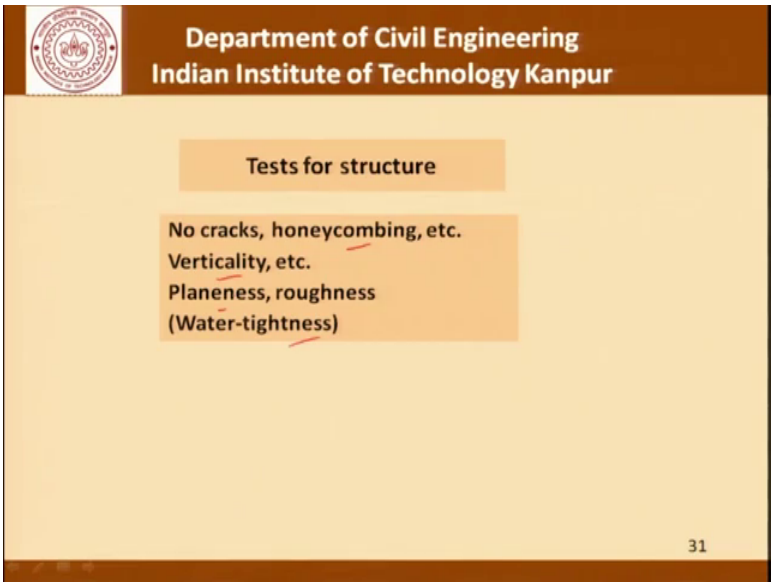

As far as testing the structure is concerned there have to be again clearly defined parameters such as no cracks, honeycombing, verticality of the structure planeness or roughness, water tightness, these are some of the test of performance requirements not from the concrete material, but for the structure. Of course, water tightness and honeycombing would depend on the kind of concrete that has been used verticality, planeness, would depend on the kind of formwork that has been used.

Finally we must remember that it is not the concrete which is being accepted. It is the structure which has to be accepted. Of course, in order for the structure to be accepted we should be placing acceptable concrete under acceptable conditions So that their performance requirements at the structures level is met.

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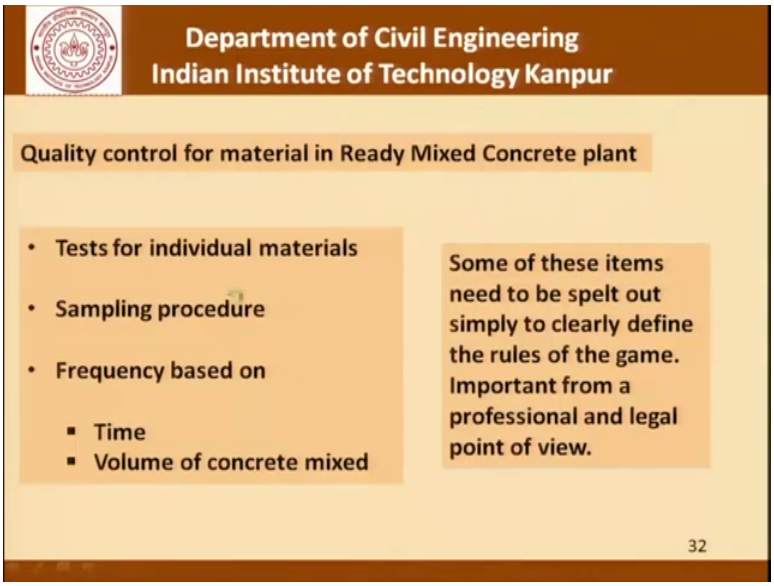

No, as far as quality control for the material in the ready mixed concrete plant is concerned we can have tests for individual materials, sampling procedures and frequency based on time and the volume of concrete mixed. Some of these items need to be spelt out simply to clearly define the rules of the game and is important from a professional and legal point of view.

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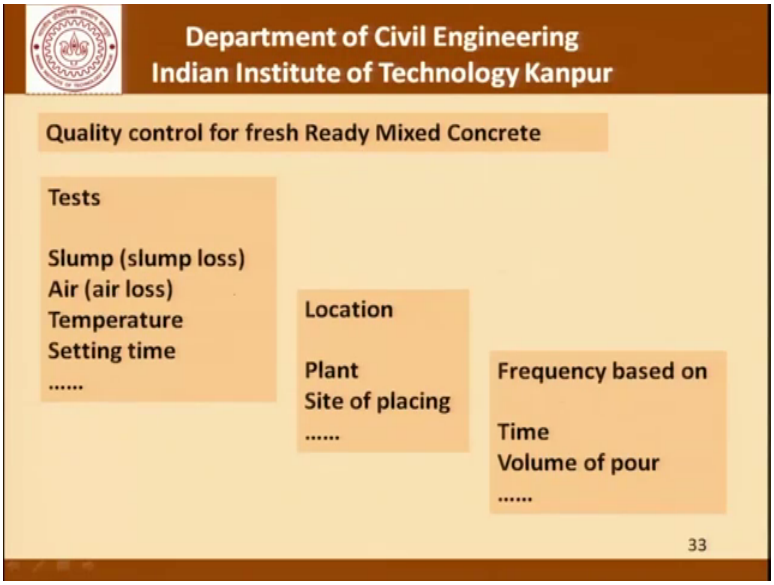

Now continuing our discussion on the quality control test for fresh ready mix concrete, there should be test for slump air setting time and temperature we could add slump loss

or air loss as an additional test. There is a location which is involved that is whether test should be carried out at the plant or they should be carried out at the site of placing the frequency which is involved whether it is related to time or the volume of the pours.

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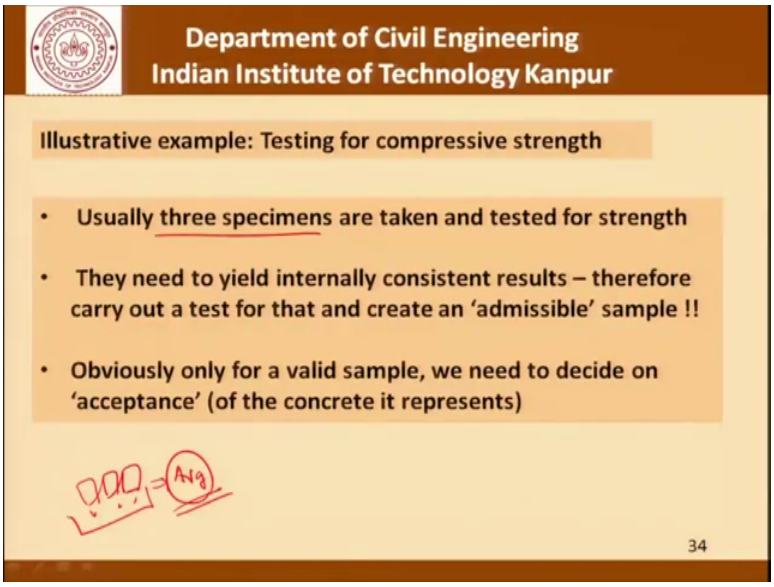

As an illustrative example as far as testing for compressive strength is concerned, usually 3 specimens are taken and tested for strength. They need to yield internally consistent results and therefore, we need to carry out a test for that and create an admissible sample. Whether the sample itself is admissible or not; obviously, only for a valid sample that is an admissible sample we will decide on the acceptance criteria. I am leaving it to you to check whether all codes require 3 specimen to be tested as far as Indian codes are concerned most of the time we say that they will be 3 cubes which will be tested and an average will be taken. And that average will be used for further processing provided there is internal consistency in the results of these 3 cubes. Now whether 3 are used by other standard as well is something which I am leaving to you to think and determine.

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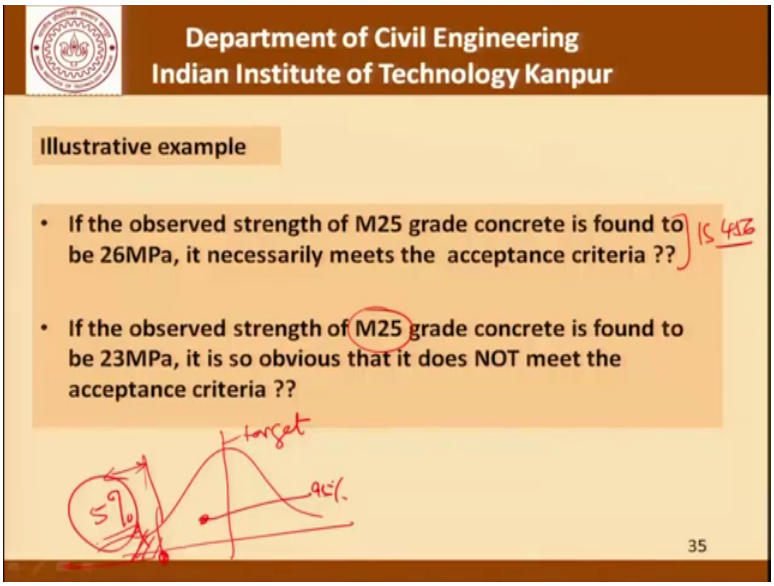

Let me ask you a question. If the observed strength of M 25 grade concrete is found to be 26 Mpa. That is the average of the 3 cubes is 26, does it mean that the concrete is necessarily acceptable? That would depend on what is the acceptance criteria being established, being followed as far as a particular project is concerned, as far as this question is concerned, if you examine this question in light of provisions of IS 456.

What would be answer be? Similarly if the observed strength of M 25 concrete is found to be 23 Mpa, that is the average of those 3 cubes is 23 Mpa, is it obvious that it does not meet the acceptance criteria? I would only have you recall that as far as the definition of characteristic strength is concerned which is important to recall because we are talking of M 25 grade concrete M 20 means the characteristic strength is 25.

We talked about a normal distribution an expected normal distribution as far as concrete is concerned, we designed our concrete mix at what is called the target mix and we define the characteristics strength here somewhere where we said that this area here is 95 percent that is characteristic strength is that strength which under normal conditions would exceeded 95 percent of the times, we are allowing 5 percent failure.

Now, the question really is that whether this 5 percent is allowed no matter where the strength is the issue really boils down to how much lower than the characteristic strength can an actual strength be. That is something which will depend on different standards and I am leaving it to you to identify it with respect to IS 456. Similarly to say that if the

strength is just higher than FCKN it is acceptable that also has it is own problems and that is something which I am leaving to you as a homework.

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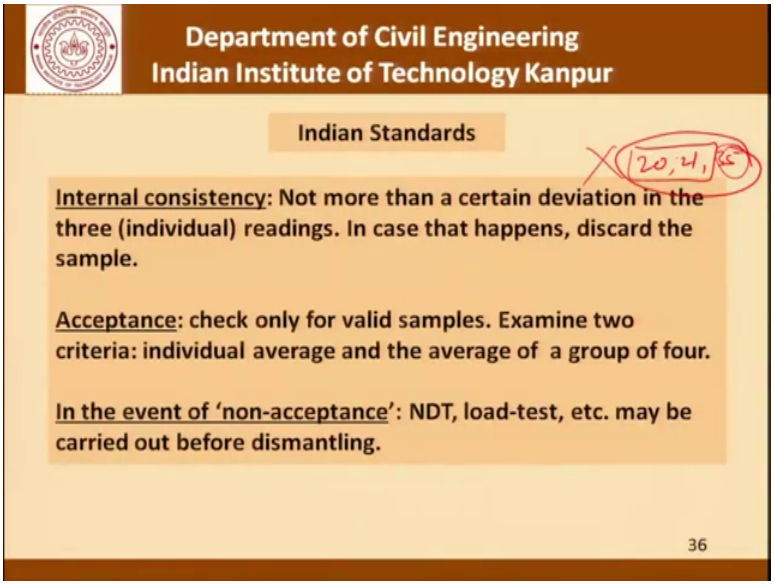

As far as the Indian standard is concerned not more than certain amount of deviation in the 3 individual reading is allowed and in that case the samples have to be discarded as far as Indian codes are concerned. For example, if we get 20, 21 and 35 as 3 readings there are 2 ways of handling it we may say that well this guys an outlier, let us work with the average of these 2, but the Indian codes say no if there is an outlier this sample should be rejected all together.

Acceptance check only for valid samples for example, this sample would not be even processed for further action, examine 2 criteria individual average and the average of group of 4. In the event of non-acceptance carry out non distractive test load test and so on, before taking a final decision on dismantling the structure.

We must understand and remember all the time that quality control especially large projects has very severe cost implications. And therefore, before we take a decision as far as dismantling is concerned rejection is concerned, there will be lot of pressures in terms of finances in terms of time, if for example there was that accident no matter what caused it. There is the clock being set back, the project will suffer as far as time is concerned. There will be additional cost involved. So, cost is a very important part of quality as far

as construction is concerned. And that is something which we must keep at the back of our mind when it comes to additional tests different tests and so on.

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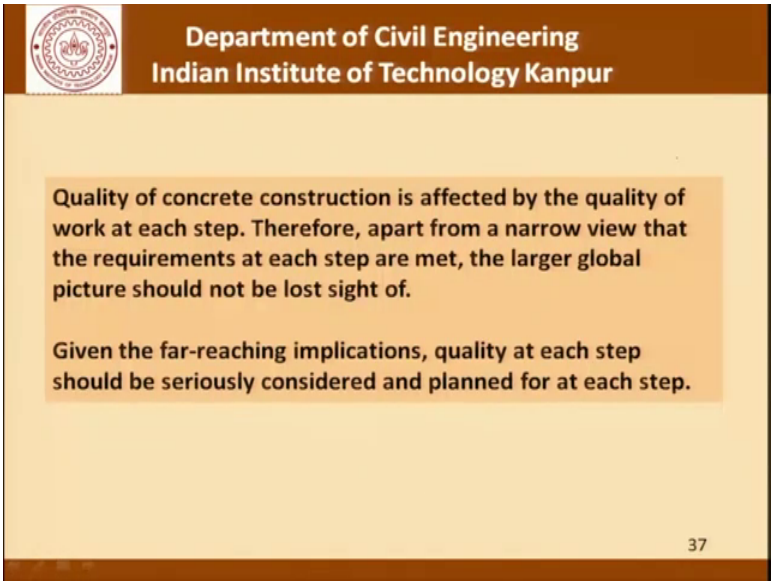

So, quality of concrete construction is affected by the quality of work at each step and therefore, from a we should not work in a narrow perspective and try to have the global picture in mind as far as possible. And given the far reaching implications quality at each step should be seriously considered and plant for, this is something which have emphasized in the previous slides also that quality reach the quality plan. In fact, you would recall that we are talking of planning as far as construction project is concerned, we said that has to be a safety plan there is the quality plan there is a resource plan and so on.

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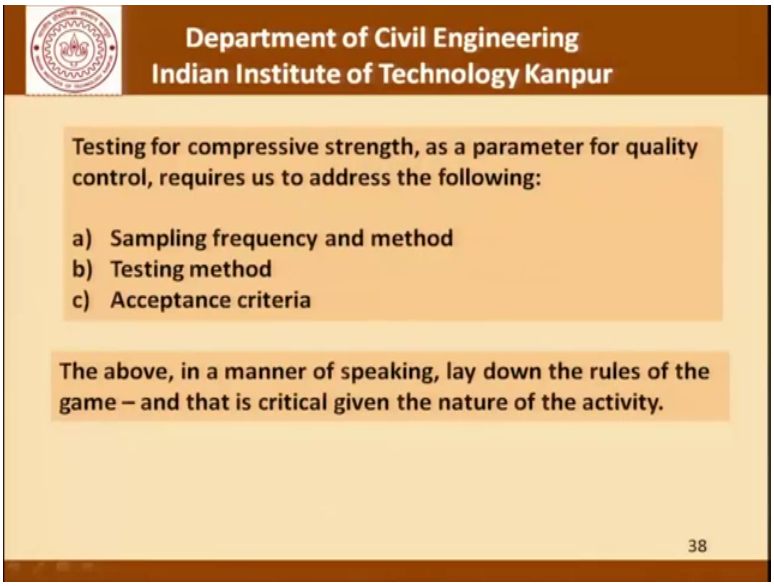

Now, testing for compressive strength as a parameter for quality control requires to address the following issues, that is sampling frequency and methods the testing method itself and the acceptance criteria. The above in a manner of speaking lay down the rules of the game and that is critical given the nature of the activity.

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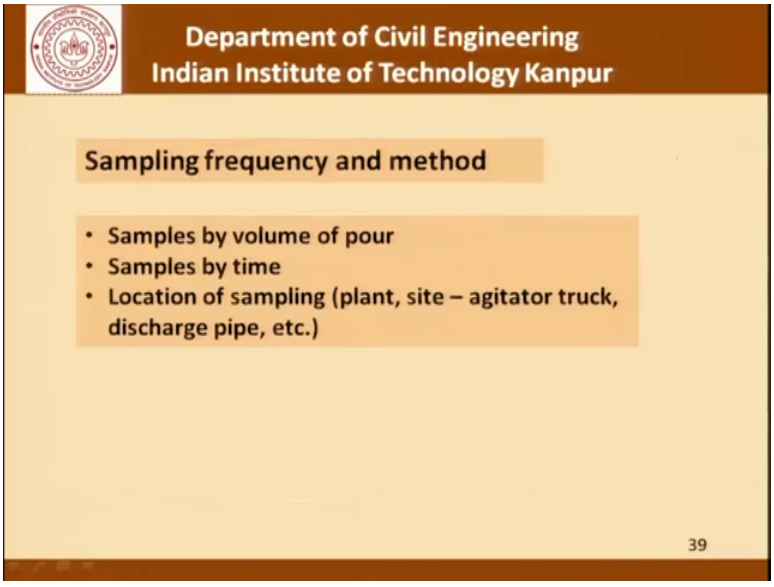

As far as the sampling frequency and method is concerned it could be the volume of pour it could be the day or that is time everyday it has to be taken regardless the volume pour involved, it is location of sampling whether it is plant site agitator truck discharge pipe

and so on. We must remember that concrete is likely to undergo changes depending on what location it is in.

The concrete which has being made at the plant will undergo some changes by the time it is placed in the beam or the column or the wall at site. Now from the point of view of quality control what is the point in this journey of concrete where the sampling has to be carried out, we have to answer the question, why we are doing it? If we are doing it from the point of view of determining what is the kind of concrete that has been actually placed in the site then; obviously, the last point is the best point.

But if we are also having in mind to determine whether the concrete supplied to us was good is not. Then we need to sample at either the plant or at the time when it is just delivered to the site.

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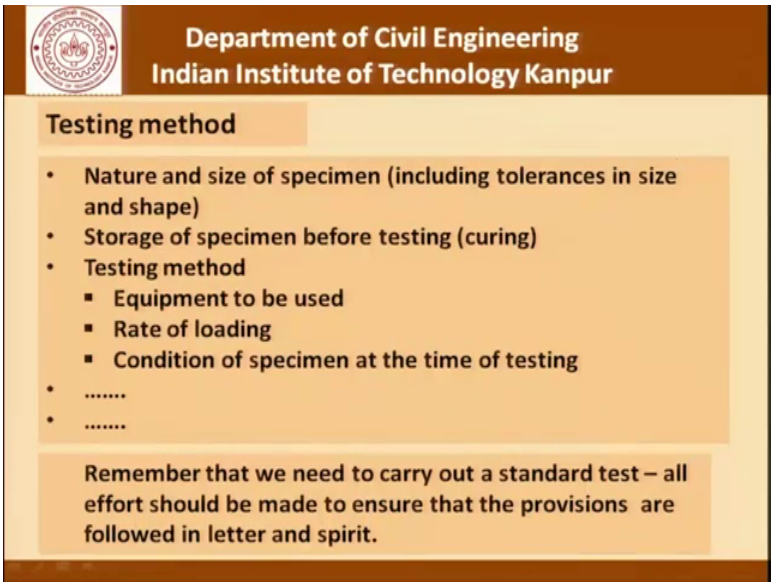

As far as Testing methods are concerned the nature and size of specimen including tolerances in the size in the shape storage of specimens before testing that is curing.

Testing method which includes equipment rate of loading the condition of specimens at the time of testing and so on. These are all part of the regime or the protocol which has to be followed when it comes to the testing method, and it is suitability for determining the strength. Remember that we need to carry out a standard test all efforts should be made to ensure that the provisions are followed in letter and spirit.

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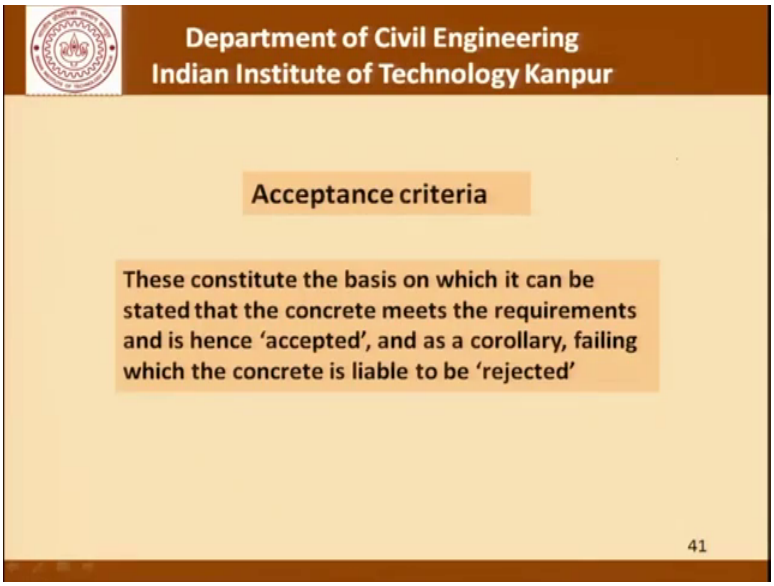

As far as Acceptance criteria as concerned these constitute the basis on which it can be stated that the concrete meets requirement and essence accepted. And as a corollary to that feeling which the concrete is liable to be rejected. So, this has to be lay down very clearly as far as contract documents are concerned as far as quality control manuals are concerned.

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And considerations that go in to defining an acceptance criteria could be the definition of characteristic strength.

Reasonableness in the criteria decision making lay down and define unambiguous flowcharts to follow, number of specimens to obtain a representative value and how to handle non-acceptance. All these have to be a part of a document of the quality control procedures for concrete construction.

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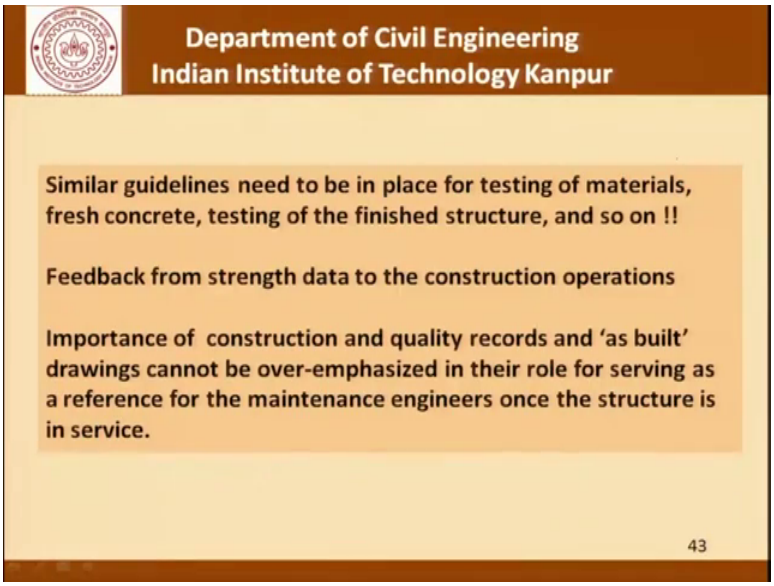

Similar guidelines need to be in place for testing of materials fresh concrete testing of the finished structure and so on. Feedback from strength data to the construction operations this is what we talked about right in the beginning and we are talking about that accident or that factious accident or factious causes of that accident that if there is a problem in strength development it has to be fed back to the design process. It has to be fed back to the design office the construction controllers and so on. The importance of construction quality records and as built drawings cannot be over emphasized in their role serving as a reference for maintenance engineers once the structure is in service.

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Now, before we close the discussion today as far as quality control of concrete construction is concerned I leave you with a couple of question to think about, we study the quality control Parameters for concrete construction in different specifications.

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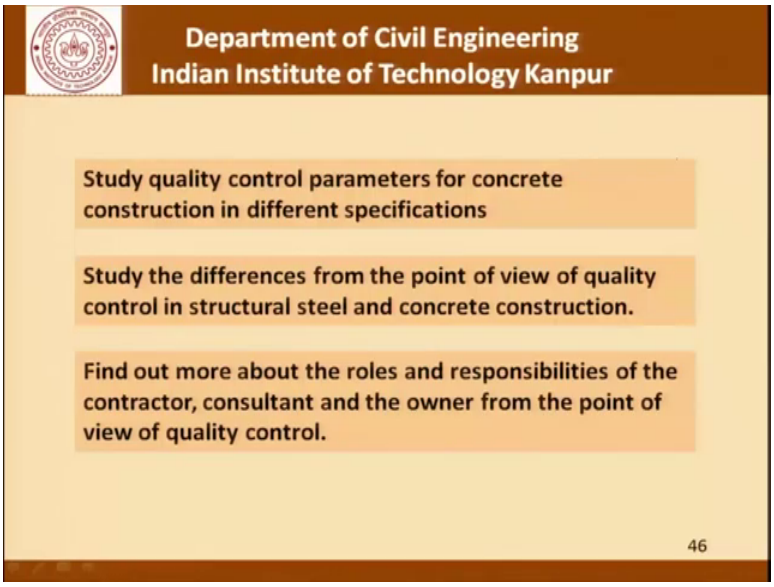

You could use specifications which are available for railways or nuclear power plants. There will be quite different and there will be an eye opener as far as you are concerned.

Study the differences from the point of view of quality control in structural steel and concrete construction. Find out more about the roles and responsibilities of the contractor consultant and the owner from the point of view of quality control.

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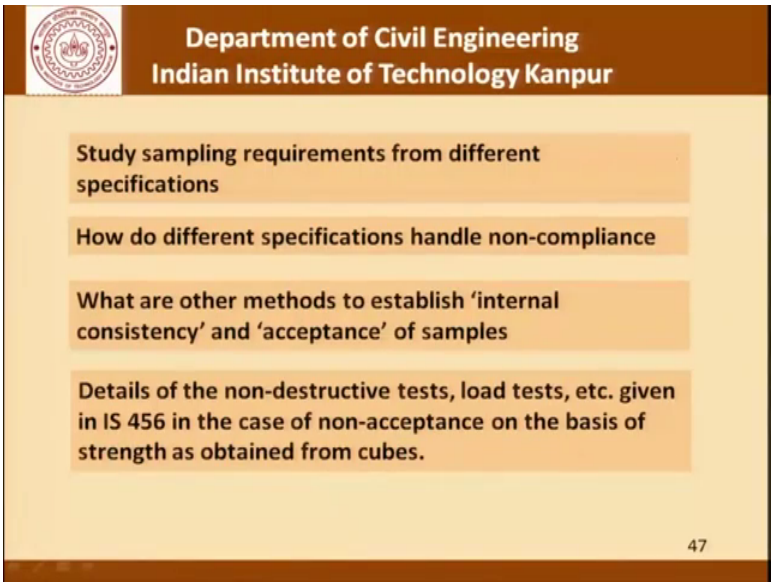

Study Sampling requirements from different specifications, how do different specifications handle noncompliance. What are the other methods to establish internal consistency and acceptance of samples as far as the Indian standards are concerned we talked about the group of 4 and the individual values the individual values should not be allowed to fall below certain number and the group of 4 must meet a certain requirement not necessarily just the FCK in order for the concrete to be acceptable. So, those of the kind of things which if you need more specifications more standards you will get a better handle of those things.

And details of non-destructive testing's load test etcetera given in IS 456 in case of non-acceptance on the base of strength as obtained from cubes. So, these are some of the obvious questions or leads from the discussion that we had today that comprised primarily of talking about quality control issues in concrete construction. It is not only related to materials the final quality is related to so many other things including workmanship as usual.

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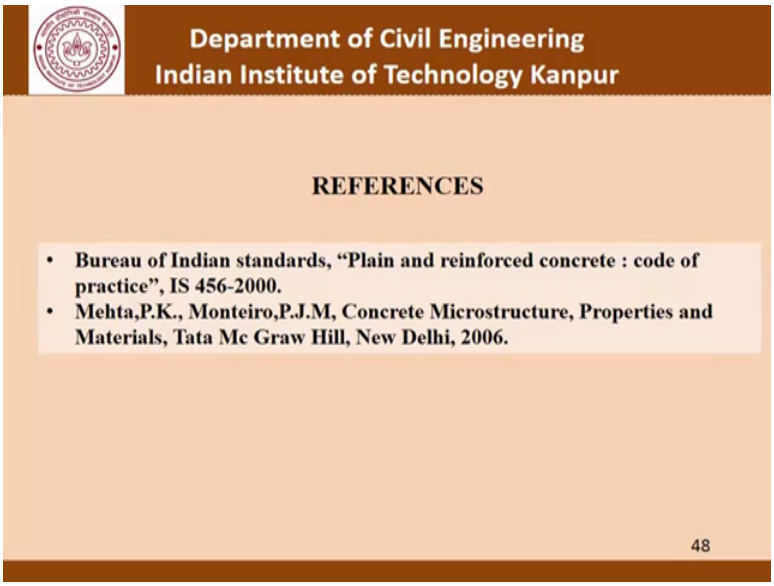

This is the list of references of some of the material that could help you understand the topic better. And I look forward to see you again in a subsequent discussion.

Thank you.