Concrete Engineering and Technology
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Lecture - 13
Quality Control and Acceptance Criteria for Concrete Based on Compressive Strength

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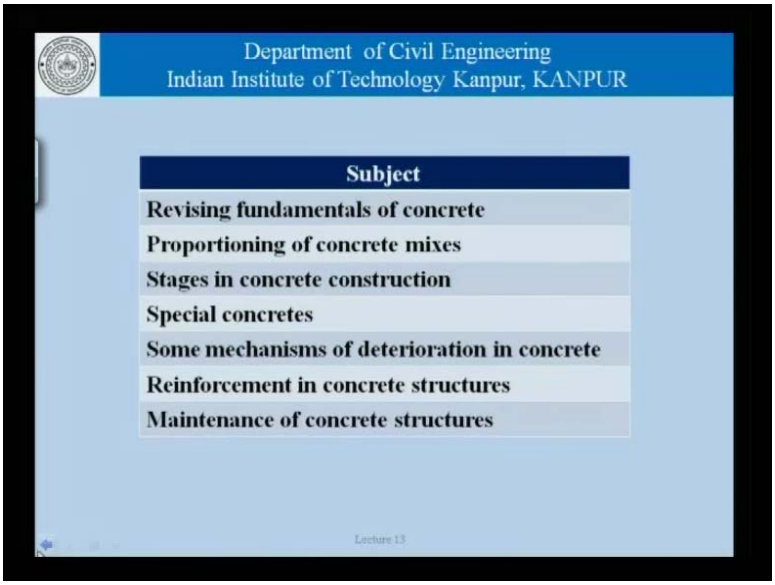

Welcome back to these lectures on concrete engineering and technology, where we are talking about different aspects related to concrete construction; fundamentals is proportioning stages of concrete constructions, special concretes, mechanisms of deterioration that we see in concrete around us, reinforcement in concrete structures and their maintenance.

Continuing with our discussion on stages in concrete constructions from the point of view of quality control and quality assurance, we saw in the last discussion that issues related to quality are very closely related to accidents and safety; poor quality construction invites accidents. And that is something, which we would like to avoid at all costs. Accidents during construction; accidents, post construction as a result of that quality construction, we need to…

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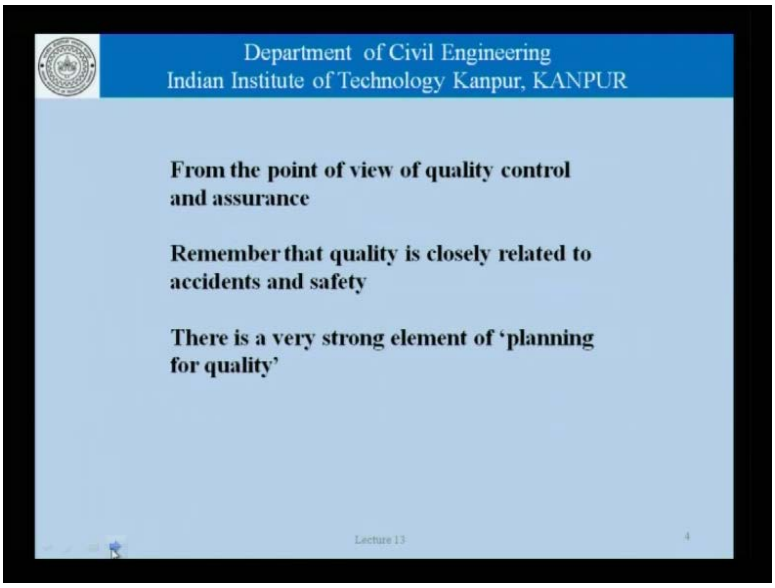

And we need to put in all efforts to ensure that, they do not happen. There is a strong element for planning for quality. That was emphasized in the last discussion, when we said that, quality of concrete construction is related to all aspects of concrete construction: material selection, proportioning of materials, mixing and so on. And each of these steps we can plan; what are the steps that we can take in order to ensure quality construction.

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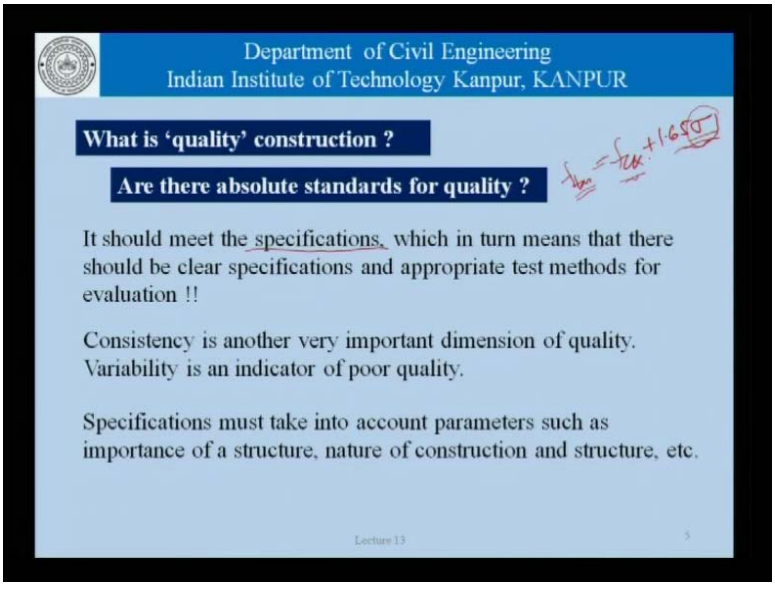

Continuing from there, we had also talked about what is quality construction and if there are any absolute standards related to quality. The basic thing is that, the concrete construction must meet the specifications. What we want from their structure should be laid down in their specifications. And we must have test methods in place, which will ensure that, what we get in the concrete structure by way of the material that we used, by way of the performance of the concrete that we have used; those specifications are satisfied. This of course in turn means that, there should be clear specifications and test methods for evaluation. Consistency we had emphasized was a very important dimension of quality. Variability is an indicator of poor quality. We have briefly discussed this aspect when we talked about proportioning of concrete mixes.

When we accept that characteristic strength plus 1.65 times the standard deviation, should be the target of the strength; we should target strength, which is equivalent to 1.65 times standard deviation plus the characteristic strength in order to proportion a concrete mix. And this standard deviation we had discussed was related to the quality control. It is related to the variability that we get in our results. So, consistency is a very very important part in quality control. The smaller the standard deviation here or in any parameter, we can assume or that is how it is defined that, lower is the variability; the data is more repeatable; it is more consistent.

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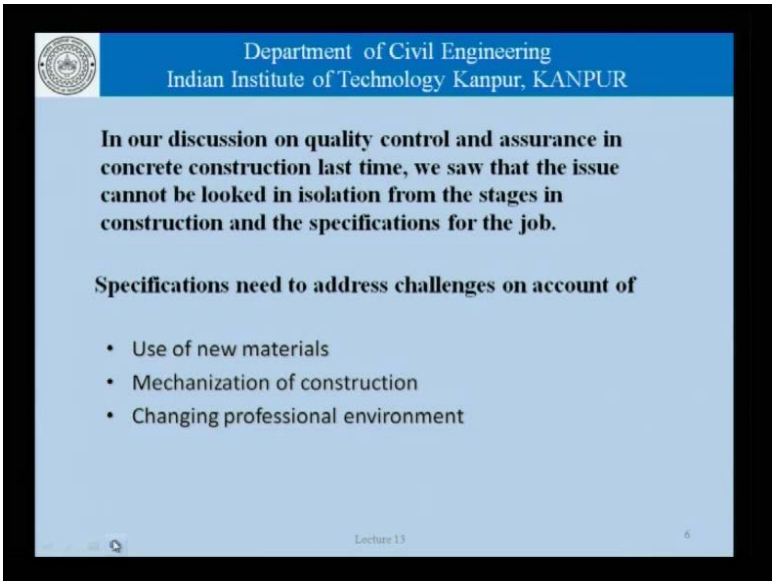

Its specifications must also take into account parameters such as the importance of the structure, the nature of construction and the structure and so on. Different structures built in different environments, need to have specific plans, specifications for those structures – the conditions in which they are built. If we are writing about building a road – a concrete road, the specifications have to be different from the concrete that is used or for the construction using concrete and buildings or bridges. So, the specifications have to be tailor-made.

When we are talking about quality control and assurance, we also saw that, the issue cannot be looked upon in isolation from the stages of construction and their specifications for the job. And the specifications need to address the use of new materials, mechanization in the construction process and changing professional environment. These issues have been talked about last time.

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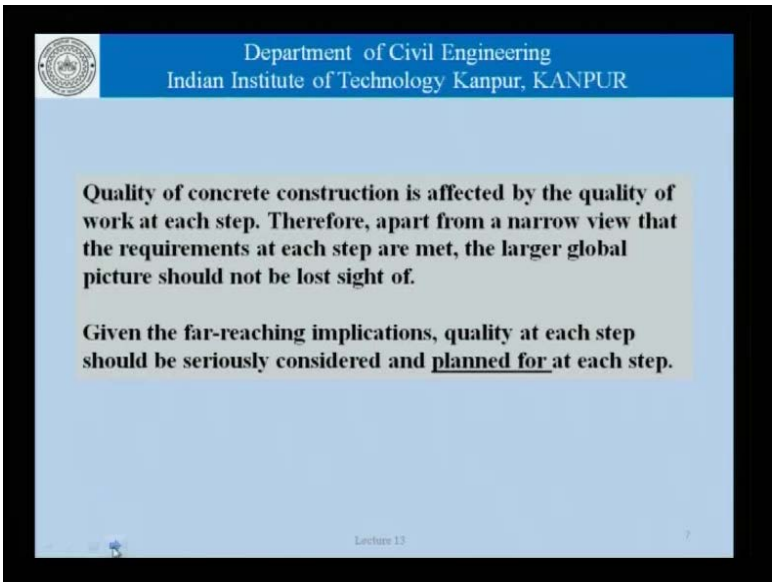

And, quality of concrete construction is affected by the quality at each step. However, we must make sure that, apart from a narrow view that the requirements at each step are met, we must ensure that the larger global picture is not lost sight of, because we may use the best of materials; we may use the best of construction processes. But, if the design itself is flawed, there is no point in having a structure of that nature; each bound to fail. So, we cannot have a very narrow view of quality. While we ensure quality at each step, the larger picture of ensuring a sound concrete structure at the end of the process, at the end

of the entire construction process, should not be lost sight off. And given the far-reaching implications, quality at each step needs to be considered seriously and planned for.

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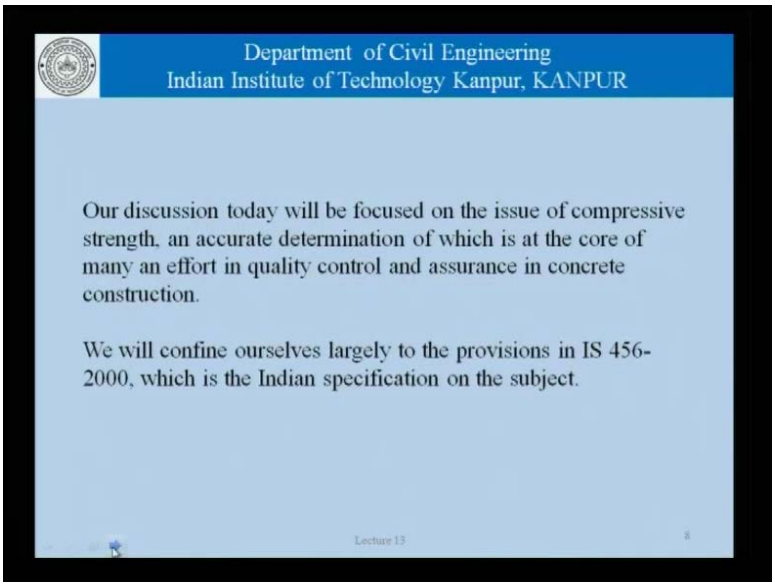

Today, our discussion will largely focus on the issue of compressive strength; an accurate determination of which is at the core of many an effort in quality control and quality assurance in concrete construction. The compressive strength of concrete is taken as one single critical parameter, which determines the quality of concrete construction. There are lots of others, but a lot of effort is related or is made to ensure and discuss the compressive strength – the strength of the concrete that we are using.

Of course, there are specifications involved; different specifications talk of slightly different things as far as compressive strength is concerned in terms of the specimens used, in terms of the age at which they are tested – the shape, the size and so on. We will confine our discussion largely within the scope as defined in terms of IS 456, which is the basic Indian specification on the subject.

Now, testing for concrete or the compressive strength of concrete as a parameter for quality control requires us to address the following. Sampling frequency and method – how much concrete should be taken, how frequently it should be taken, how the sample should be taken and so on; the testing method that should be used to test the concrete specimens – all the nitty-gritty details; and finally, the acceptance criteria – given the results, whether the concrete is acceptable.

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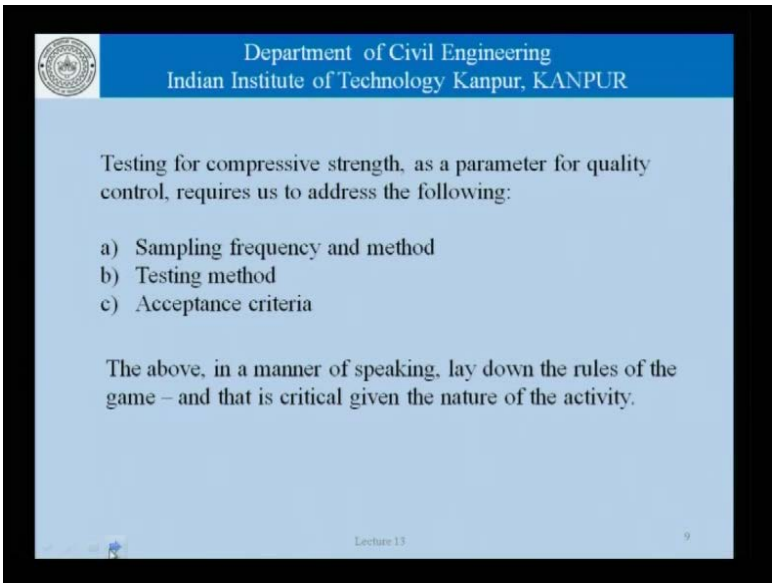

We must remember that, any test method – if we follow it religiously, will yield the result. The issue is whether that result is acceptable to us or not. And that is the core of the acceptance criteria, which is a very very important part as far as writing specifications is concerned. These three aspects: sampling frequency and method, the test method and the acceptance criteria – in a manner of speaking, lay down the rules of the game; and it is very critical given the nature of the activity. These rules have to be defined before the game begins.

We cannot change the rules in the middle of the game. We cannot certainly say that, the project started with the certain acceptance criteria or a certain method of testing, but it will be changed in the middle of the project. We indeed can do that, but we should be very very careful in doing that, given the fact that, quality control is not really just one player problem; it just does not involve a single company or an organization. There are different players in the game, the contractors, the consultants, the clients, designers. And if we want to change these rules in any of these ideas or in any of these aspects, everybody has to be on board; they have all to agree. And they have not only to agree as far as the technical and professional issues are involved, but also the financial, legal issues that are involved. It has to be a very careful decision.

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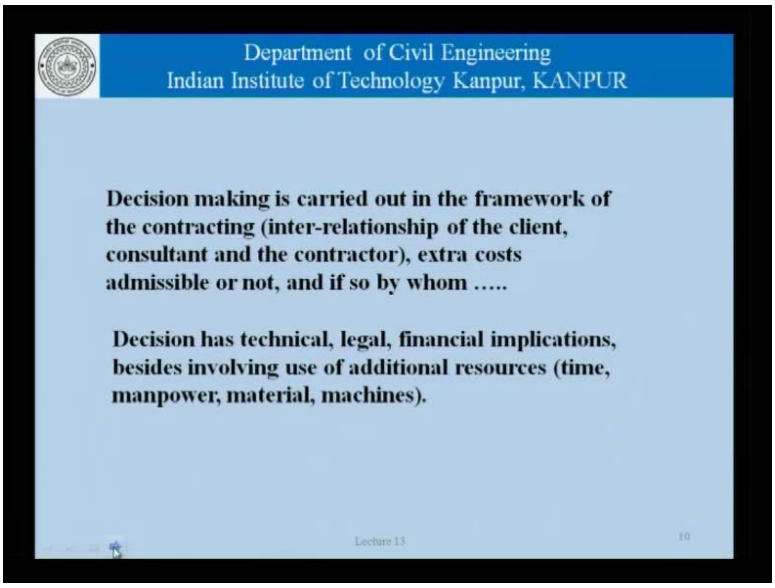

As I was mentioning, this decision making has to be carried out within the framework of contracting. And these contracts define the inter-relationship of the clients, consultant and the contractor. There could be extra costs, which are involved whether they are admissible or not. And if they are admissible, who should bear them; these decisions have technical, legal, financial implications and have an effect in terms of use of additional resources, which could be time, manpower, material, machines and so on.

As far as the sampling frequency and method is concerned, we could sample by volume of pour that, for every pore exceeding a certain amount of volume or for a certain amount of concrete pour at a construction site and a project, so many samples have to be taken. Or, it could be by time that, everyday regardless of the volume of concrete be used, a sample has to be taken, which should be tested for compressive strength. What is the location of the sampling? Whether it is taken at plant or whether the concrete is taken at site as far for compressive strength.

At site again, there is a possibility that, it can be taken at the agitator truck, where the concrete lands up at site or it could be taken at the discharge pipe. Now, between the agitator truck and the discharge pipe, there is the pumping operation that happens; and concrete is pumped from the place, where it is being discharge from the agitator truck to the actual site of placement. So, all these things have to be pre-decided.

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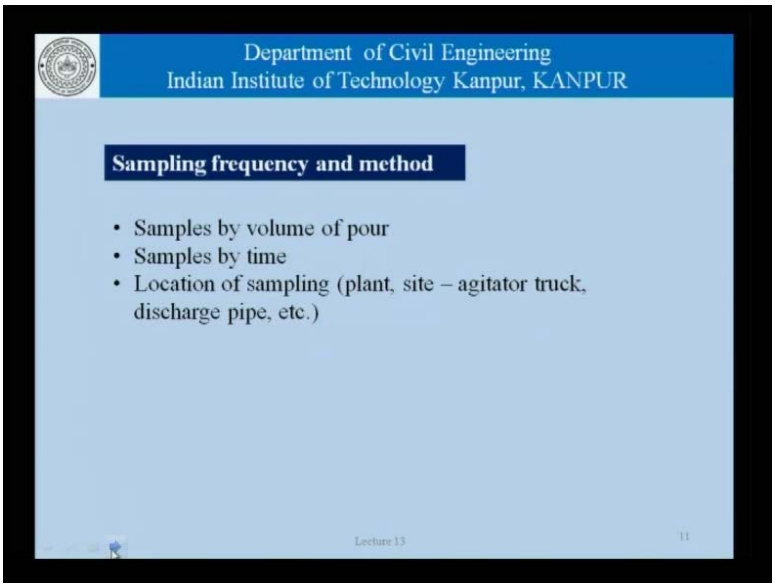

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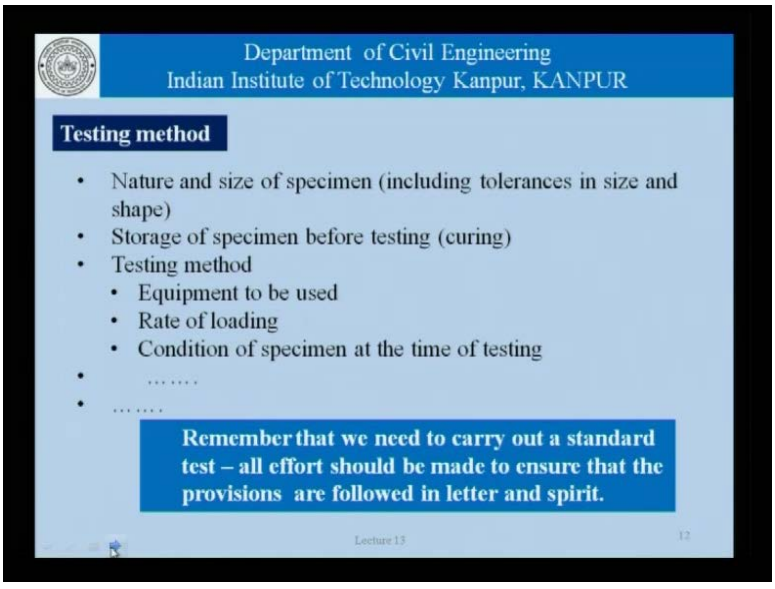

As far as the testing method is concerned, that has many many interesting variations; the nature and size of the specimen including tolerances in size and shape. It is very nice to say that, we will use a 150 mm cube. But, what is the tolerance that is allowed? Obviously, in engineering, when we make concrete cubes, they may not measure exactly 150 by 150 by 150; there may be a tolerance or there may be a difference of 1 mm or 2 mm. So, we have to specify as to what is the tolerance, which is acceptable; beyond which, the cube will not be acceptable as a valid specimen.

Similarly, in shape, it is nice to say that, the edges or the angles between faces should be 90 degrees. If it is not, then what is the extent to which we are going to allow a deviation. How are the specimens going to be stored before testing? What kind of curing will be carried out? At what temperature will the water be if it is water curing? As far as the testing method is concerned, once the concrete specimens have been cured, what kind of equipment will be used? What is the capacity? What are the characteristics in terms of the stiffness of the machine, the capacity of the machine and so on?

What would be the rate of loading? The rate of loading is one of the parameters, which determine the strength. We should keep in mind that, the strength of the concrete is something which we determine. The concrete does not tell us that, I have strength of 23 MPa. We carry out certain tests; and anything which is related to that test, will affect whatever strength that we get. With the same concrete cube, we may get 23, we may get 24, we may get 25; sometimes we may get 22 depending on any or all of these factors. And these are the things that contribute to the differences in values to small extents. Now, when this extent or these differences become unacceptable, we really need to revisit our entire quality control regime.

Now, other than rate of loading, there could be the condition of the specimen at the time of testing; whether the concrete is being tested immediately after it is removed from a curing tank or it is allowed to stand till such time is all excess water adhering to the surfaces evaporated or removed or the specimens are taken out from the curing tank and tested the next day and so on. So, what exactly is the condition of the specimens at the time of testing and so on, and so on? So, we must 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. It is difficult to lay down absolutely all the conditions that are required. But, we must try to understand as engineers and quality control engineers especially that, what are the issues involved and try to make engineering decisions. The fewer or the less the scope for such decisions, the lesser is the variability that we will get as far as quality is concerned.

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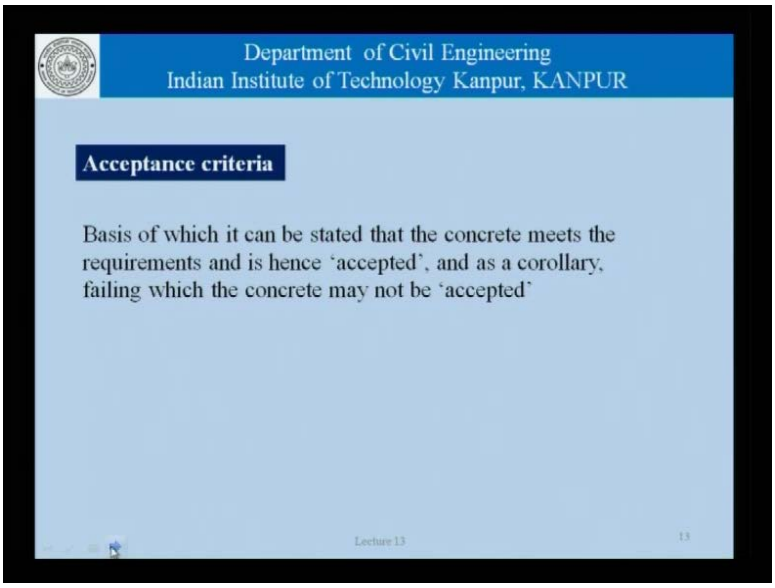

Now, coming to the acceptance criteria; now, this is the basis on which it can be stated that, the concrete meets the requirements and is hence accepted; and as a corollary that, failing which the concrete may not be accepted. Please… And remember that, I am using the word may not be accepted. There could be conditions, which specifications have to lay down that, if the strength has determined by cubes does not meet a certain requirement, what should be really done?

Let us take an illustrative example. If the observed strength of M25 grade concrete is found to be 26 MPa, it necessarily means that, the concrete meets the acceptance criteria. Is this statement true or false? What we wanted was an M25 concrete. That is what the designer wants. M25 means a characteristic strength of 25 MPa.

Now, for all the conditions that are in place – 28 days water curing and so on and so forth, the strength observed is 26 MPa, which is higher than 25. Does it necessarily mean that the concrete meets the acceptance criteria or the criteria for the designer that, the concrete is... As a corollary to that, if it is observed that, for the same M25 concrete, their strength in turns out to be 23 MPa, which is less than 25; is it obvious that, it does not meet the acceptance criteria?

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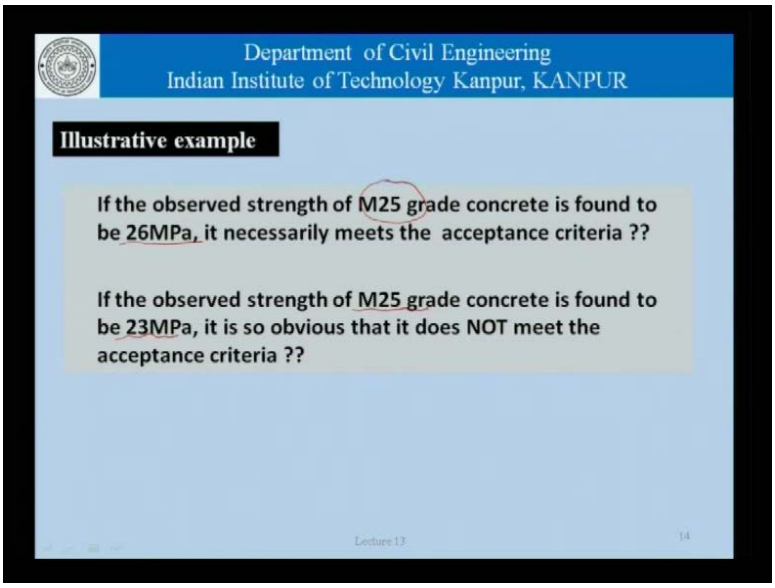

If we are able to answer these two questions, I think we have understood the whole issue of acceptance criteria as far as compressive strength is concerned; and its specifications need to define these rules clearly. If the definition was simple enough, that, anything higher than characteristics strength is acceptable; anything below characteristic strength not acceptable; then the situation would be very simple. But, let me assure you, that is not the case; and that is why we are talking about it at such length today.

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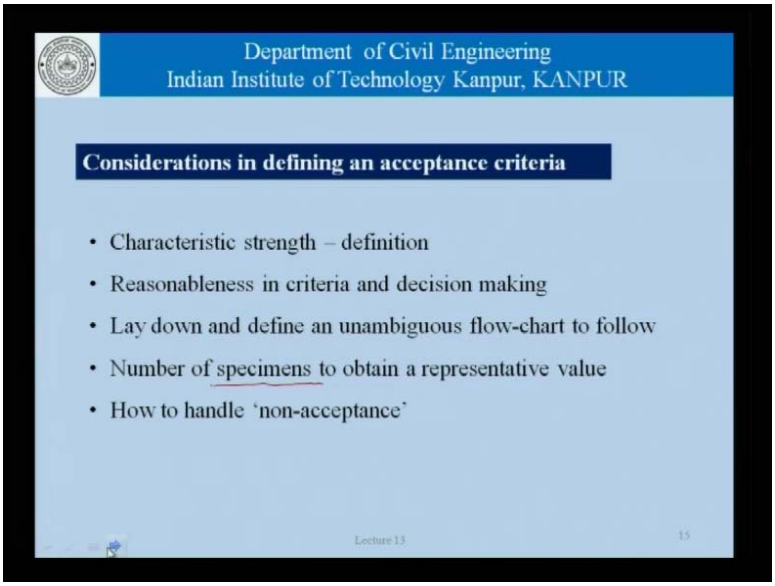

What are the considerations that go in our mind, when we define an acceptance criteria? One is the definition of characteristic strength itself. Now, let us try to revisit this definition once again having done that once when we were talking about the proportional of concrete mixtures. Let us try to understand what we did at that time once again.

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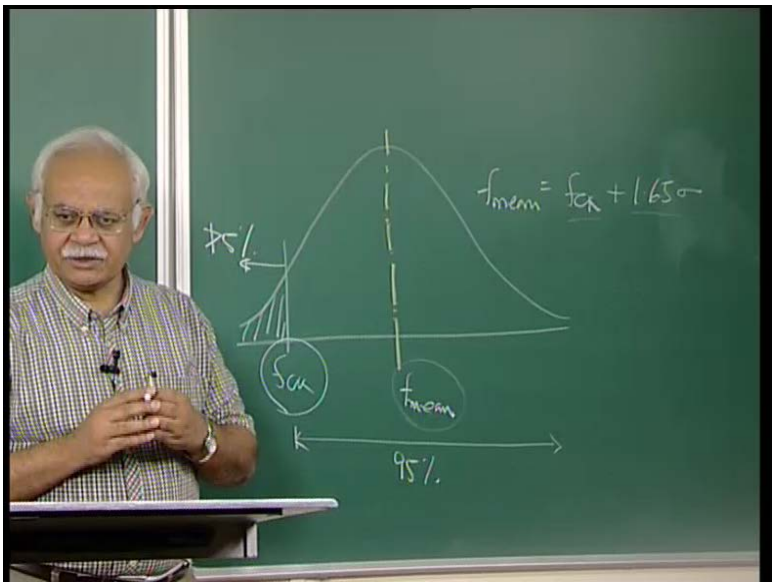

Now, this here is the frequency distribution of strength data as far as concrete is concerned for a given condition. By definition, characteristic strength f c k means or refers to that strength, below which not more than 5 percent of the specimens are allowed to fall. In other words, the area under this curve beyond the characteristic strength should be 95 percent. When we were doing proportioning of concrete mixes, we said that, in order to achieve this characteristic strength, the concrete should be proportion such that the mean strength of that concrete mix should be f c k plus 1.65 times the standard deviation. And the standard deviation – if it is not known to us to begin with, we are allowed to assume certain standard deviations, which are given in the specifications depending on the grade of concrete, which is being used.

Now, the picture really is the following. We have concrete, which has been cast in a structure; with the concrete whose mean strength was higher than the characteristic strength; and we have also accepted the fact that, a certain amount of specimens, certain amount of samples will be allowed to fall below the characteristic strength with the provision that not more than 5 percent of the samples will fall there.

Now, this allowance of allowing or permitting a certain number of samples falling below characteristics strength throws out of the window the idea that, any concrete, which is higher than f c k is acceptable; and anything which is lower than f c k is unacceptable. By our own definition of characteristic strength and the design process, we have allowed a certain amount – 5 percent of these specimens to be below f c k. Similarly, the concrete is not designed for f c k; the strength of the concrete itself is not the characteristic strength; the strength of the concrete is a value, which is higher than the characteristic strength. And these two aspects must be addressed when we talk about acceptance criteria, when we talk about laying down acceptance criteria.

So, continuing with our discussion as far as considerations in defining or laying down acceptance criteria, is concerned apart from the definition of characteristic strength has been discussed. There has to be reasonableness in the criteria and decision making. The reasonableness now comes from engineering considerations. It is alright to say theoretically or scientifically that, 5 percent of the specimens or the samples may fall below characteristic strength. But, would we like in a structure to have 5 percent area or 5 percent volume in that concrete to be very very poor as far as quality is concerned? The answer obviously is no; which means that, now, from an engineering judgment, we will temper the criteria of 5 percent specimens being allowed to fall below characteristic strength.

Similarly, we need to take a decision within a reasonable time frame; we cannot wait for the decision making till a large number of samples have been tested. We need to take decision, so that the concrete construction can proceed. And therefore, certain groups or certain time spans have to be identified and the decisions taken, chapters closed as the construction proceeds. Similarly, poor construction or good construction at one point in time cannot be allowed to affect the decision making beyond a certain point in time. We should keep in mind that, concrete construction in large projects often continues for a period of several months and maybe a couple of years in certain cases. And therefore, it is very likely that, due to certain reasons, there might have been very good construction at some points in time and maybe some very average kind of construction at different points in time. Those outline periods cannot be allowed to cloud our thinking for all the time as far as the construction project is concerned or for the entire construction project.

Basically, what the acceptance criteria should do is to lay down and define an unambiguous flow chart to follow. The step by step process should be very very clearly defined; and it should define not only what should be done in one case, but also the other case. For example, we may say that, if a certain condition is met, the concrete is acceptable. We must also say that, if that condition is not satisfied, what are the steps that need to be taken such that all possibilities that arise as a result of the testing of concrete are covered? What are the number of specimens to be used to obtain a representative value? Now, here we have use the word specimen. And a specimen is a single piece; a sample comprises of several specimens.

So, sometimes we talk of samples and sometimes we talk of specimens; we should be clear as to what is a significance of the result in terms of the result obtained from the specimen or the result obtained from the sample. And that is something, which we are going to talk about as we go along. Acceptance criteria should obviously handle non-acceptances as well. And that is what we said that, it has to cover all possibilities.

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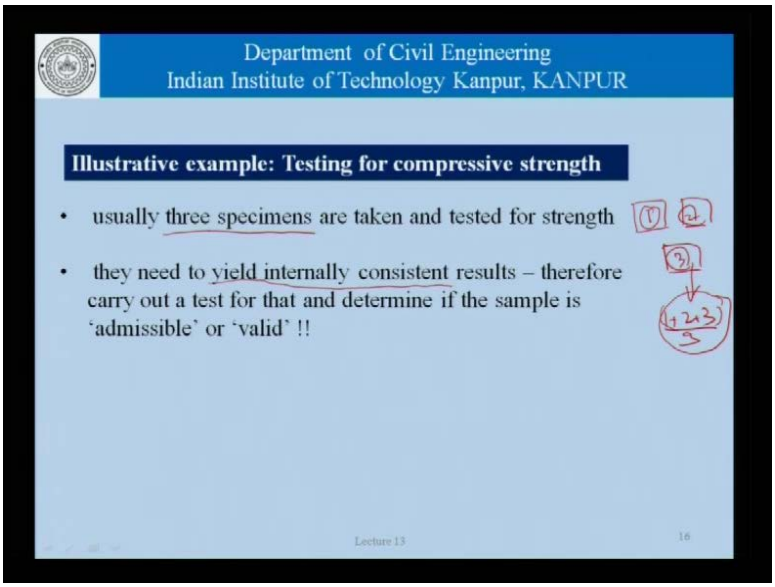

Let us take an illustrative example once again. Now, as far as testing for compressive strength in concrete is concerned, we usually use three specimens and test them for strength. And these three specimens constitute a single sample. So, we take three cubes: 1, 2 and 3; test them for a strength; maybe we will get strength 1, 2 and 3; and then we take an average of 1 plus 2 plus 3 and try to see, what is the average strength that we get

as far as these specimens are concerned. And that becomes this strength of the sample that we have taken. And we are not going to the statistics of why to take three specimens. Continuing this discussion with three specimens, first thing that we need to ensure is that they yield internally consistent results. Therefore, we need to carry out a test and determine if the sample is admissible or valid.

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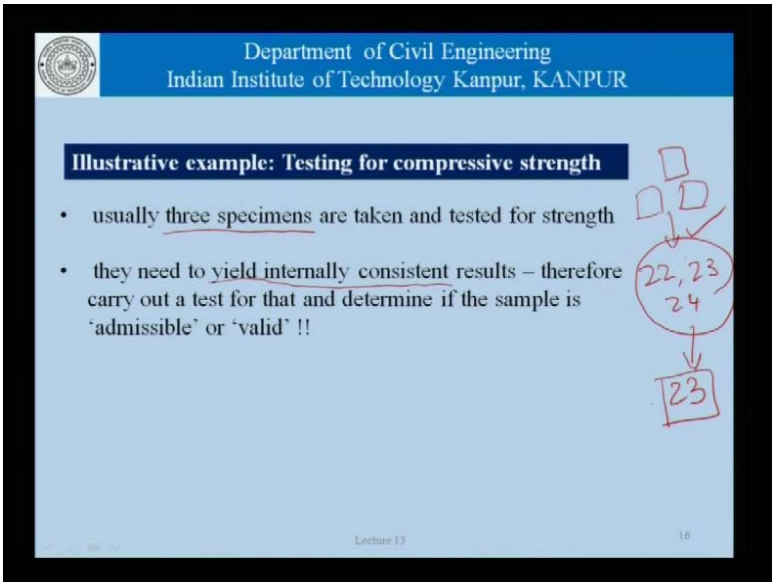

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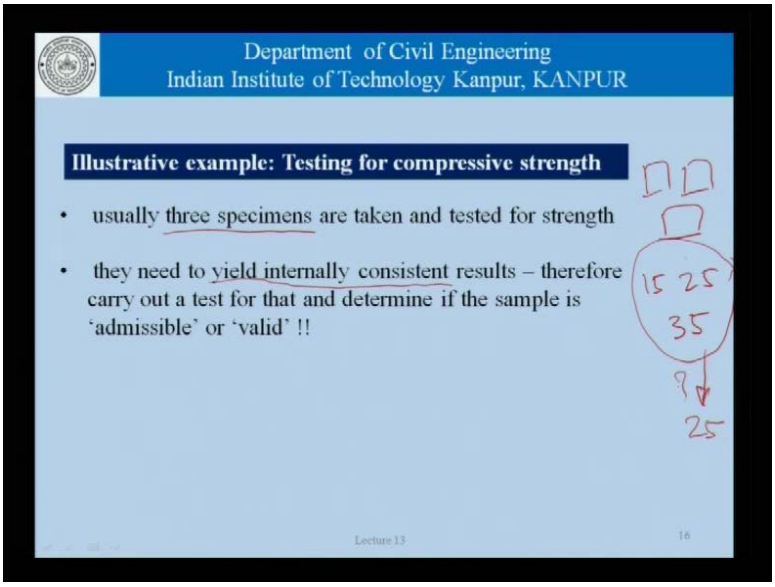

Let us take an example. We take three specimens and these three cubes; they yield a value which is 22, 23 and 24 MPa. They seem to be internally consistent; and they does

not seem to be anything wrong in taking the average here and saying that, as for as the concrete sample is concerned, the average is 23 MPa.

Having said that, now, instead of 22, 23 and 24, if these three cubes were to yield 15, 25 and 35 MPa as the values, then it is difficult to say that, this is a sample, which represents a concrete within average strength of 25, because we are not sure which of these specimens is really are true representative of the concrete.

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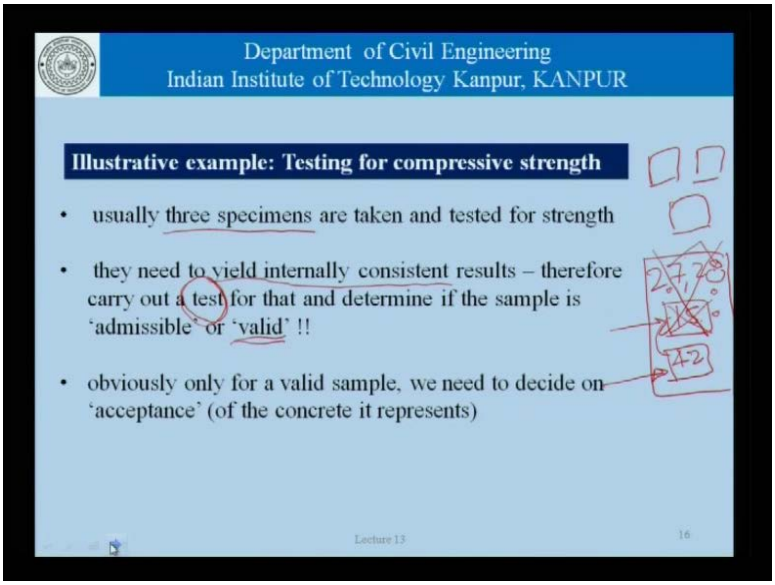

Apart from these two examples, there can always be a situation, where the three specimens that we test give us values, which are 27, 28 and 15 or 42. Now, in either of these cases, we have these two as outliers. These two will affect the average of the sample if we want call it a sample. And this is what we refer to; and this treatment or this test that we are trying to carry out now, is one which defines internal consistency of the specimens in order to ensure that, they constitute a valid sample. The acceptance business comes much later.

First of all, we have to establish that, the three results are internally consistent. How do we determine or establish this internal consistency? Now, how do we establish that, these specimens or a set of results that we get from three specimens is internally consistent? And for that, we need a test. The Indian specifications tell us that, the results will be deemed to be consistent if the standard deviation within these three results is within a

certain number. We must carry out the test and see if the results are within this permissible range; and then we know whether the sample is valid and admissible or not.

Now, coming to the assertion that, the specifications need to cover all possibilities, we also need to say that, in case the specimens yield results, which are not internally consistent; then what should be done? One possibility is that, in a situation like this, where we get 27, 28 and 15, we say 15 is an outlier and the average of these two will be taken or the average of these two may be taken or, we can say that, if the sample is such that the standard deviation is higher than the acceptable level, the entire test is thrown out; it is not to be used; it can be one or the other. The Indian specifications tell us that, it should be simply thrown out of the window; the test should not be considered; or, the test results should not be considered. Once we do not have a valid sample, there is no question of talking in terms of any acceptability of that sample. And indeed only for a valid sample, we need to talk about acceptance of the concrete that it represents.

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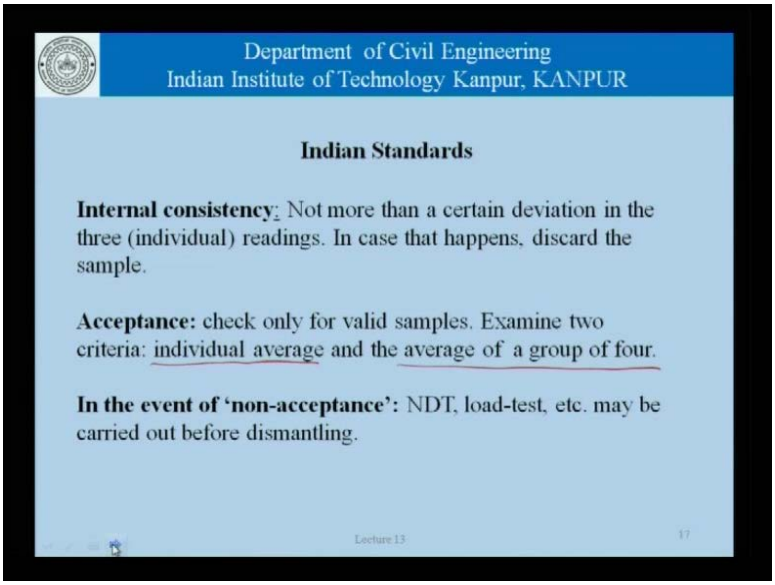

Summarizing, there is a criterion on internal consistency, which says that, not more than a certain deviation in the three individual readings is allowed; in case that happens, discard the sample. As far as acceptance is concerned, we need to check only for valid samples and examine two criteria: the individual average and the average of a group of 4. So, when we get a sample, we have to decide two things: whether as an individual sample, that value is acceptable or not; and the second thing is, is it acceptable as an

average of 4 or group of 4. We will try to see this in the subsequent slides. And in the event of non-acceptance, there is a provision in Indian standards for non-destructive testing, load test, etcetera before a final decision on dismantling is made. This is how the acceptance criteria is laid out as far as Indian standard is concerned.

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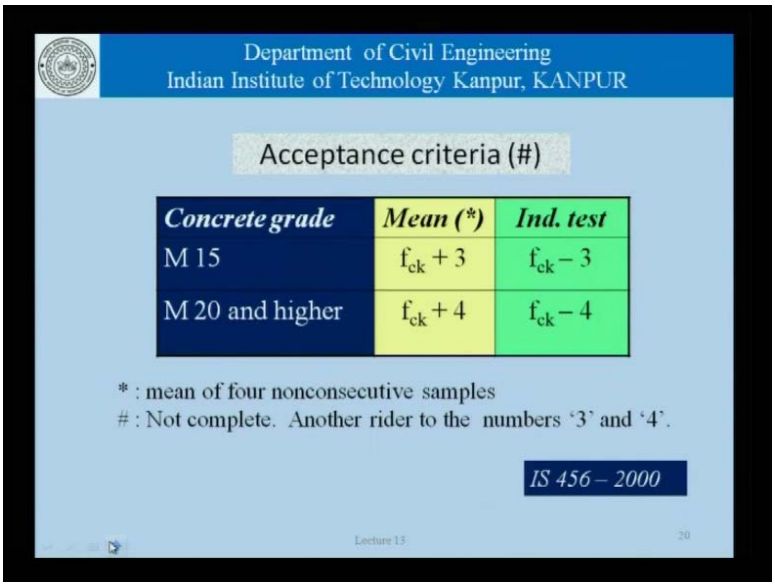

This is the part of a summary I should say. For acceptance criteria, for concrete grades, if it is M 15, which is normally not used in reinforced construction; the mean as far as the mean of four non-consecutive samples are concerned, should be f c k plus 3. And if we are dealing with concretes, which are M 20 and higher, then this value should be higher than f c k plus 4. As far as the individual tests are concerned, no value should be lower than f c k minus 3 and f c k minus 4 as is shown here. These values 3 and 4 are given as absolute numbers and are also given in terms of the standard deviation that we get in the field. As far as this illustration is concerned here, we are using 3 and 4. But, once we understand the principle, then it is only a matter of choosing between a fixed number or determining that number on the basis of the standard deviation.

As far as Indian standard is concerned for assumed standard deviations, now, we can see that, for different grades of concrete, there are different standard deviations that may be assumed in the absence of actual field data. Now, this is the kind of table that we used when we did proportioning of concrete mixes. Initially, we may have to do that, even when we are doing acceptance of concrete early in the project when enough data has not

accumulated in order to enable us to determine or understand for ourselves, what is the real standard deviation as far as concrete is concerned for a particular project. But, as the project moves along, we can and should start using the actual standard deviations that we get.

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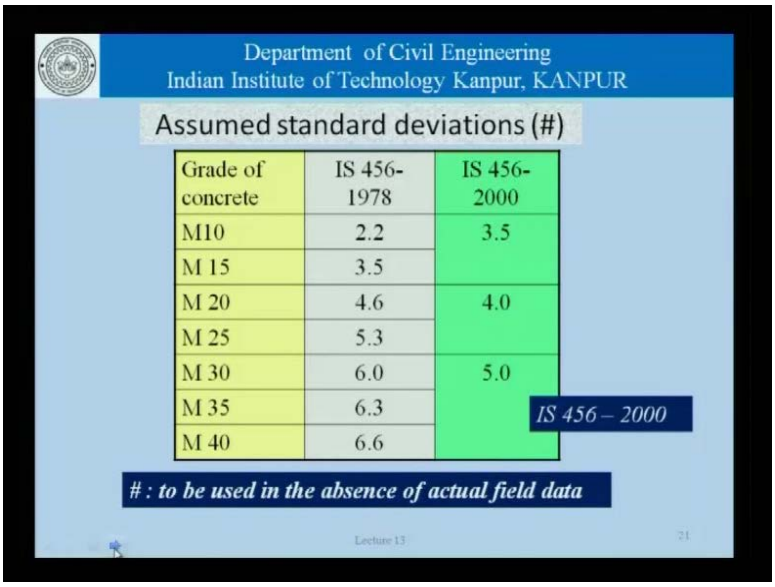

Now, coming to the concrete quality control itself, let us say these are the individual values of samples strengths; that is, strengths determined on the basis of three specimens each – all of them of course, have to be valid. Now, what we will get is a certain compressive strength. The compressive strength as determined is not really related to the characteristic strength accept that, of course based on the characteristic strength that we want, we would decide acceptance of a certain value. What that means is that, we have a line here, which is characteristic strength.

So, the way these dots or the individual values have been placed, they are all above the characteristic strength. So, all these samples are higher than characteristic strength. Now, whether they are all acceptable? The course tell us that there is another line here, which is f c k plus 0.825 times sigma or 3 or 4 as we saw in the table earlier. And the sample should really be above that line – above this line in order to be acceptable. This comes from our fundamental that, the concrete at the end of it, which is being used, is not being designed for giving us characteristic strength; it is being designed to give us a value,

which is higher than characteristic strength. Now, when it comes to acceptance criteria, we have put down a number, which is f c k plus 0.825 times sigma.

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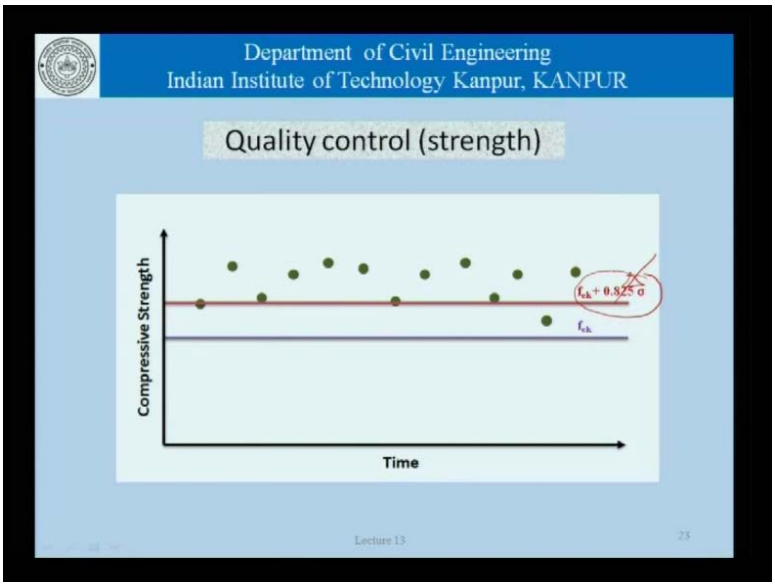

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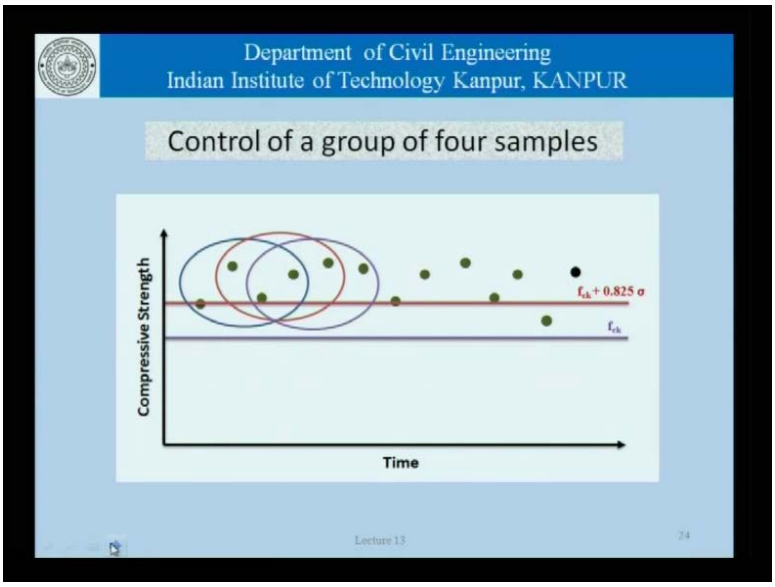

This is the control of a group of four samples. So, now, how do we control that? Here is the group of four samples, which will have their own average. This is another group of four samples, which will have their own average. This is another group of four samples, which will have their own average and so on. So, this is one possibility, where the groups are being defined in terms of overlapping groups; something like a moving average

concept. And these averages have to be higher than the line of f c k plus 0.825 times sigma.

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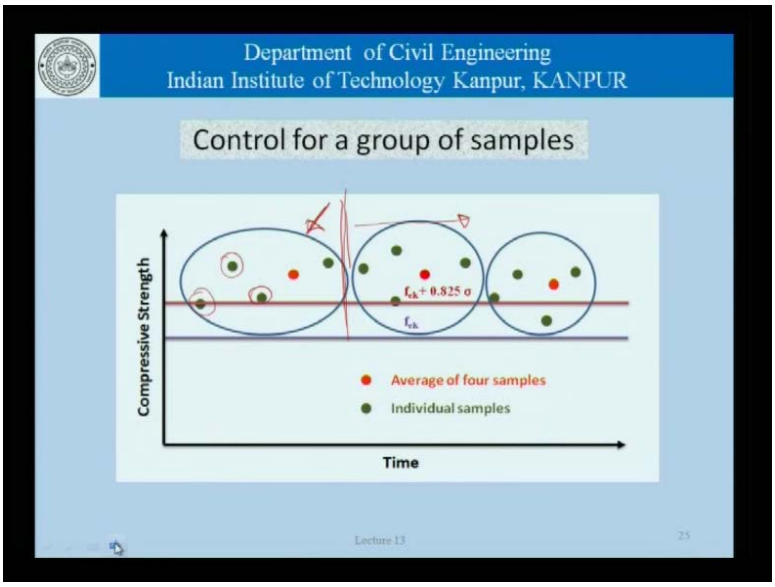

Another possibility could be define an average using these four; and then define the average here. Define an average of these four, take the average here; define an average of these four and take the average here. Now, the difference between this method and the previous method is the fact that, in this case, these are non-overlapping samples. So, basically, once we decide the fit of one group of four, the chapter as far as that group of four is closed. Whatever happens with this strength here or this strength here does not affect any decision making beyond this point in time. So, whether it is a bad result or a good result, all the decision making is done at this point in time. And that is something, which is very important and a very key aspect as far as quality control is concerned.

Now, coming to individual samples, we have line here, which is as usual f c k and we have values, which may be here or here. Now, as individual samples, are these values acceptable or not, regardless of what happens to the average? For that, we have a line, which is defined here, which is f c k minus 3 or f c k minus 4. This value being 3 or 4 or it is something related to the standard deviation; and we say that, no individual sample is allowed to fall below this line.

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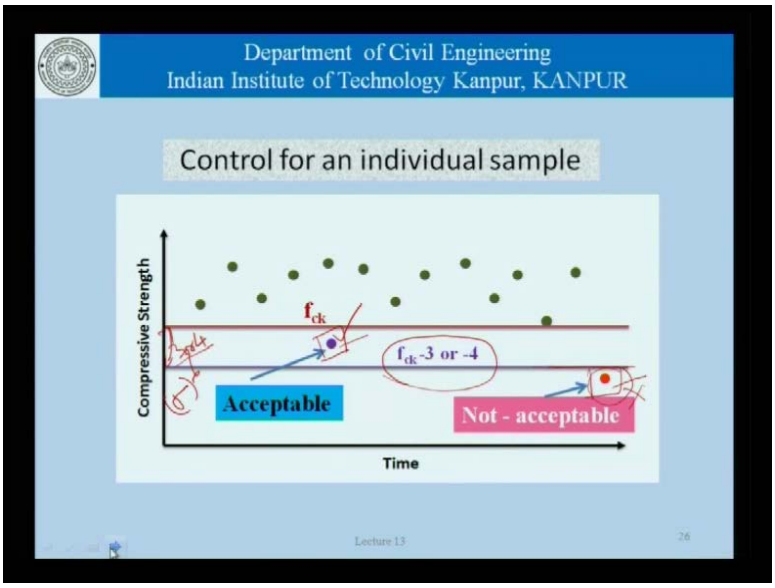

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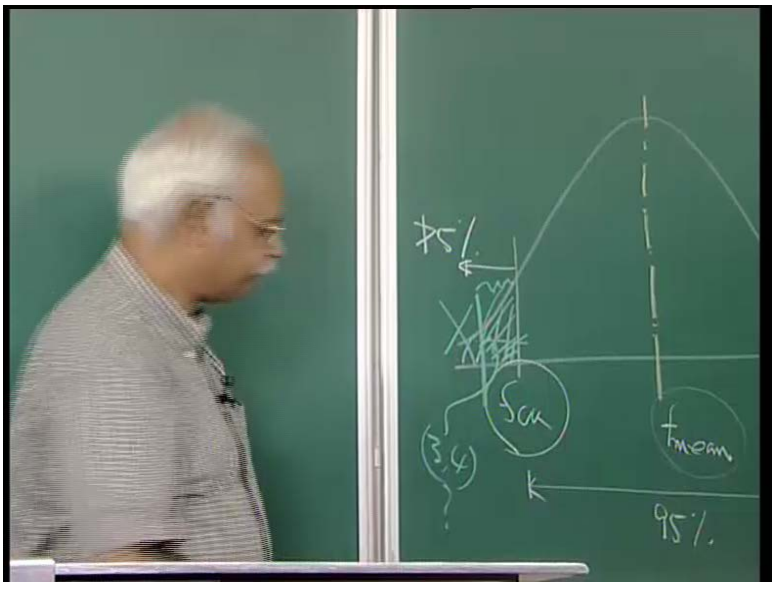

This is acceptable, but this is not. Basically, what we are saying is that, all our understanding or all the theoretical idea that, 5 percent samples are allowed fall below characteristics strength – it stops at those values still being within 3 MPa or 4 MPa or within some predefined level of f c k.

If you look at this picture once again, what engineering is telling us is that, 5 percent of samples are allowed to fall below this line, but nothing here is acceptable. Only this is the region, where concrete may fall below the characteristic strength. This region here is

this 3 or 4 MPa or whatever it is. And therefore, this value is acceptable, because even though it is below f c k, it is above this critical value of f c k minus 3 or f c k minus 4 depending on whether we are testing M 15 concrete or M 20 concrete or M 25 concrete; and of course, this 3 and 4 are related to the standard deviations and so on, whereas this concrete is not acceptable, because it falls below the minimum strength.

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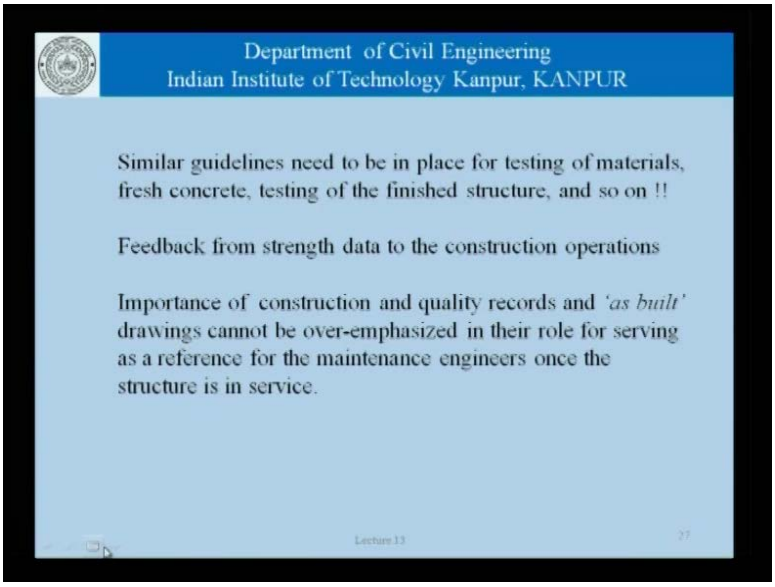

We need to have similar guidelines for testing materials, testing fresh concrete, testing of finished structures, and so on. We need to have individual values and how to handle them; we need to have guidelines for how those individual values are going to be integrated into a system; and how will we go about continuing to make our decision making from time to time without getting clouded with decisions made far back in time. We need to have systems in place, which will enable us to provide feedback from strength data to the construction operations.

If for example, we find that, the standard deviations that we are getting are lower than what we had planned or lower than what we had assumed, this has implications in terms of the actual strength we are getting. And the proportioning of concrete that we have done, we may be able to save cement or we may have to put in extra cement depending on what are the actual values of the standard deviation. There may be a situation, where a designer may have to be told that, due to certain considerations, we are getting a higher strength or a lower strength than what we had initially assumed. And can we modify

something in the design process in order that, the construction becomes economical. So, there is nothing wrong in understanding the economics of quality control.

Quality control is an exercise at the end of it being carried out to ensure to the concrete meets the specifications, meets the required bench mark. Now, if it is being met, then the second decision is to be made, whether it is being done economically. Is there a possibility of being able to reduce the cost, reduce the dimension of the environment and so on without compromising quality?

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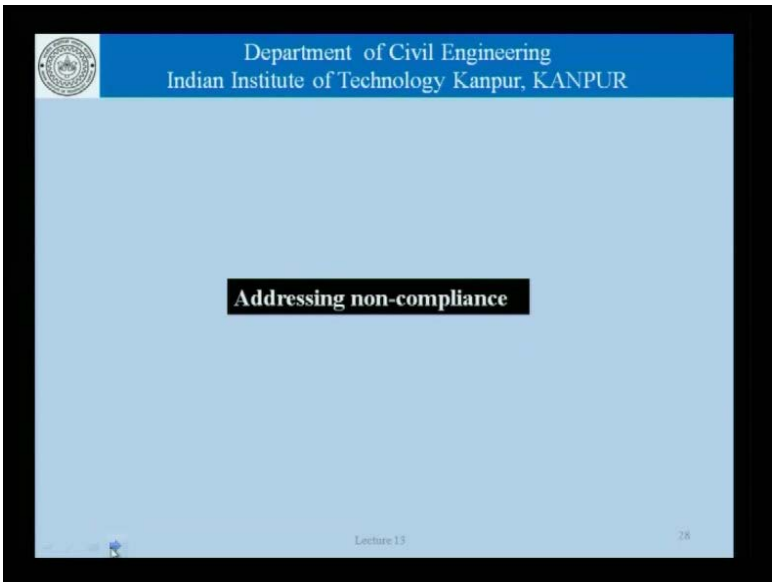

We need to also emphasize the importance of construction and quality control records and as built drawings, because this serve a very important role as reference material for the maintenance engineer once the structure is in service. So, if we have, we need all the constructions records when it comes to maintenance. We must understand what was the actual strength of concrete, which was poured; not only the fact that, the structure was designed for M 20 or M 25, we should know the actual strength, because that helps us in understanding the behavior a lot better.

Now, as far as addressing non-compliance is concerned, there is always a possibility like I said that concrete in a part of project is found an acceptable on account of insufficient strength as determined by the cubes taken at the time of casting.

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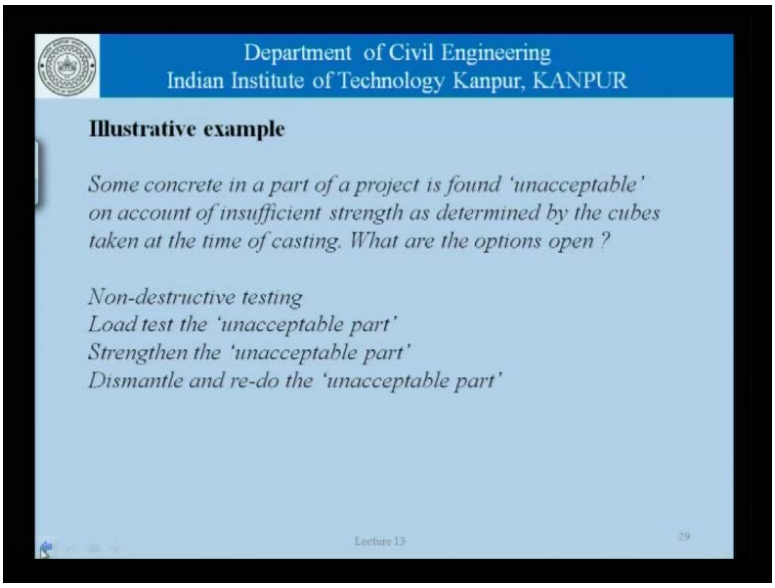

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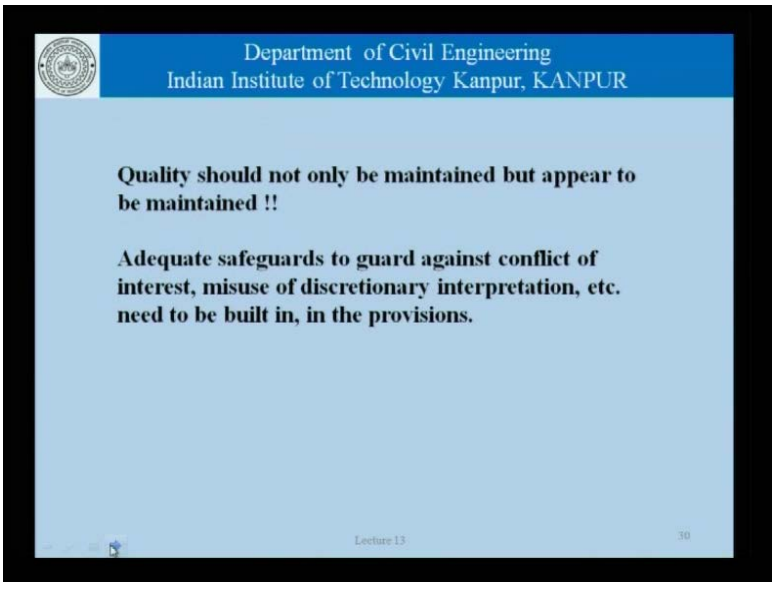

The options open to us are non-destructive testing, load tests, strengthening the unacceptable part and dismantling and re-doing the unacceptable part, any decision that is made as financial implications. We must remember that, quality should not only be maintained, but also appear to be maintained. We need to have adequate safeguards to guard against conflict of interest, misuse of discretionary interpretation, and so on in the provisions. But, having said that, if these provisions are made, in the specifications itself, which is a professional document, then the possibility that, somebody is charged with misuse of discretionary interpretation reduce so much more.

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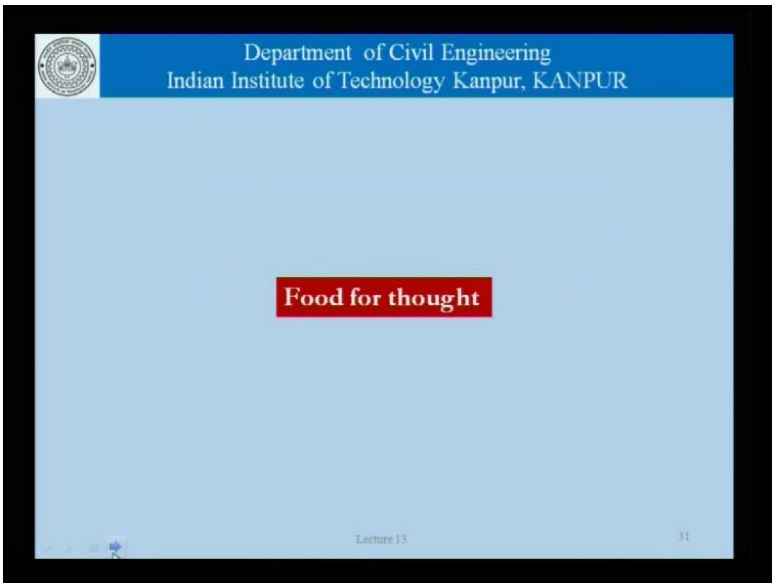

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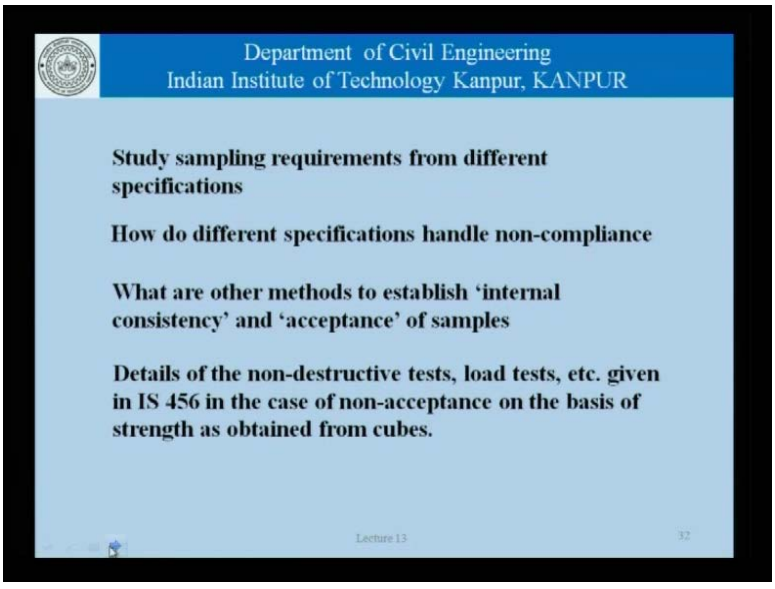

Now, coming to a close of our discussion today, let us try to recapitulate and go back with some things, which we need to think about a little more. We could study the sampling requirements from different specifications. We did not talk in detail today about sampling frequency. And that is something which we must get a better handle on. How do different specifications handled on compliance? We talked a little bit about what is Indian standards as far as IS 456 does in terms of permitting a non-destructive test or a load test, and so on, if the cubes fail.

We should also think about a possibility that, as far as non-compliance is concerned, we should carry out certain non-destructive test or load test, and so on. But, is it not required at all to carry out this test in case the structure continues to meet the requirements as far as cube test is concerned? What I am saying is that, if the concrete strength as determined from the cubes, continues to be sufficient; then is there no need at all to actually test the structure? The answer is yes and no. Depending on the criticality one might like to say that, regardless of what happens as far as cube test is concerned, once in a while, we should carry out certain (( )) test to determine or understand the actual strength of the structure.

Another argument could be that, that is not required; so long as the cubes are being tested and the results are acceptable, we can assume that, the concrete in the actual structure is also acceptable. What that we should remember is that, the end of it; only an assumption that, if the cubes are, everything is ok. What are the other methods to establish internal consistency and acceptance of samples? We talked briefly today in terms of the standard deviation within the three specimens and we talked in terms of acceptance based on individual sample results and a group of four kinds of sample results. There could obviously be other methods based on which a concrete could be accepted. We also need to know a little bit more about the non-destructive test, the load test, and so on given in IS 456 in the case of non-acceptance on the basis of strength as obtained from the cubes. And with this, we come to a close of the discussion.

Thank you.