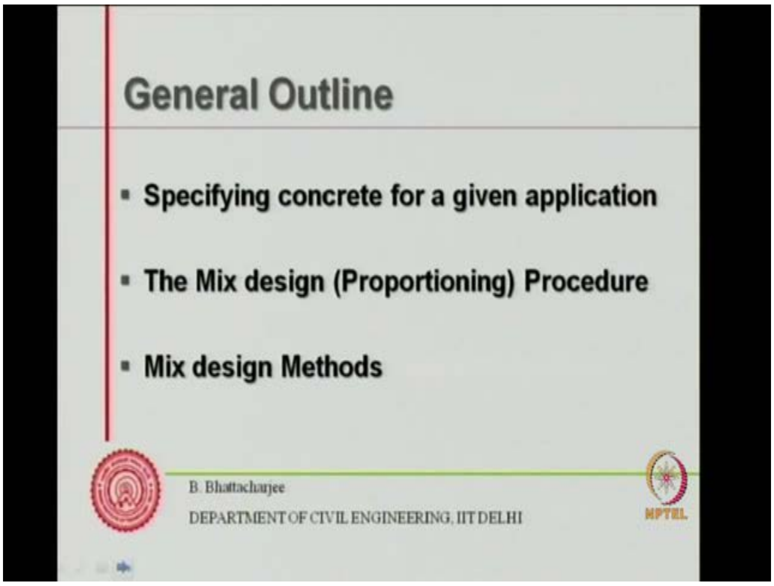
Concrete Technology
Prof. B. Bhattacharjee
Department of Civil Engineering
Indian Institute of Technology, Delhi

Lecture - 14
Mix Proportioning of Concrete: General Principles

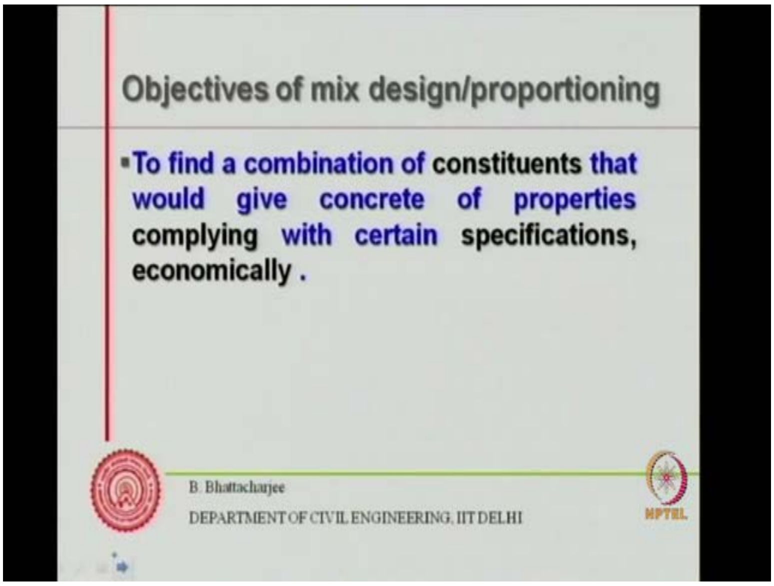
Welcome to the module 4 of concrete technology. You may recall a module 1, 2 and 3. We discussed about the materials, those goes into the concrete and having done that.

(Refer Slide Time: 01:10)



Now we can look into the. procedure of mix proportional. Conventionally this is called mix design as well and in our discussion the general outline of the discussion is we first mention about how do we specify concrete for a given application. The mix proportioning or mix design procedures by in large in general, then the methods those are available. So today we would be talking about general method you know method in general and in successive classes will be talking about various methods those are adopted.

(Refer Slide Time: 02:06)



So what is the mix objective of the mix design, what is the objective of the mix design principle? First of all to find the combination of constituents, that would give concrete having properties complying with certain specifications. And of course, it must do it economically, because that is of basic fundamental principles in all engineering designs or principles.

(Refer Slide Time: 02:35)

Now then, one must specify the properties right or the characteristics of concrete those satisfy the need at the fresh and hardened state.

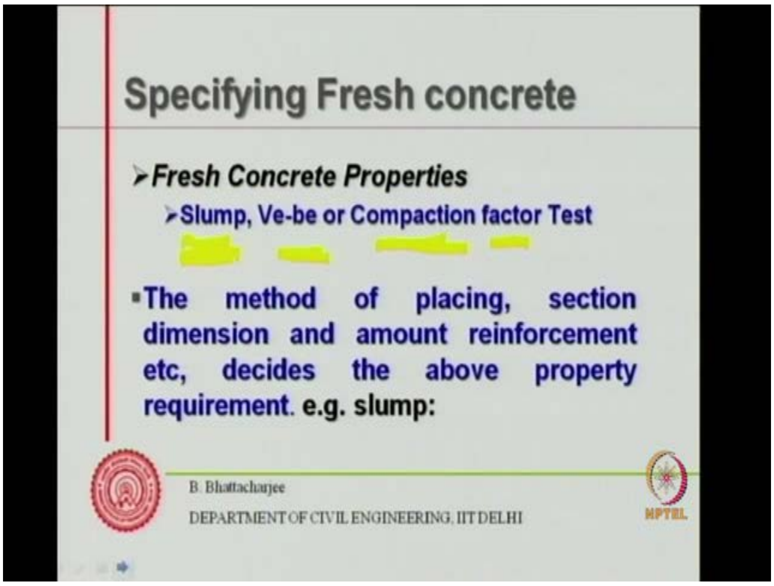
(Refer Slide Time: 03:35)

That is, you see characteristics of those satisfy the needs at the fresh and hardened state those goes into the specification. So we must find out the constituent proportion of the constituents in the concrete, which will satisfy certain properties and those properties decided they based on certain specifications. Characteristics of the concrete are those, you know those will satisfy are the properties of fresh and hardened concretes. So this are the properties of fresh and hardened concrete fresh and hardened concrete you know constituents would select such that we get the properties of concrete with certain specifications.

(Refer Slide Time: 04:05)

Now these specifications are in terms of properties of fresh and hardened states properties of concrete. These properties are of course, selected based on application and expected performance.

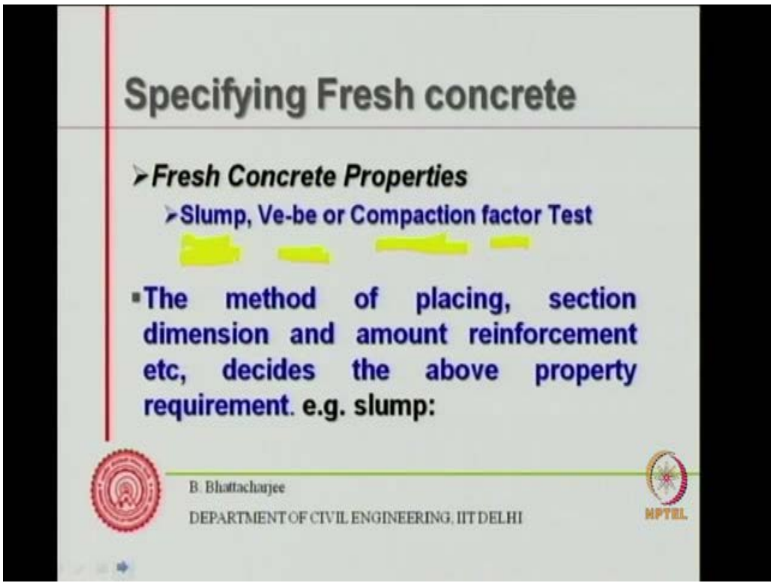
(Refer Slide Time: 04:35)



So this is important to understand expected performance right. So they are selected based on application and expected performance. Now we said fresh and hardened concrete properties, although we have looked into or not really defined various kind of properties of concrete as yet. We should do in our successive modules. Fresh concrete properties are specified in terms of some of those engineering characteristics, called slump ve-be or compaction factor. These are some engineering properties devised for measurement of fresh concrete properties. What this values are, what are they will come to this in detail sometime later on? Will also talk about a little bit on the measurement methods, but commonly adopted one is the slump. So this specify concrete fresh concrete properties in terms of a property called slump.

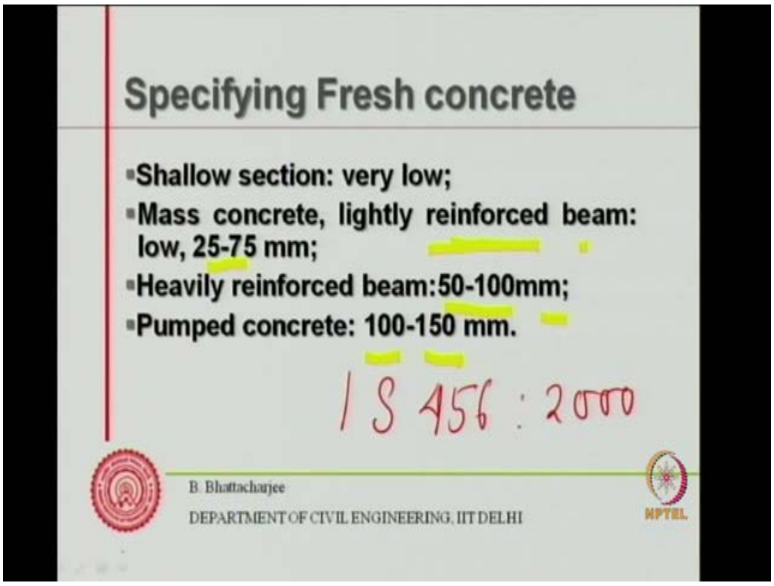
And this values, what is slump will come to it in out next module, when we talk about fresh concrete more in details. But for the time being, let us understand that it is the height or settlement of a standard conical shape of concrete, prepared in a standard manner at its fresh state. So it is settlement of such a shape concrete under its own way will see that sometimes later on, but at the moment let us say the slump is the one of the properties.

(Refer Slide Time: 04:35)



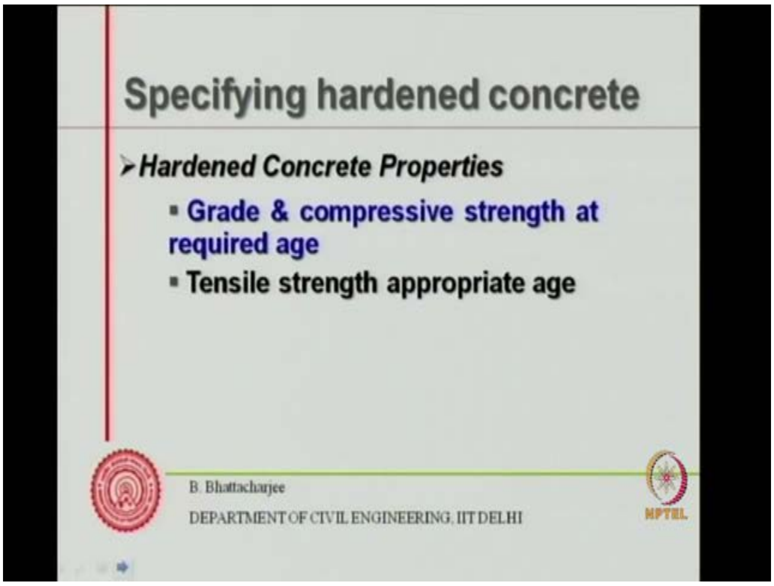
And this property is most commonly used. The method of placing section dimension amount of reinforcement present, this decides the property requirement; that means slump could be decided or compaction factor or Ve-be time Ve-be unit of Ve-be time. This is of fraction, all this has decided based upon the method of placing, section dimension and amount of reinforcement present.

(Refer Slide Time: 07:35)



For example slump of concrete specified, let us say Indian standard method for shallow section it is very low. For mass concrete, you know foe shallow section is very low for lightly reinforce beam it is low, from 25 to 75 millimeter, heavily reinforced beam 50 to 100 millimeter. And if you want the pump the concrete it should be 100 to 150 millimeter. These are given in code. For example, Indian standard code of course, is Indian standard code of course, is I s 456 2000. So Indian standard code is I s 456 2000, and this are specified in such code. Alright, so this is how we express or you specify the properties of fresh concrete.

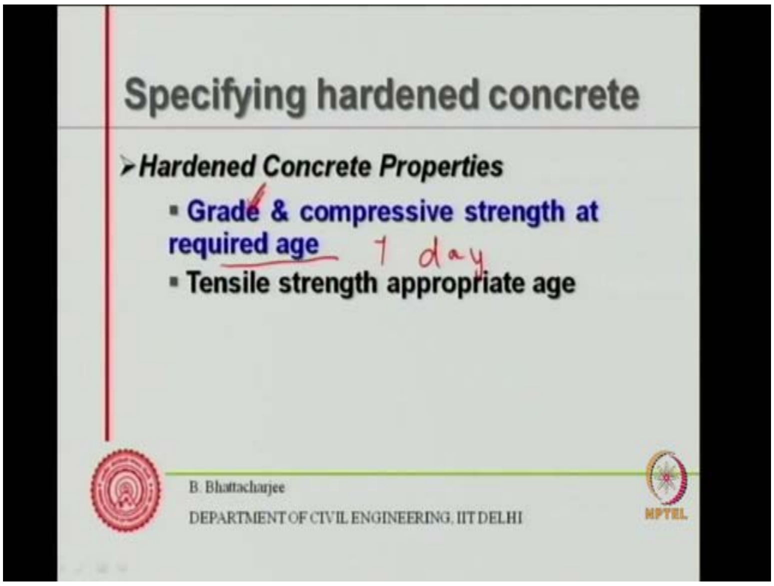
(Refer Slide Time: 08:50)



Hardened concrete since concrete is a structural material we specify the grade of concrete in terms of it compressive strength, at certain age. Because in the module 1 we have seen that reaction of cement with water produces a material which is stone like, but this formation of this hardened material from a plastic state takes time first its solidifies and then gradually it gains strength. And this process of strength gain takes time, quite often could be months.

It has been standardized, age has been standardized for measurement of compressive strength, in you know through standard samples or specimens at the age of 28 days. So we measure the compressive strength of concrete at this 28 days age, but not necessarily always will specify the concrete strength along with 28 days. You might specify it at some ideal age also depending upon the requirement. For example, you know in some cases we might specify this at 7 days we might specify it at 7 days 7 days or 1 day.

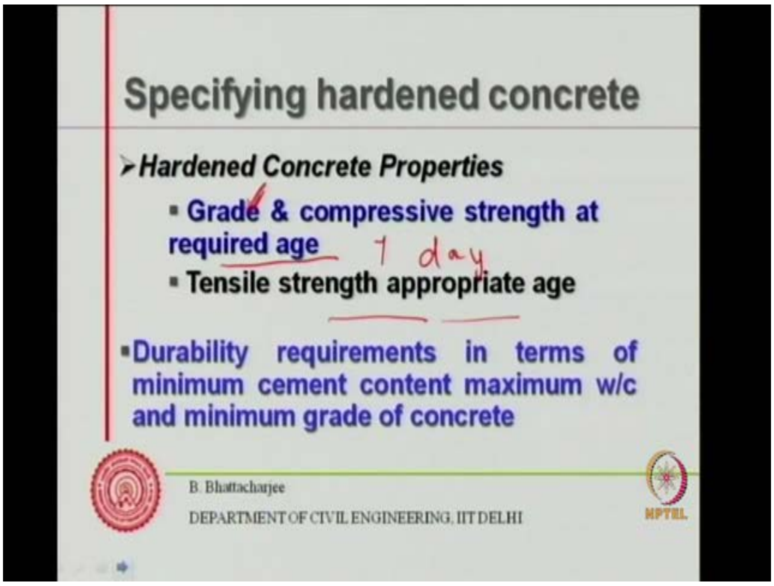
(Refer Slide Time: 10:55)



Grade of concrete is always defined with respect to 28 days compressive strength. Generally in Indian scenario it test cubes and will talk about that in sometime later on. Why I mean how you know concrete strength is affected by the specimen, size, shape etcetera, etcetera. So in Indian scenario we talking terms of grade of concrete. Measuring the strength at the age of 28 days compressive strength at 28 days and we specify in terms of something called characteristic strength. Characteristic strength is defined as that strength which would be (( )), you know which would be exhibited by more than 95 percentile of the cubes.

We might also specify the concrete strength in terms of its tensile strength at certain appropriate age, in some cases. May be in your designing for you know tensile strength of concrete. Sometimes let us say in motor retaining structures or where flexures can be very important criteria, where the same pigment we might specify the required specify the concrete in terms of tensile strength also, flexure tensile strength also in addition to 28 days compressive strength 28 days compressive strength and grade.

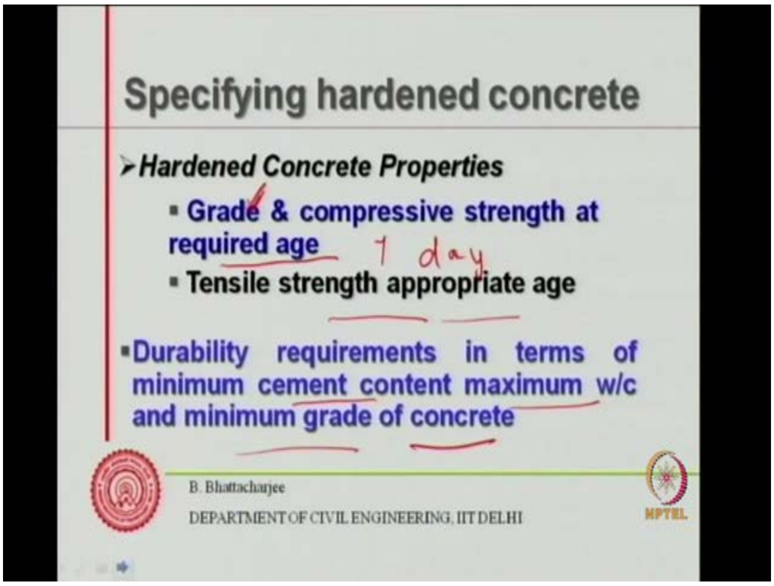
(Refer Slide Time: 12:40)



But this is not all concrete must remain durable or must be able to endure the environment to which it is exposed to over a long period of time right. And that is related to its durability. Durability is the property by virtue of which, the concrete can with stand the environment to which it is exposed over a long period of time. So although at the moment most of the codes do not quantified the durability in terms of let us say service life of something. But, we understand durability is the property related to its endurance to various kinds of exposure condition.

And our understanding in-terms of quantitative way of understanding this durability property is limited at the moment from the knowledge of the mix proportion and knowing the exposure condition, i may not be we may not be able to say how long concrete would be able to perform as required. It must perform or it must be functionally satisfactorily it must exhibit functional performance respectively functional performance. Performance would mean that it should be able to carry the load all other satisfy all other serviceability requirement should excessive deflection, cracking, etcetera etcetera, so performing satisfactorily for a period. Now but this period is not really known to us at the moment or other we cannot calculate the precisely. The current state of knowledge of concrete. Therefore, most of the codes or all codes actually still date specify some prescriptive measures or rather requirement some kind of prescriptive measures in order to ensure adequate durability performance, during the intended design life intended design life.

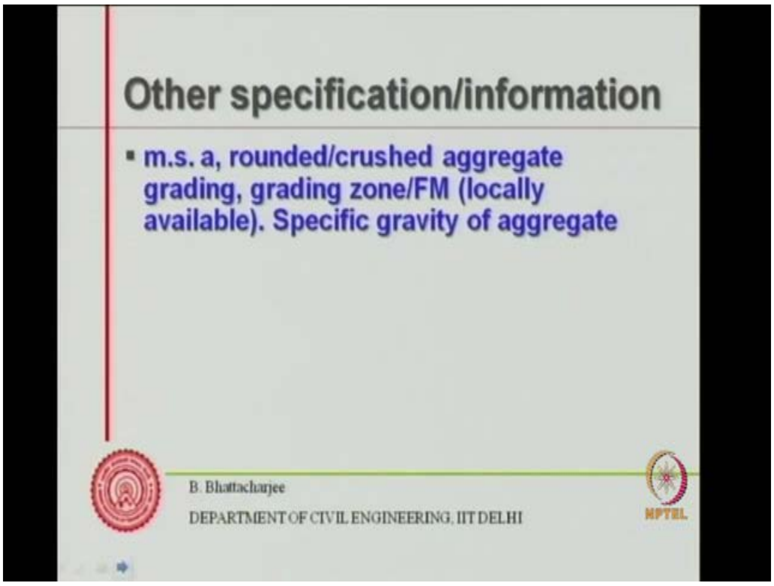
(Refer Slide Time: 15:40)



Alright, so durability requirement therefore, specified or rather you know they are specified in terms of some prescription of cement minimum cement content and maximum water cement ratio or minimum grade of concrete etcetera minimum cement content maximum water cement ratio and minimum grade of concrete etcetera, minimum grade of concrete etcetera Alright, so what we have seen we specify concrete first of all in terms of fresh concrete property. And a common way of doing that is in terms of slump. We specify also concrete in terms of its grade, which is generally related to 28 days of characteristics of compressive strength at the age of 28 days. We might specify strength of concrete or hardened properties of concrete in terms of strength at some appropriate age, may be ideal age. Some cases we require that, for example, where we want do r d de-molding right. Say at P tension precast system, where I would like to apply some p tension to the concrete. Expose it to some kind of p tension in such situation I might require high r d strength. So n addition to grade of concrete I might also specify the strength at some early age. Some other cases I might specify tensile strength of concrete at, let us say at the same age.

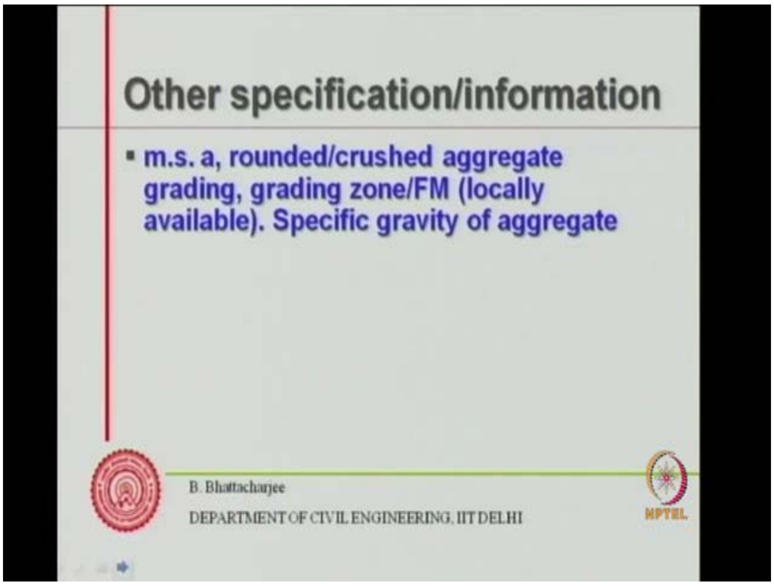
Then comes the long term properties at the hardened state, at the moment we have some prescriptive recommendation given in codes namely we specify minimum cement content, maximum water to cement ratio and minimum grade of concrete to ensure adequate durability of concrete. Now why water concrete ratio; why minimum grade of concrete; and why maximum sorry minimum cement content and maximum water cement ratio? All this will be understand understood when we talk of durability of concrete sometime, later on in some additional module. So at the moment we are trying to look at the mix design, so this is how we specify the concrete.

(Refer Slide Time: 18:45)



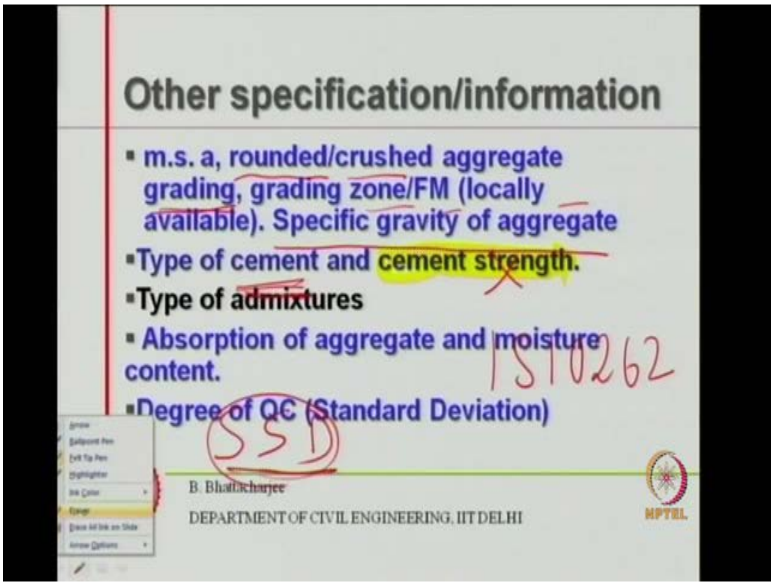
And once these specification are available some more additional information may be needed. These additional information’s are maximum size of nominal maximum size of a aggregate, which is again decided by the spacing of the reinforcement, the section, the cover and also, somewhat related to the strength of concrete. A high strength concrete may be relatively more easily designed with lower maximum size of aggregate, compare to let us say a low strength concrete which can consume even the larger size aggregate. The reasons will explain and we will understand sometime later on, but what at the moment we haven’t understand, is maximum size of aggregate is an important information. I would need what would need to do the mix proportion, alright.

(Refer Slide Time: 19:50)



Then, whether the aggregate is rounded or cursed? Natural aggregates are rounded as we have seen earlier and we have seen also that shape go bares the packing characteristics of a aggregate.

(Refer Slide Time: 20:12)



Because we have talked about aggregate material and rounded or cursed. And we know that, rounded aggregate rounded aggregate rounded aggregate (( )) better then cursed aggregate. They are grading the proportion in its size. That is what we have seen if we depending upon proportion the packing characteristics of the aggregate depends upon the proportion of each size, that goes into making of the or packing of the aggregate themselves. Similarly, for sand the grading zones may be important. Again that is telling us what is the size fraction belonging to which size proportion belonging to each size fraction.

That is what it is. Fineness modules also we have discuss sometime earlier is again related to the kind of a measure of an average size. So size of the aggregate there packing characteristics proportions in you know packing characteristics as govern by shape of the aggregate, maximum size of aggregate and proportion in each size, this issues are this information's are important. Now these are important from the point of view of availability of aggregate. Because one would like to use locally available aggregate to minimize the cost of the concrete and all other transportation related, you know negative aspects, for example, energy consumption in transportation and so on and so far. So one would like to use locally aggregate available aggregate and therefore, what is the size fractions available, if there is anything missing such information's would become important in mix design.

But, we have already seen how this I may say the effects packing characteristics of aggregate, how shape aggregate shape of aggregate effects the packing characteristics and its effect on fresh concrete etcetera will understand of course later. One more important one more information is important is a specific gravity of aggregate. Because volume occupied by (( )), you know volume occupied or mass in unit volume, this is what unit volume of the aggregate. So volume to mass ratio is through specify gravity and therefore, these also in important information. What we do is we actually measure this before doing the mix proportioning or before doing a mix design is generally measure this if this information is not available.

We would like to know type of cement and cement strength is not a necessity these days cement strength is not a necessity cement strength is not a necessity, is this not a necessity. But, our some of the some of the codes might use cement strength is an input to mix design. In fact earlier in Indian standard was using this cement strength as an input, but now it is not a necessity in Indian code, that is 1 0 2 6 2. Indian code 1 0 2 6 2 so I s 1 0 2 6 2, this is not a necessity any more this is not a necessity any more But, earlier, the code was is using it such this that is why this appears here but by enlarge you do not need this information now. Now type of cement is important, particularly related to durability particularly related to durability.

Well this inform much this information is important in the sense that from the point of view of minimum cement content we have got some important not really much but what would be important for us to know, the for our possibly past experience of our record. How much is a strength you know kind of strength, water, cement ratio well essential for concrete, that become an important. When a type of cement may be may be specified because this is what you would be using. So if you have to do a trial casting you already use that particular type of cement. If I am using some admixtures what is the time of admixtures? I am using that information is important and this compatibly with the cement and other system over all system that is also an important aspect, absorption of aggregate and moisture.

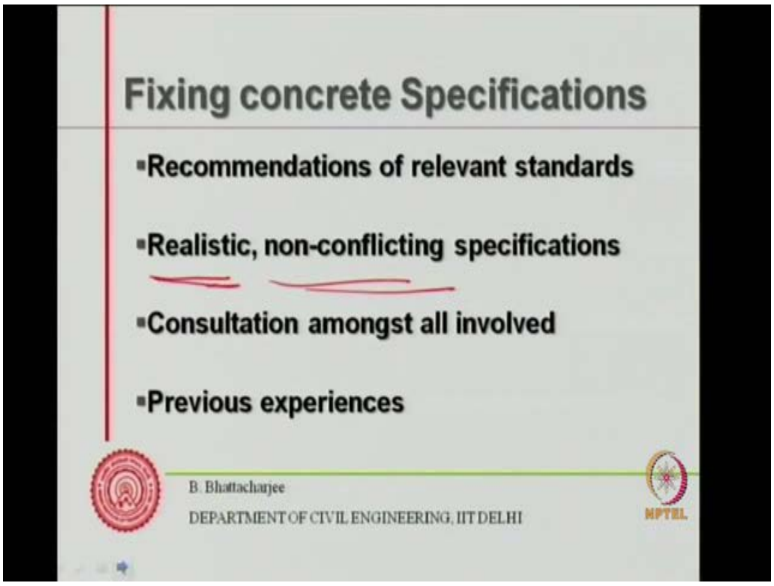
Absorption of aggregate and moisture content of an aggregate, this is an important information. This will act to know, we measure the moisture content that what is called saturated surface dry s s d condition, which we have seen earlier. Earlier we have seen. So you measure the moisture content record for attaining s s d condition from mone dry to s s d condition what is the moisture content and how much is the moisture content related to a s s d condition? That is the information is important. Because in actual size, moisture content will be different so it will be do some adjustment accordingly. And then, this is an important information. Degree of quality control degree of quality control, that is achievable at the size, this is an important information. You know standard deviation, will discuss this a little bit more in the next couple of slides.

(Refer Slide Time: 26:44)

So degree of quality control over control that is achievable at the size this is very important. Remember grade of concrete is always related to the size situation, although concrete is you know concrete is prepared and tested in the laboratory, which can be site laboratory very well it should be a site laboratory. Now the site laboratory should take a count of actual control available while production. So that is what the degree of quality control is important, why it is important? It become clear as we go through our next couple of slide. How do you fix this, this is fixed based on recommendation of relevant standards, like we said that like we said that the slump is given is I s 456 2000 or let us say pumpable concrete ratio should be about 100 to 150 m m. In fact 120 m m or 130 m m is possibly the minimum good slump at which pumpabilty can be achieved.

So relevant of the standard is very important. You know recommendation of the relevant standard is very important. Should we select this specification based on recommendation of the standards. In India of course, mostly we do it based on I s 456 I s 456 2000. At the moment we do it is the 2 this one we do it with respect to this, right. So in many other country they will have all other countries will have their corresponding standards and according to it we selected.

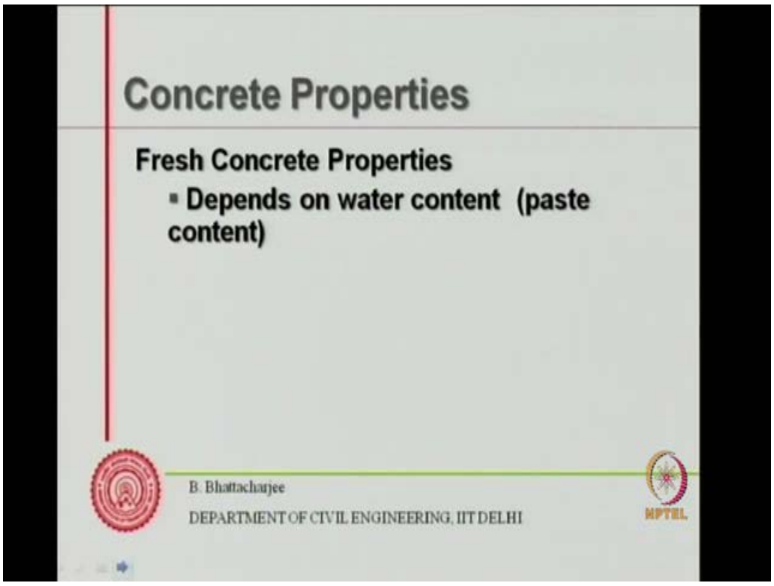
(Refer Slide Time: 26:45)



Now this specification must be realistic, I mean what is achievable. So it must be realistic, it should be achievable. There must be non-conflicting no conflict no conflict non-conflicting. You know two specifications, for example, specification tension in case of durability, should not be conf conflictive something else some other specification. So this would be this would be very important they should not be conflicting, conflicting specification should not be there and they should be realistic. Guidelines of the codes are usually taken relevant standards and code.

And then it must be discussed with all parties involves, before fixing this specification. Let us say contractor the man the you know group which will be actually doing the job of the site, construction work, execution of the construction, the designer there may be even depending upon the situation even sometime you know the owner may be also involved if there knowledgeable. So all contribution of all the people in involved, that should be taken into account and then this specifications are finalized. And obviously previous experience in the similar site plays a big role, so specifications are fix according to this kind of you know this past experience codes, ideas from everybody involves and so and so code.

(Refer Slide Time: 29:20)

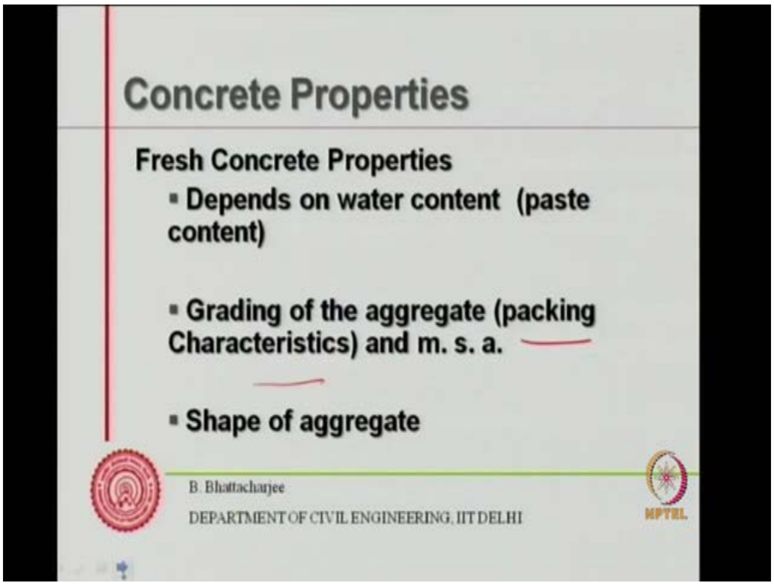


Now on what does the fresh concrete property depend? Well this will talk in details in the next module. But, we take from granted at the moment that it depends upon namely on paste content namely on paste content we can understand this. Sometimes perhaps when you are talking of aggregate we have discuss that they should packed very well. Now the aggregates themselves are known.

You know moldable, paste concrete properties related to moldabilty. I should be able to mold it easily and fresh concrete properties relates to moldability. How can I mold, molding process involves essentially grabbing out the air on the concrete. Because fresh concrete, concrete when I place it, it contains about 30 percent air avoids into it, right. Normal concrete will contain about 30 percent air involved in it. And this has to be driven away. In second issue is seldom it is in the location where final you know it is in the shape, is not in the shape of mold itself. So there has to be some flow to get to acquire the shape of the mold itself. So therefore, it you must grab out the air and also it must acquire it shape also.

That means, there some modality is needed and by this process of modality the aggregates and the concrete itself should get traced into the mold in it appropriate position and air must be also driven away. This is best done by vibration this is best done by vibration in normal concrete of course, there is special concrete called self compressive concrete, which have becoming popular and popular now a days. But, in normal concrete we adopt vibration in order to grab out the air and get the shape of the concrete appropriate same shape as you desire. We desire shape according to the mold. Therefore, concrete must be able to flow. It must able to flow. Now this flow ability, if we look at it aggregates are not flowable. There stones and their answers are just not provable or they can little bit flow and you know move and from a hip.

(Refer Slide Time: 32:12)



They have an angle of repair reports, right. They can form an hip and there will form hip like this and they will have what is called as angle of hippos. So some angle of hippos where this sort of an angle where some you may can if some sort of angle. So they can form an angle you know from a hip. Now paste therefore, you can vibrate it may not move a little bit but not much. But, if I have paste inside them paste in the aggregate system paste in the aggregate system, this paste are easily flowable, because there will there are more occur plastic state. So con aggregates and paste together is in plastic state. And it is the paste which is easily flowable, in fact in the paste again the water is most easily flowable.

So if I have small amount of paste within the aggregate it is not going to the wall. I should have sufficient paste which will fill in all the wall within the aggregate system. And when I put a little bit if vibration the paste themselves should be able to move and also take the aggregate along with them. So therefore, paste content is an important issue as far as their fresh concrete properties are concerned, right. It depend upon water content and paste in the paste the main thing which is actually flowable easily or which causes getting into the new shape under vibration it is the water. We should see this sometime later on. So paste water content or in other words paste content is the most important thing which dictates the flowablity or moldability of the concrete and therefore, fresh concrete properties is largely governed by moldability. The other issue of course, is it should remain plastic during my placing and compaction. So that is related to what is called setting properties.

We have seen setting properties of cement. Setting properties of concrete depends upon the setting properties of cement alright, but it also depends upon the setting characteristics of the admixture that I have added. Because some admixtures can be tug, that is what we have seen when we talked of admixtures. Some admixtures can be tug the setting of concrete, therefore, in concrete setting properties of concrete is governed by properties of both cement as well as the properties of admixtures they control. So it should remain plastic during the compaction up to the compaction state complete molding stage actually. Come they have to complete molding stage, alright. And it should be easily flowable. Now this property is dictated by paste content and water content mainly water content and paste content, right. And I wouldn't like to keep too much of paste, because paste contents cement which is costliest of all the materials and therefore, you know if I have too much of paste the cost of the concrete will increase in normal concrete.

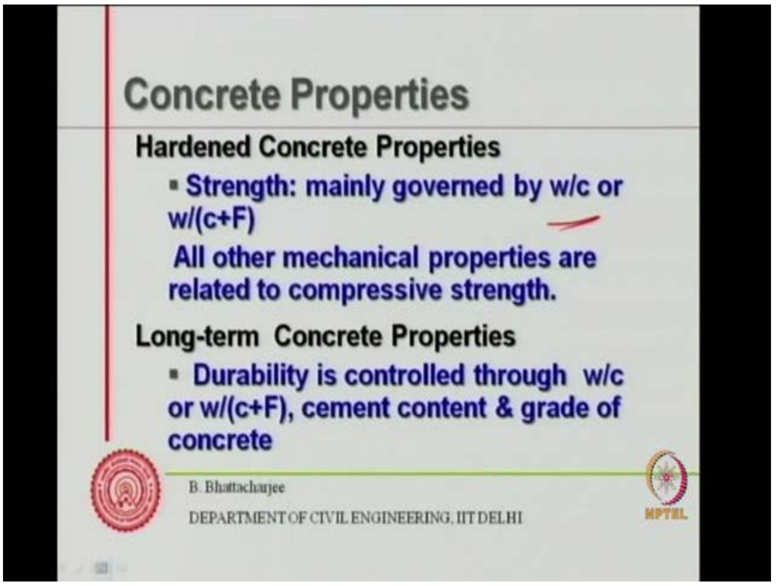
So I would like to keep the optimal quantity of paste and yet get the right kind of moldability related properties that is slump is one of one such property. So optimal quantity paste means water as well as fine material such as cement flier and similar other material, right. Now that would be ensured if I want to keep minimal material that would be ensured by packing characteristics of the aggregate. If they pack very well we remember we talks something of packing density, which is the mass of solid in let us say unit volume of

the bulk material. So one minus you know mass or volume fractions sorry it is volume fraction of the solid material. You need volume of the bulk material. So one minus packing density gives me the both content in the aggregate system. So this both content should be minimum; that means I should have just packing. And good old days ideas of this packing density is relatively less known, because science of particulate matter was not so well developed. So we talked in terms and we understood of course, it is understood of by observation or empirically, that if I add different proportions of you know different materials, it packs better. And appropriate proportions of each fraction of this each size fraction would

make the packing better that is what we have seen while discussing about aggregate. Therefore, grading of aggregate is an important issue, grading of aggregate is an important issue Grading means proportion corresponding to each size, that was that is an very important issue. So aggregate grading of aggregate and we have also seen as I increase the maximum size of aggregate or number of size of if I increase by packing them in groups or the void system in the aggregate is good. So good grading higher I may say you will always reduce down the void system in the aggregate and therefore, my paste content require for right kind of or appropriate kind of moldability or work ability would be less. So it will make the concrete economic. So paste content or water content they would have dependent on the grading of aggregate and maximum size of aggregate alright. And also shape of aggregate. We mention that they are rounded aggregate packs better.

Therefore, they will require unless paste I repeat rounded aggregate packs better that is what we have seen in the unit of the aggregate. Therefore, we require lesser paste for the same workability, so concrete would economic for the same workability. The strength is not govern by large by shape, if anything governs it should be texture of those aggregate but not by the shape. Shape governs the packing characteristics. So these are the factors which will dictate how much is my water required or paste required and for you know water required is decided on the suspect.

(Refer Slide Time: 38:40)

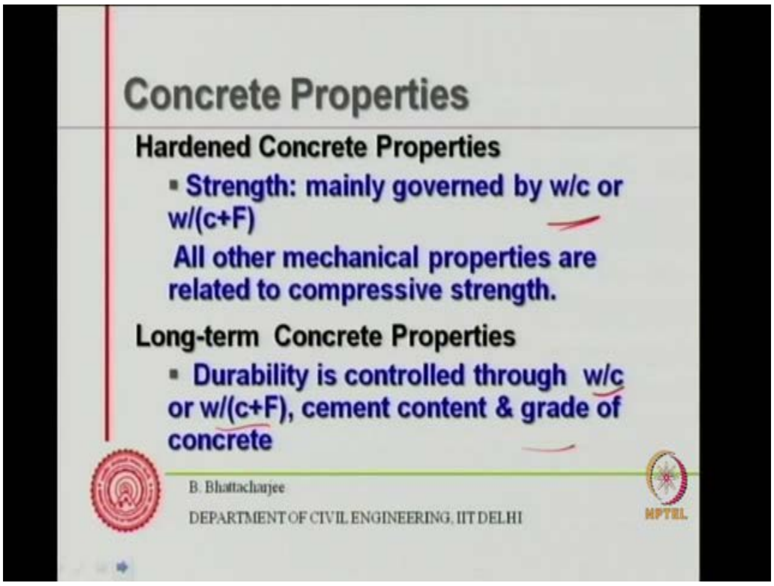


Strength is mainly governed by water cement ratio or water to cement and fliers ratios strength is largely governed by water cement ratio or water to cement and fliers ratios. You know all others properties can be related to compressive strength all others properties can be related to compressive strength all others properties can be related to compressive strength. I mean all other mechanical properties, empirically, for example, empirically modules of elasticity as we measured, right.

Elastic modules using design they can be related to compressive strength. Even flexural tensile strength can be empirically related to the compressive strength. So largely we design concrete for compressive strength only in special cases for tensile strength. And water cement ratio governs those, why does water cement ratio governs this? Because water cement ratio controls the porosity in pore sizes of cement paste waves in even in concrete same thing happens.

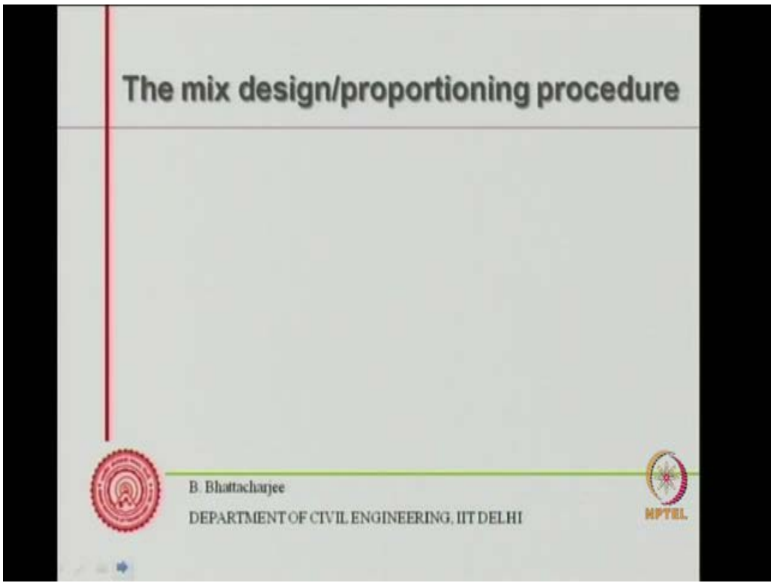
We have seen in the case of you know micro structure development of cement is, it is a water to cement ratio which governs the capillary porosity. Higher water cement ratio means more capillary force. Therefore, strength of the concrete which is a function of the porosity and pore size of concrete is governed by water cement ratio. You shall see this in detail sometime on when we talk of strength the factors affection strength of concrete, that time we should see this and will understand more about it. But, at the moment we understand it is the water cement ratio is governs the strength of concrete and therefore, or if you are adding some other supplementary cement ratio like flier or let us say silica fume they you know the ratio of water to cement plus those once would actually governs this one.

(Refer Slide Time: 41:26)



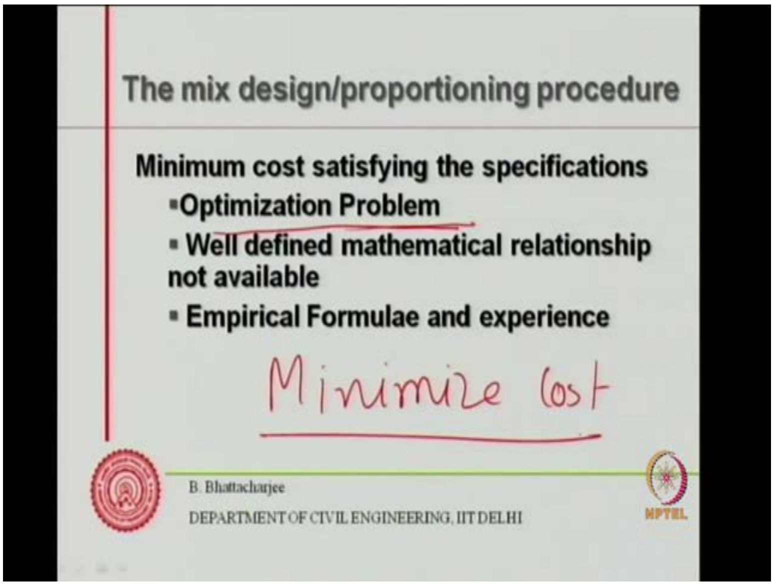
Now we also understand that detoriation process in concrete takes place through in there some material from outside. And again through this course an inter connected course, therefore, porosity governs the strength again, sorry durability again or detoriation again. So porosity governs the detoriation. And therefore, durability aspects and control to again water cement ratio or water cement to flier ratio and grade of concrete etcetera. So water cement ratio is an important factor which governs the durability as well as strength, because we have prescribing maximum water cement ratio.

(Refer Slide Time: 41:46)



So mix design procedure first thing is we determine actually water cement ratio from the strength requirement, and durability requirement or durability requirement whichever we know gives me the higher value of lower value of water cement ratio that is what I am saying.

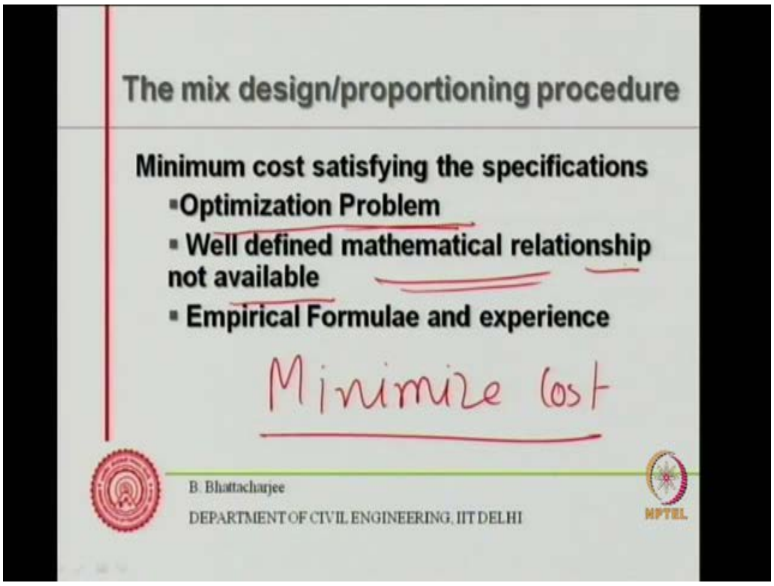
(Refer Slide Time: 42:05)



Let us see controlling one would be the lower value. Let see the procedure then, mix design procedure, then but before that just one more thing I would like to understand or other I would like to make clear is that I should design the system for minimum cost, satisfying a set of specifications. So I am minimizing the cost, therefore, it is an optimization problem. Minimize the cost minimize cost it is you know minimized cost.

This is one problem of optimization in fact in classical optimization problem we either maximize the profit or minimize cost or maximum gain, minimum loss. So whatever it is in classical optimization problem. And I would have love formulate mix design process is an optimization problem you know. Then I have a software and I am through it in just put on those data and you get the output in an optimization problem many, many you know many cases it is used. Many engineering problem we can use this optimization process. Mathematics of optimization is very well defined in mathematics.

(Refer Slide Time: 43:22)

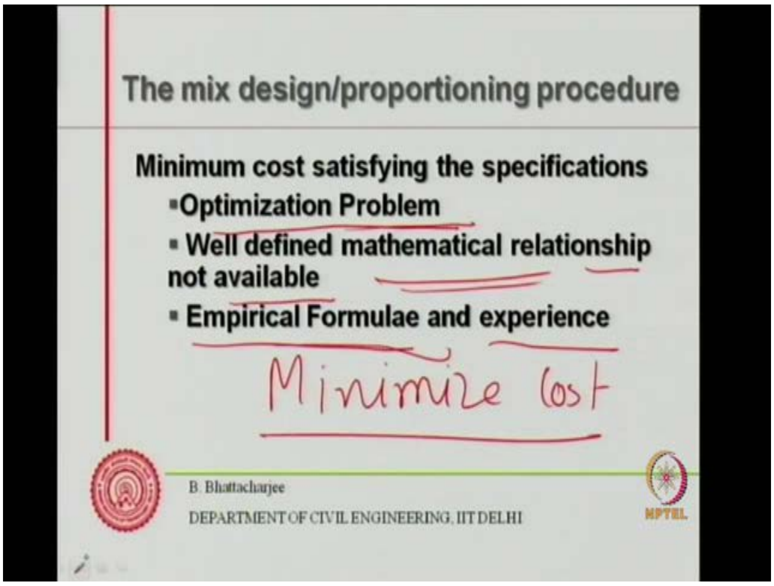


But, to do that usually in an optimization process I will have some objective functions or some objective like here the minimization of course, and cost of each component of the material if I know, then total cost I can always minimize. Subjective to certain constraints, let us say my strength must be greater than specified strength; slump must be greater than specified slump etcetera. So these are certain specifications can be form in terms of a constants right will say you know what we usually mention in case of classical optimization problem. So my specifications could have been constraints.

My objective could be minimization of the cost and I could have easily done an optimization process, optimization you know process mathematically. And it would been a very good thing very, very easy situation. But, unfortunately we do not have well defined equations relating strength and mix factors. Neither we have very well defined equations relating slump and mix factors. So well defined mathematical relationships are not available. In fact if you look at a book by sender popo biks he has listed down as many as 50 plus equation of equation for slump of concrete, related to various factors. Now what does it mean, they cannot be general.

A general equation satisfying all the conditions, so it has been only one, like one Newton's law can express or can be you know all most equations you know all motion or movement of or moment you know moving bodies behavior of moving bodies can be expressed in terms of one general equation. We do not have such general equations for slump of concrete. That is why there are 51 equations, each was developed empirically for may be for the specific condition of that particular experiment.

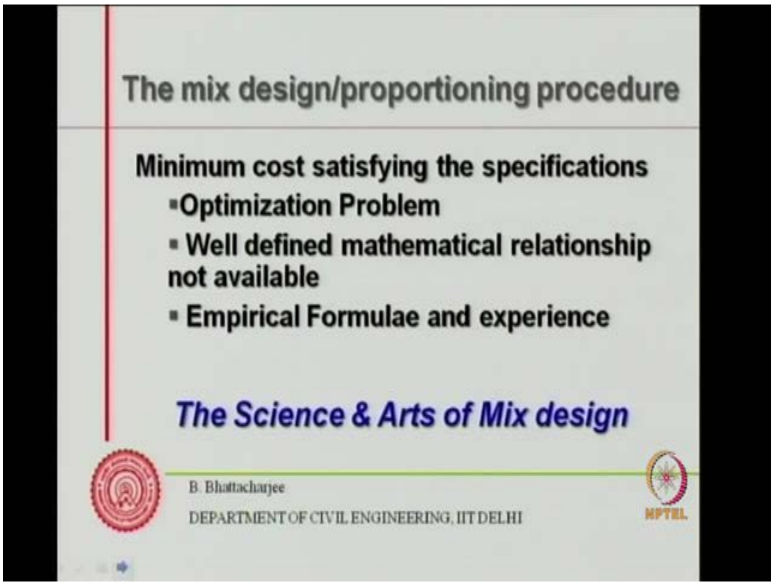
(Refer Slide Time: 45:45)



So you do not have general equation therefore, you cannot create it as an optimization procedure. We do not have well defined relationship, neither for strength nor for work ability and durability is out of question, because we are only at the stage of prescriptive level now. So what we have empirical formulae and experience. Some empirical formulae ah not very general not very general but still some formulae is available and experience of people.

Therefore, we cannot formulate the mathematical problem. And if we even if we do it it will be case (( )). So use of very sophisticated software's etcetera really does not make at the moment you know they are not they are not very much very much conducive. In fact finally, you have to make a transverse.

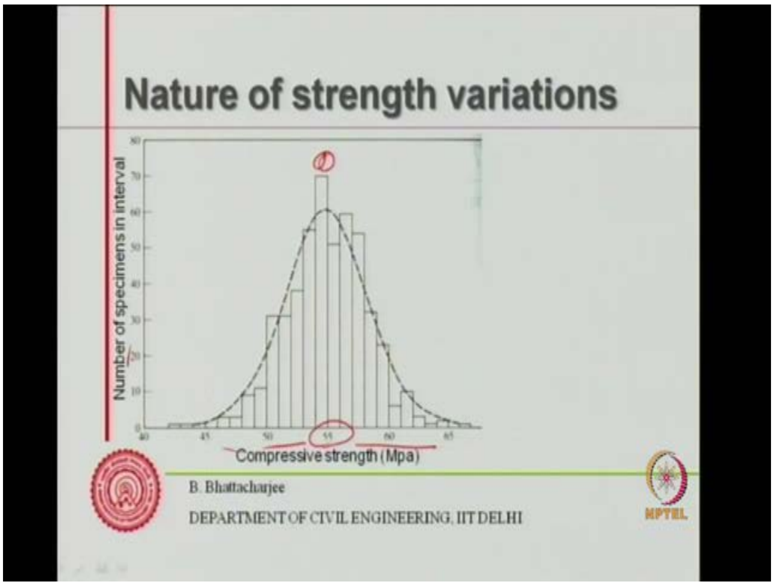
(Refer Slide Time: 46:35)



So you must understand that mix design procedure is largely empirical in nature and it is not only science. It has got large arts component. The person would have mixed design day in day out, for a given type of aggregate and cement system or various cement system in a particular locality, he come out he or she will come out easily with a mix proportion for any grade of concrete, under that situation. Because experience is very very important very very important with the experience in this at the moment, because we do not have generalized relationship and material varies from place to place.

And even from the same source you go getting material you will find that the properties of the concrete bed. So experience plays a very, very strong role and mix design procedure also involves some trial casting. The mathematics or procedure, mathematics is very little there is hardly anything, the procedure involved is only looking at few charts and tables and coming at the proportion starting proportion. But, finely you have to do a several trials and come to the place so it is more often empirical sort of an procedure, and therefore it is more of arts and you know the science is obviously there but there is good lot of arts is also in there.

(Refer Slide Time: 48:05)

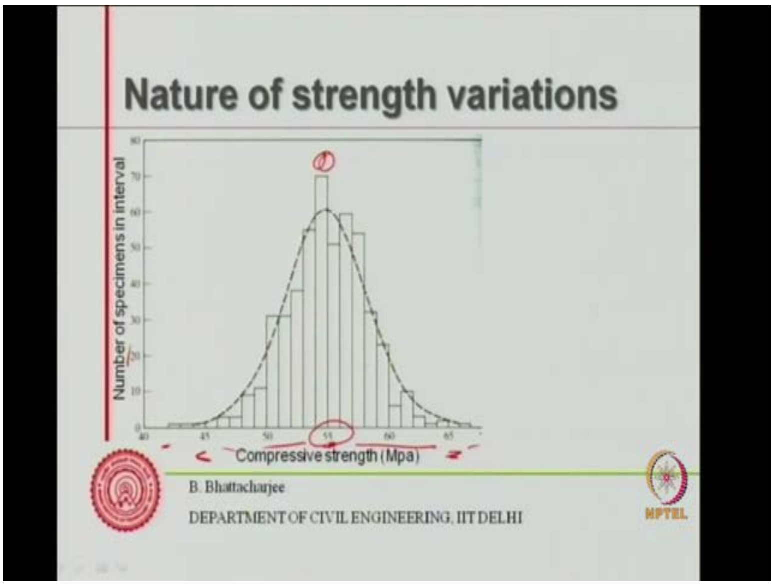


And one must realize this right. So mix design is more often art together with the science point of view. Now let us understand the procedure. To understand the procedure first thing I must understand is a nature of variation of concrete strength. Supposing I have a concrete strength, I thought the mean strength would be somewhere let us say somewhere 28 days age I am talking of or you know let the moment let us say 28 days. I have decided that it should have a some kind of mean strength of let us say 55 or so this would be vary for anything any other mean strength also. I will find that if I test large number of cubes and plot a frequency diagram like this, then good lot of majority will show the strength flows to what I have actually concealed does a mean.

But, possibly large number of 50 percent of the strength would be lower than that and 50 percent of the strength will be higher than that. This is because concrete is strength few concrete strength at the age of 28 days depends upon to many factors there are too many variables. For example, it depend upon the error in mixing proportioning first of all what we call batching there would be some kind of error in batching, you wanted to put 180 liters of water. You might have your measurement system would have meant it to you know you might have put it around 180 instead of 185 or 190 instead of 185 there will be some tolerances about the actual quantity specified quantity of water, you want to mix similarly, the quantity of cement, you wanted to put in let us says 320 k g just of the cement you wanted to put you might add up actually 310 or 330; this is very difficult to put or ensure absolutely same quantity of cement time and again it is very within certain tolerances elaborate tolerances. And therefore, you can see that water cement ratio would vary from admix to the other mix even in the same mix the mixing procedure itself could add to variations first 15 percent of the discharge from a mixture machine than would be exactly same as the last 15 percent of the discharge from the same mixture machine.

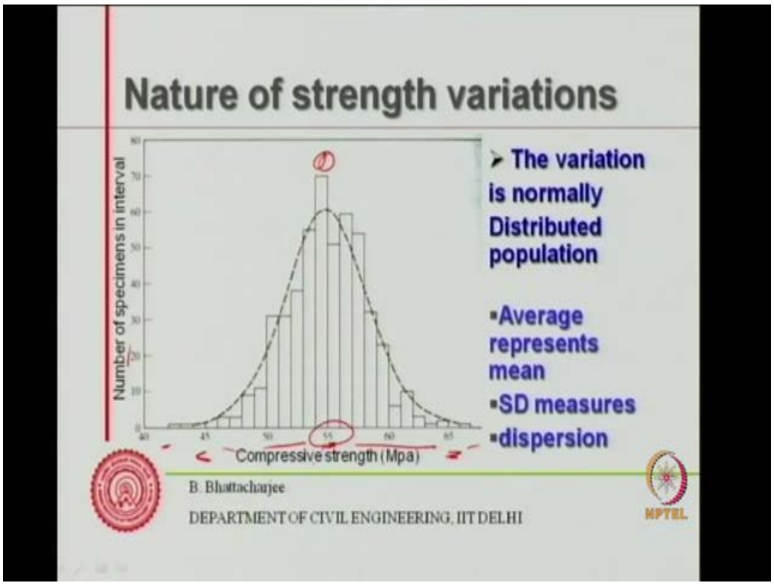
So therefore, there is a kind of variation strength variation that could occur because of mixing many other factors like aggregate in one batch might vary from the other batch, aggregate in a given cube might vary from another cube which I have molded for testing. So therefore, there are several such factor which governs strength finally measured strength even the testing machine interaction with the machines you know every time the load is showing there are some errors in load measurement there will be minor errors random errors. So there are too many random errors which control the strength of cube strength as measured, and statistics tells us from central limit theorem that in such situation random variable which depends upon number of random variable will vary normally; that means, it will show exhibited bell shaped curve as shown here it will exhibit bell shaped curve as shown here the strength although I wanted to be 55.

(Refer Slide Time: 52:00)

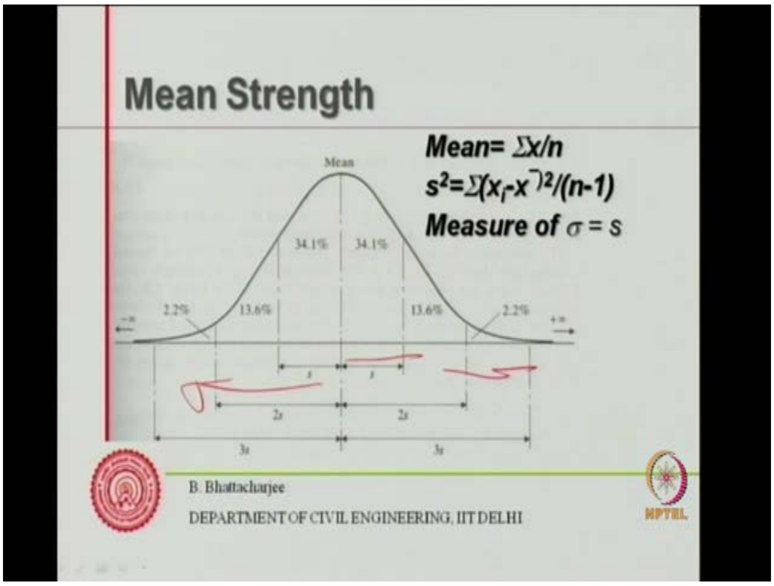


It will actually vary from 45 to 65 or 67 to 43 to 67 and therefore the range over which it implies hence when I specify my strength my specification of strength actually goes in terms of you know this variation is normally distributed and average represents what is called mean and it will have some kind of dispersion about this mean.

(Refer Slide Time: 52:17)

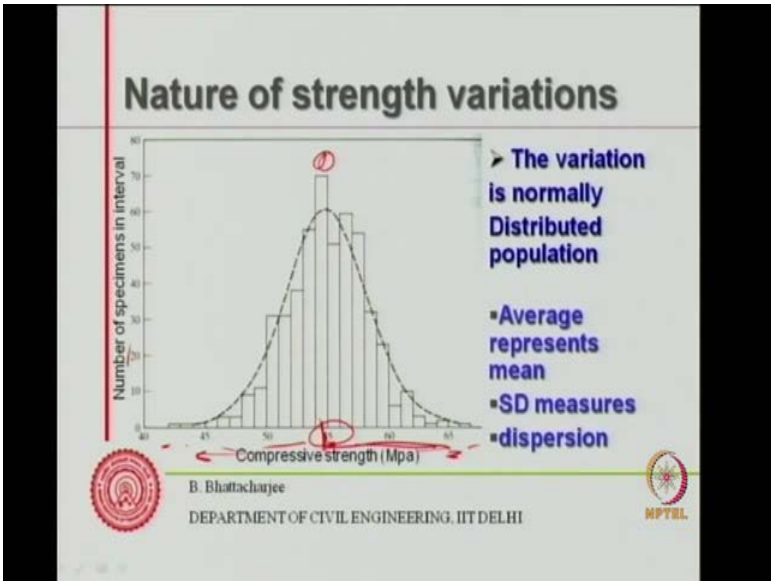


(Refer Slide Time: 52:35)



Just if you recall that we define you know and this this also comes from statistics that whole of this area under this curve, if I considered to be 1 then 50 percent of the carbizone on this side 50 percent of the carbizone this side in other words 50 percent result should be above this mean which is that average.

(Refer Slide Time: 52:55)



And 50 percent of the result will be above this mean which an average and 50 percent of the result will be below the mean 50 percent will be above the mean 50 percent will be below the mean. Now we have defined our characteristic strength is that strength which will be exceeded by 95 percent of the cubes therefore I must define my characteristic accordingly now this is what we do in next lecture so to sum up what we have discussed with how do you specify the concrete? How do you the specify the concrete?

For mix design purpose 3 issues we have looked into one is the fresher properties which is said slump is more common then we looked at the strength property and then we also specify it in terms of durability requirements which are prescriptive like maximum water cement crystal limit is given minimum cement content is etcetera. And then we just try to say why this you know little bit of why and what are the what are the factors in the mix proportion that governs this property for example, we said water content or paste content will be under slump fresh content properties water cement ratio is govern both the strength and durability therefore, from the strength.

We would like to fix the durability from the strength we like to fix the water cement ratio and from durability. We will try to fix the water cement ratio which ever gives me the lower water cement ratio that is what I will select and from the slump requirement etcetera. Will fix the water content or paste content we should see that in the next class to start with I just started about how do we decide, how do we define to start with how do we define grade of concrete. And in the next lecture will start from here will start from here from the grade of concrete, and then overall mix design procedure will you know will explain followed by some of those methods.

Thank you very much.