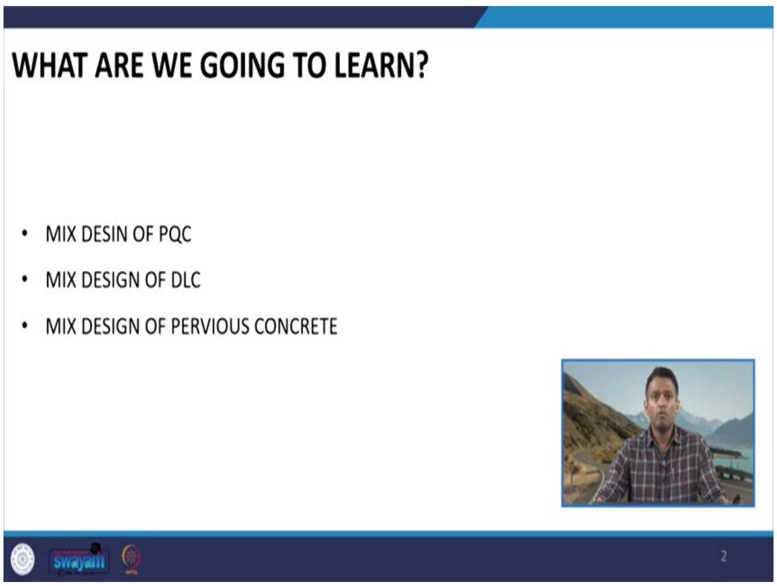
Pavement Materials
Professor. Nikhil Saboo
Department Of Civil Engineering
Indian Institute Of Technology, Roorkee
Lecture 53
Mix Design of PQC- IRC 44

Hello everyone. Today we are going to start a new module which is on mixed design of concrete mixtures that we typically use in the construction of concrete pavement.

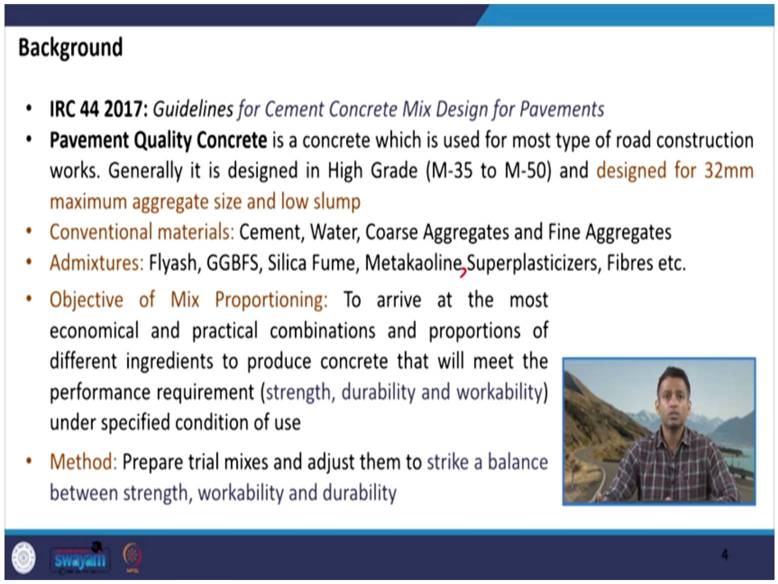
(Refer Slide Time: 00:41)



In this particular module, we will be touching upon these following topics which are Mix Design of PQC, which is the pavement quality concrete. We will be talking about Mix Design of Drylin Concrete Mixtures, which is a layer or a mix which is typically used just below the top slab in the concrete pavement. And we will also discuss about the mix design of spatial concrete that is pervious concrete. The details which are presented in this particular module are taken from the relevant Indian specifications that are on mix design of these mixtures.

So, let us start discussing about the mix design of PQC. In today's lecture, we will try to understand the parameters that are involved in the mix design of PQC. And we will also try to understand the various steps and the corresponding values of different parameters that we need to consider for designing the pavement quality concrete. And in the next lecture, we will try to solve two problems to understand these steps which will be discussing in this particular lecture.

(Refer Slide Time: 01:46)



In this particular lecture, we will be referring to IRC 44 2017, which is the guideline for cement concrete mix design for pavements. Talking about pavement quality concrete, so, pavement quality concrete or PQC, as we call it is a concrete which is typically used for road construction works, and it is designed for higher grade when I say higher grade, it is we typically go for above M-30 usually. So, M-35 to M-50.

And, it is designed corresponding to a higher nominal maximum aggregate size which is about 31.5 mm or 32 mm, and the slump in this concrete which we use is typically a low in comparison to the other concrete which we use in different structures, talking about the materials, materials remains the same, just like we use in any other concrete the ingredients include cement, water, we have coarse aggregate and we have fine aggregates.

We also have admixtures depending on the design or depending on our requirement. Admixtures can be of various types, we have already discussed about these common admixtures we have understood their production process and how they react in the concrete mixture to provide strength.

So, these admixtures includes Flyash use of Granulated Blast Furnace Slag, we have Silica Fume, we can use Metakaoline we can also use Superplasticizers or Plasticizers. And there are provisions of using fibers or in different forms in the concrete to increase the strength or to achieve certain desirable properties.

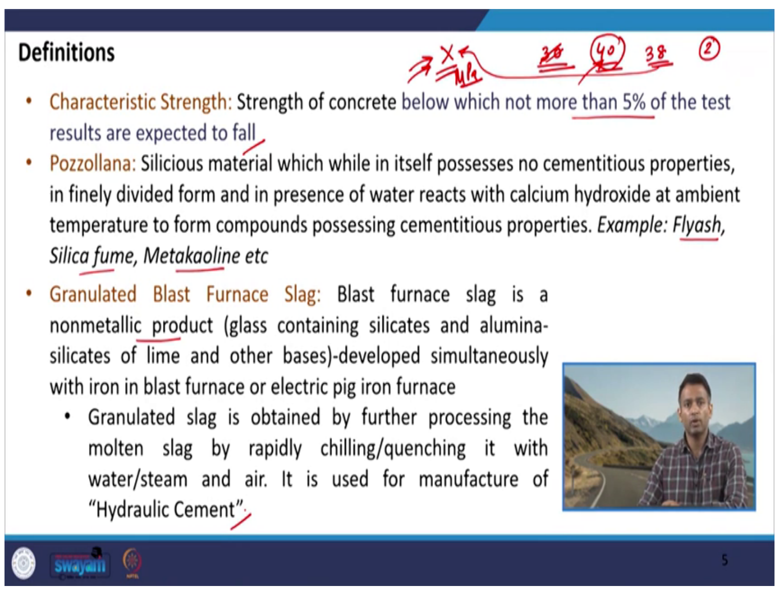
Now, what is the objective of mixed proportioning I mean ultimately, what are we trying to achieve? Rather we can call it as the objective of mix design, which is to arrive at the most economical and practical combination and proportions of different ingredients to produce concrete that will ultimately meet our performance requirement.

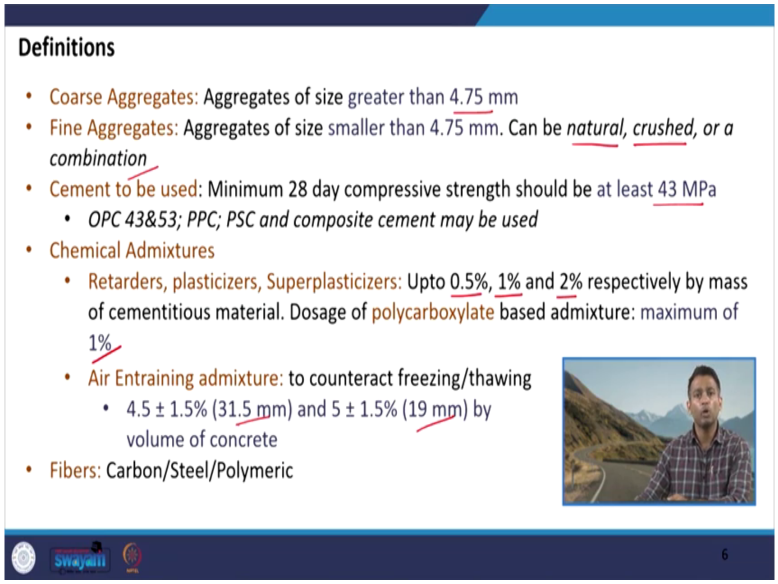
It can be the requirements related to flexural or compressive strength, our requirement can be related to the durability in the mixtures, our requirement is also should be related to the workability characteristics of the mixture. So, these parameters need to be optimized, we have to strike a balance between these parameters to finalize the appropriate proportions or combinations of the different materials with which we are going to do the mix design.

Now, the method of the mix design mostly remains based on trial and error. So, we have to prepare trial mixes. Even though we do the theoretical calculations, we can select the initial proportion by doing the theoretical calculation, but even after doing the theoretical calculation, we have to prepare trial mixes we have to test them and then we have to adjust the proportions so that the final mix which will be ready should have a proper balance between strength characteristics between workability and durability characteristics.

Now, there are certain terms, there are certain types of materials which we need to understand before we can talk about the steps that are involved in the mix design process.

(Refer Slide Time: 05:09)





So, one term which we use in the mix design process is the characteristic strength. So, how do we define the characteristic strength of the concrete it is the strength below which not more than 5 percent of the test results are expected to fall which means, if I am testing let us say 30 to 50 samples. Let us say I am testing 30 samples or let me take another value here let us say I am testing 40 samples so that I get an appropriate number to explain.

So, if I am testing 40 samples and I have some desired strength x. So, this is what I am defining as the characteristic strength. So, this will be called as the characteristic strength if out of these 40 samples, at least 38 samples meets the minimum criteria of the strength has a value of x Mpa, if I am talking about let us say the compressive strength. So, at least 38 samples should have the minimum value of x Mpa because, if you take 5 percent of 40 it is basically 2. So, not more than two samples should have a value less than x Mpa in this case. So, this is how we define the characteristic strength of the concrete.

Another term which we are already aware of because we have discussed this term in detail in the last module, that is Pozzollana. So, just a repetition of what we have discussed that Pozzollana are basically silicious materials which while in itself do not possess any cement, cements property, but in finely divided form when they come in contact with water and calcium hydroxide that is released during the hydration process of cement, they form compounds that possess cementitious properties.

And there are several examples we can use Flyash which is a Pozzollana material, we have Silica Fume, Metakaoline, we have rice husk ash and so, on. We have also discussed about glass granulated or granulated blast furnace slag, and we say that GVFS or GGBFS also possess some amount of calcium oxide because of which the material when itself it comes in contact with water it can form some cementitious product, however, more amount of calcium oxide is required. So, usually it is used in combination with cement.

So, blast furnace slag is a nonmetallic product, which we get from the blast furnace during the process of iron manufacturing. And we have discussed that the molten slag has to be subjected to a jet of cold water, after which it will convert into granules, and then we have to remove the water in the dehydration tank and has to be further grounded so that it can be used in combination with the cement and it is typically used for the manufacturing of hydraulic cement some other terms.

Again these terms we are aware of because we have we also have a background on the mix design of bituminous mixtures. So, aggregates remains the same with the specification might be a little different from what we need in case of concrete mixture and then what we need in case of bituminous mixtures. So, we understand the term Coarse Aggregate. So, these are materials that are greater than 4.75 mm.

Similarly, Fine Aggregates are materials that are smaller than 4.75 mm and in case of concrete mixture, we have various options of for Fine Aggregates we can use natural sand. Now, this natural sand is not permissible in case of bituminous mixture. So, as I said the requirements of the or the specification of the material can be different, but these materials I mean generic materials remains the same at least the granular part.

So, the fine aggregates which we can use for the production of concrete mixtures can include natural sand, it can also be crushed sand. So, gravels can be further crushed to in that particular size range and we will call it as crushed sand or it can be a combination of natural and crushed sand. We can also have aggregates from other artificial sources for example, slag and so on.

Talking about the cement to be used again something which we have already discussed that typically in concrete which we use in pavement, we go for either OPC 43 or 53. So, the minimum 28 the compressive strength should be at least 43 Mpa we can use OPC 43 and 53. We can also use PPC Pozolnic Cement we can also use slag cement and also we can use a composite cement. So, these are the options available.

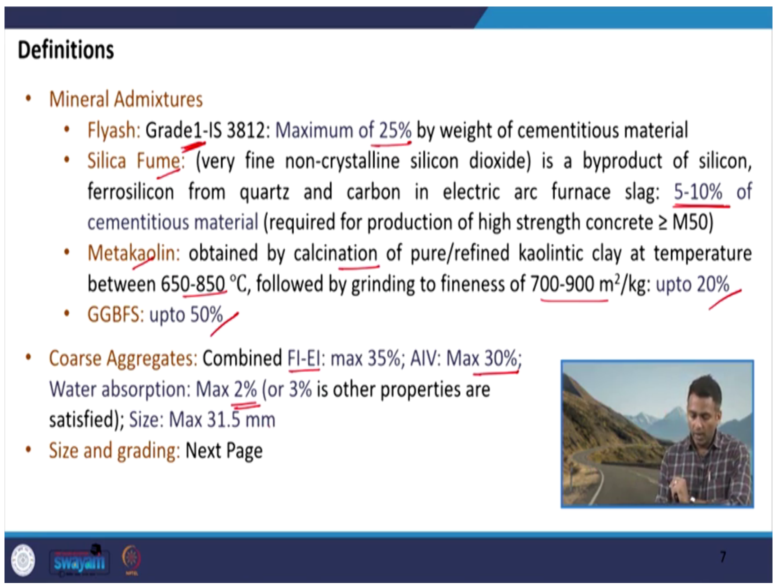
Talking about chemical admixtures, we can use retarders we can use plasticizers, superplasticizers the ranges of this was also discussed in the last module, for example, retarders typically 2.5 percent by weight of the cementitious material can be used, if we are using plasticizers we can go up to 1 percent again the percentage has to be decided optimally.

Then in case of superplasticizer, we can go up to 2 percent. But, if the superplasticizer is a polycarboxylate ether or polycarboxylate based admixture, then the maximum percentage is limited to 1 percent. Even in 1 percent we can have a huge reduction in water content. Or we can also use air entraining admixture in special conditions especially when we are worried about freezing and thawing cycles.

The amount of air entrained is typically in the range of 4.5 to 5 percent, depending on the nominal maximum aggregate size in case of 31.5 mm the range is 4.5 plus minus 1.5 percent. While in case of 19 mm, it is 5 percent plus minus 1.5 percent by the volume of concrete. We also have an option of using fiber fibers can be in various forms of various sizes.

We can have carbon based fibers, steel based fibers and polymeric based fibers. Now, the use of these fibers are required only when we have certain desired properties to be achieved.

(Refer Slide Time: 11:41)



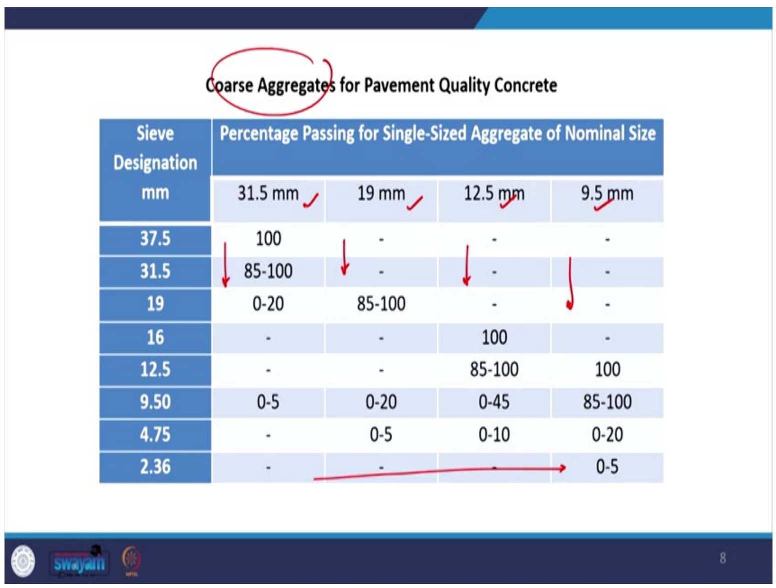
So, talking about mineral admixtures we have these following options like Flyash, Silica Fume, Metakaolin and GGBFS. Flyash has been recommended to use Grade-1. So, Grade-1 is basically the bituminous based Flyash, which has high silica and alumina content of typically more than 70 percent in contrast to the lignite based which has a lower percentage of alumina and silica content. So, it is recommended that we use Grade-1 and the maximum dosage should be limited to 25 percent especially when we are mixing it on site.

We can use silica fume the percentage is limited to 5 to 10 percent by weight of the cementitious material. And we also understand that from where we get silica fume through the process of production of silicone metal. So, and then we have Metakaolin, which we get from the Kaolin mineral Kaolinite based clay materials, it is obtained by calcination of those clay materials at temperature between 650 to 850 degrees Celsius, and then we ground it to find powder and the fineness value ranges from 700 to 900 meter square per kg.

And in case of Metakaolin, we can use it up to 20 percent and GGBFS can be used up to 50 percent. So, these are the typical mineral admixtures, which we can also use for the production of concrete for pavement application. Now, talking about the specification related to coarse aggregate, so, these are some physical properties requirement for physical properties.

For example, the combined flakiness index and elongation index should not be more than 35 percent the aggregate impact value should not be more than 30 percent water absorption should be limited to 2 percent. So, the source of the aggregate should be selected accordingly. However, we can also go up to 3 percent if we are satisfying all the other required properties in the concrete. The maximum size or the nominal maximum size which we use typically is 31.5 mm. Talking about the size and grading. So, this table shows the gradation for the coarse aggregate.

(Refer Slide Time: 14:03)

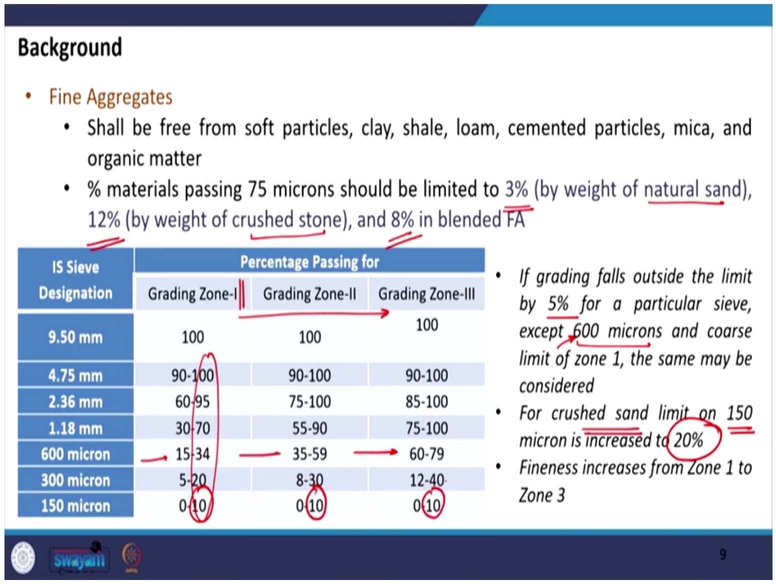


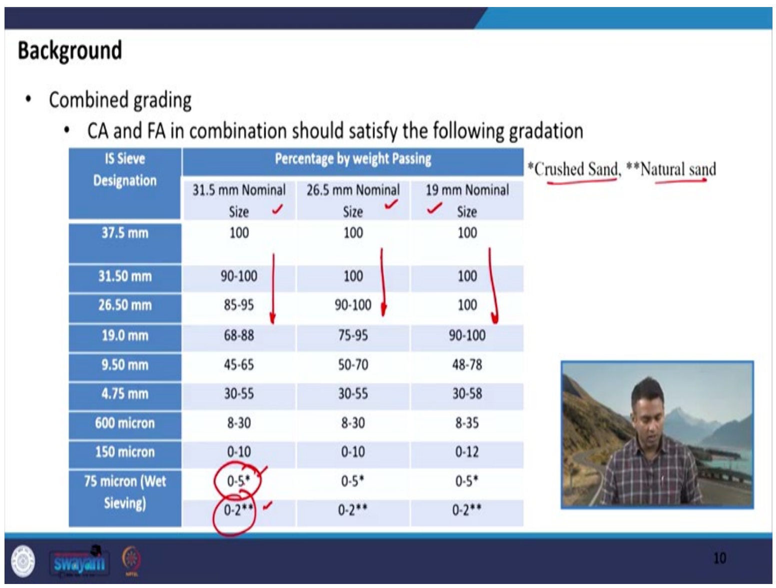
Coarse Aggregates for Pavement Quality Concrete

Sieve Designation mm	Percentage Passing for Single-Sized Aggregate of Nominal Size			
	31.5 mm	19 mm	12.5 mm	9.5 mm
37.5	100	-	-	-
31.5	85-100	-	-	-
19	0-20	85-100	-	-
16	-	-	100	-
12.5	-	-	85-100	100
9.50	0-5	0-20	0-45	85-100
4.75	-	0-5	0-10	0-20
2.36	-	-	-	0-5

you can see we have four options or four different nominal maximum aggregate size options here and corresponding to that the requirement of percentage passing is shown in this table. So, as you can see, as we are moving from here to here, the gradation becomes more finer, we have smaller particles in the mixture. So, these are the options available.

(Refer Slide Time: 14:32)





Similarly, there are guidelines for fine aggregates. Fine aggregate materials should be ideally free from the presence of organic materials and large amount of clay materials, because the presence of these materials can harm the durability of the concrete mixture. So, there are limits available on percentage passing 75 micron sieve. So, it should be limited to 3 percent, if we are using natural sand, I mean by weight of the natural sand in case we are using crushed stone. So, this will be more of inert material, we can go up to 12 percent. And if it is a blend of natural and crushed material, then we can go up to 8 percent by weight of that fine aggregate source.

Now, fine aggregates have been divided into 3 Zones. So, these zones again if you move from left to right degradation becomes finer. So, depending on the fineness of degradation, we have 3 zones 1 2 3, Zone-1 being the coarser one, while Zone-3 being the final one, and Zone-2 has an intermediate, a gradation which falls between Zone-1 and Zone-3.

So, once we get the fine aggregate we have to do this sieve size analysis and then we have to see that, which is the zone in which our fine aggregate falls and according the mix design should be done or the appropriate proportioning should be done. Now, the chordal provision also permits that in case the gradation falls out of this range say about 5 percent.

So, if it is outside the limit by 5 percent for any particular size, you can still use that gradation you can still consider the gradation in that particular zone, but this is not permitted for the sieve size 600 micron in any of these zones. So, we have to ensure that the percentage which has been specified here, this is exactly the criteria is exactly met.

Also in Zone-1, we cannot permit this variation of more than 5 percent especially on the coarser side of the limits. So, again this two points should be remembered and other than that, we can we have a flexibility of plus minus 5 percent. So, the limit can go up to outside the limit by 5 percent.

Some other points related to again this gradation it says that, if we are using crushed sand not natural sand, then the limit of percent passing up to corresponding to 150 micron can be increased up to 20 percent. So, you see here it is 10 percent presently, but if you are using a crushed sand, we can increase this limit to 20 percent.

And as I mentioned, that this gradation it indicates the fineness of the gradation. So, as we move from 1 to 3, our gradation becomes more finer. In addition to these two individual grading options, we also have an option for combined grading and the coarse aggregate and fine aggregates when they are mixed together.

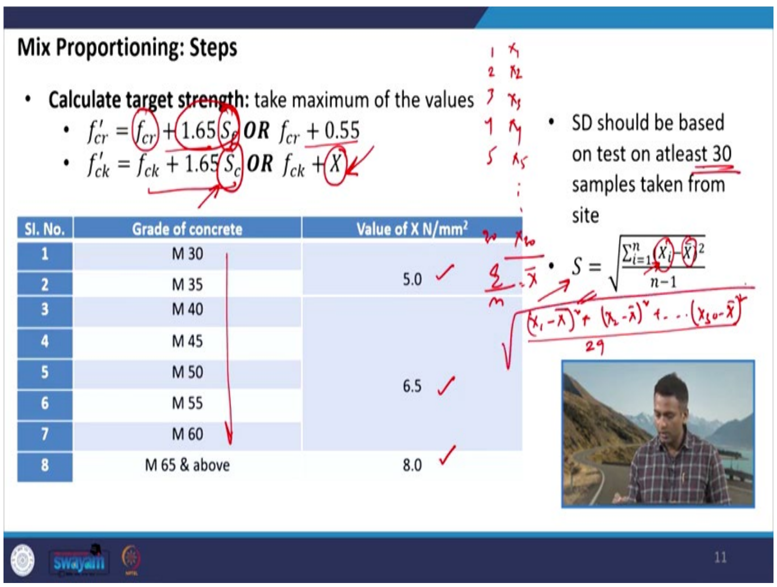
They should satisfy these following gradations corresponding to different nominal maximum aggregate size. So, you can see that different percentage passing corresponding to different sizes have been given I am sure that by now we understand what this gradation means, because, we have already discussed in detail about aggregate gradations.

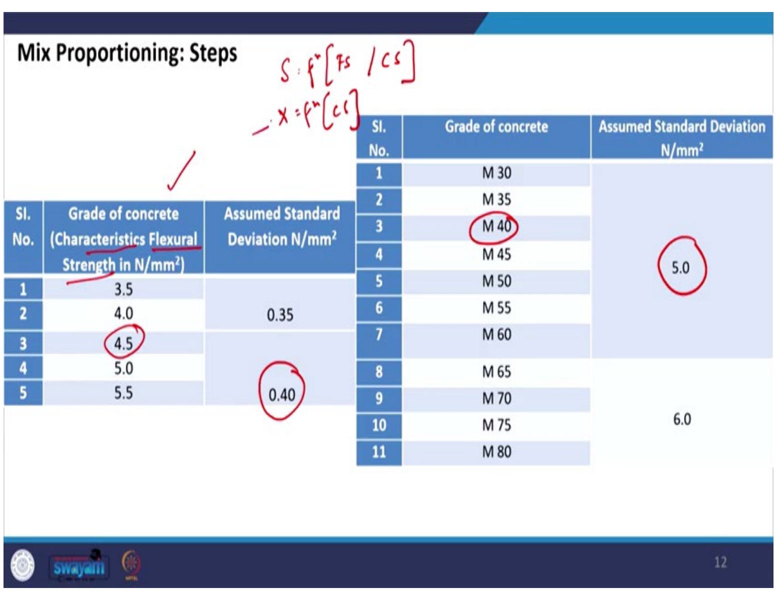
Now, here there is a star in double star mentioned corresponding to 75 micron sieve. So, this says that the limit is 0 to 5 percent, If you are using crushed sand, but if we have natural sand, this limit is 0 to 2 percent. So, this is the meaning of star and double star here, now, let us talk about the steps having understood these terminologies.

The requirement of the gradation and the material properties. Now, let us see that what are the typical steps that we follow in the mix design again, in this lecture, we are discussing only about the steps, these steps will be more clear. So, this lecture might appear to be a little confusing once we conclude it, because it is all theory here.

But, ultimately we are going to refer this presentation when we start solving a problem in the next class. So, you do not have to worry even if you are not able to specifically follow this lecture, because this lecture will make sense it will be clear once we solve a problem in the next class. So, let us look at the steps now. So, as per IRC 44, there are two options corresponding to which the mix design can be done, either we can do the mix design corresponding to the target compressive strength.

(Refer Slide Time: 19:28)





Or we can do the mix design also corresponding to the target flexural strength. So, usually when we see the concrete pavement design the critical failure mode of concrete is corresponding to the flexural stresses. So, flexural strength is considered as one of the design parameters to do the cumulative fatigue damage calculation. Therefore, it is also important that we should be able to do the mix design corresponding to the target flexural strength.

So, both the options are available in this particular chordal provision. So, we can calculate first we have to calculate the target strengths. So, if you remember we have discussed about the characteristic strength. So, in order to achieve the criteria of the minimum characteristic strength, our target strength should be higher, we should target for higher strength, and then only we will be confident that once we complete the mix design.

The actual strength at least satisfies the minimum criteria of the characteristic strength. So, therefore, this f' corresponds to the target strength whereas f corresponds to the characteristic strength. So, the first equation if we are designing corresponding to the flexural strength of the concrete the second equation is where we are using the subscript ck. This is when we are doing corresponding to the compressive strength of the concrete.

So, as you see here we have two set of equations similarly, we will have sets of table one will be corresponding to flexural strength and the other will be corresponding to compressive strength. So, if we are doing corresponding to flexural strength, this is the equation. So, it is the $F_{cr} + 1.65 \times S_f$ where S is the standard deviation of the flexural strength of the samples or $F_{cr} + 0.55$. So, you do both this calculation and we take the higher one to do the mix design.

Similarly, we have this equation here, this Sc corresponds to the standard deviation of the compressive strength of the samples and similarly, here we do not have a specific value, but we have a value x. Now, what should be the appropriate value of x has been given in a separate table. So, this is the value of x which is for different grades of concrete. So, depending on the grade of concrete you have to select appropriate value of x. Now, the question is how do I select the value of S which is the standard deviation?

So, ideally standard deviation should be based on strength test either samples from the site or if we are making in the laboratory so, we should be able to make at least 30 samples, and we will do our test on those 30 samples it can be either a flexural strength test. Or it can be a compressive strength test and then we use the standard formula for standard deviation which is under$\sqrt{(X_i - \bar{X})}$. So, Xi is the suppose we have samples 1,2,3,4, 5. So, let us say the value is X1, X2, X3, X4, X5 and so, on. So, this is up to 30, X30 so, we will have an average value here summation divided by total number.

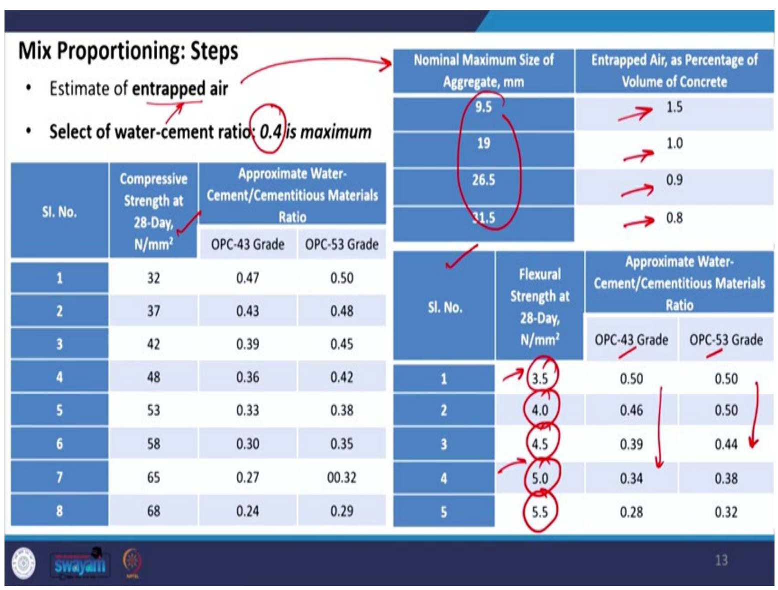
So, this is X average. So, what how do I calculate this I will calculate this as $\frac{(X_1-\overline{X})^2 + (X_1-\overline{X})^2+\cdots\ldots\ldots\ldots\ldots(X_{30}-\overline{X})^2}{n-1}$ if we have 30 samples and under root of this. So, this gives you the value of the standard deviation.

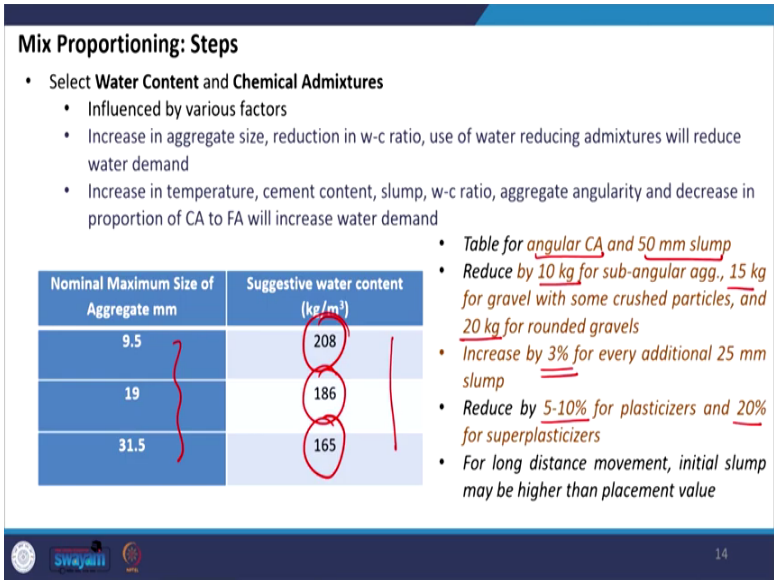
However, if we do not have the data available, if we do not have the results available, then again we have two tables one will be corresponding to flexural strength the other will be corresponding to the compressive strength to decide the value of S and these are those tables. So, this table is for the flexural strength.

So, if I know the characteristic flexural strength, let us say I am designing corresponding to a flexural strength of 4.5 Mpa, then I have to take the value of standard deviation to be 0.4. If I am doing it say for M 40, then the standard deviation to be chosen is 5. So, depending which means standard deviation is a function of flexural strength or compressive strength.

So, this is what I want you to remember and similarly, X is a function of compressive strength and we do not have any X in case of flexural strength because the value is already fixed to 0.55. The next step is we should know entrapped air.

(Refer Slide Time: 24:46)





Now, this entrapped air is not the entrained air which we have discussed in the previous lectures. So, when we talked about air entraining admixtures. So, entrained air means the air which is entrapped between the particles inside the mixture because ultimately it is a mix. So, it has a volumetric configuration and it is possible that some air has been entrapped inside has been entrapped or we have to assume during the mix design process.

So, the entrapped air again this is what I want you to remember is a function of the nominal maximum aggregate size in the mix. So, depending on the nominal maximum aggregate size, we have to select the entrapped air percentage which is corresponding to the volume of the concrete. So, 1 percent by volume of the total concrete or 0.9 percent by volume of the total concrete and so on. So, in this way we will select the percentage of entrapped deer for our mix design problem.

Then, the next step is to select the water cement ratio. Again the need of water cement ratio can be based on trial can be based on previous experience with those mixtures. But if we do not have laboratory data available on trial mixtures. We can also use this table to select appropriate water cement ratio. What water cement ratio again is the maximum value is limited to 0.4 for pavement application.

Now, here also you see two tables one will be for design flexural strength, the other is for the design compressive strength. So, this table is for designed flexural strength and here you see that the water cement ratio is a function of the flexural strength of the concrete which we are choosing. Similarly, and is a function of the flexural strength and is also a function of the type of cement which we are using. So, depending on the type of cement the values will change.

So, again one point to remember is water cement ratio is a function of the strength and the grade of cement which we are using, same goes with compressive strength function of compressive strength and grade of cement which we are using. If our strength falls somewhere in between, then we can interpolate those values. This will be clearer when we start once we solve an example problem.

So, we have selected water cement ratio, now, we have to select the appropriate water content corresponding admixture content and then we have to make changes in the water content after we select the dosage of the chemical admixture. So, the first is water content now, why we are using water? One is for hydration; we need the cement to get hydrated in presence of water. So, they did develop strength and also we are doing it to achieve a target workability in the mixture.

So, these are the two important functions which water has to serve. Therefore, the selection of appropriate water content will depend on various factors for example, angularity of the aggregates. So, you can now imagine that if the aggregates are more angular, it will be difficult to work with those aggregates.

So, the requirements of water will be more, because we need to apply more force to mix the ingredients. If we have a lot of fine aggregates in the mixture, again the specific surface area will be higher in the mixture we need more water to wet the surfaces, if we are using admixtures like silica fume say so, they are again very fine particles.

So, the water demand will be higher though those water demand can be controlled by use of other admixtures like plasticizers or superplasticizers. But ideally the water demand is a function of various parameters see the gradation if it is a tight gradation, well gradation or compact gradation, you need more water because there is a lot of variation in the particle sizes.

So, ideally the need of water content is influenced by various factors. Generally, if the aggregate size increases, if we reduce the water cement ratio, if we use water reducing admixtures plasticizers or superplasticizers. This will reduce the water demand for a given target workability again for a given target workability if the temperature increases.

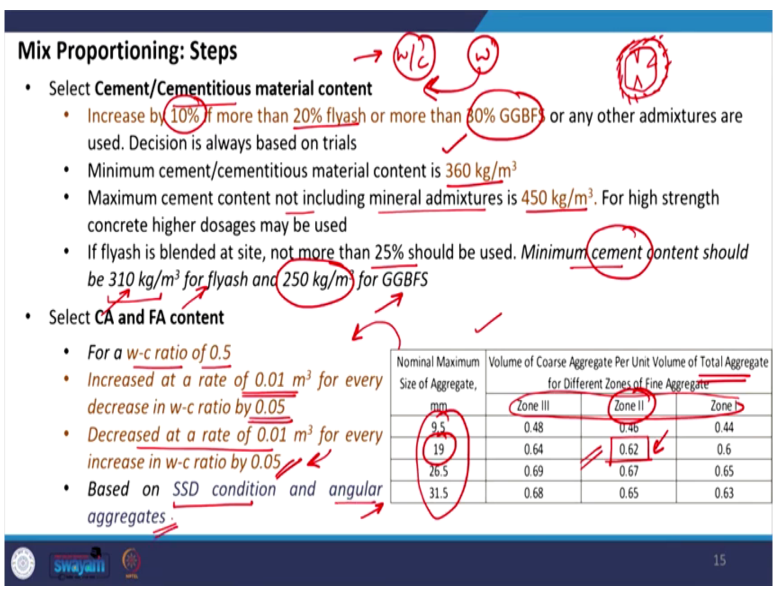
Then the evaporation of the water will increase. If the cement content increases, then again the demand of water will increase if we are increasing the slump requirement water cement ratio if you are using angular aggregates, and if we are, increasing the amount of fine aggregates in the mixture, so, all these factors will increase the water demand.

So, we have some suggestive water content with which we can start the mix design process. And again here I want you to remember that the suggestive water content is a function of the nominal maximum aggregate size. So, depending on the nominal maximum aggregate size, you can choose the water content to start the mix design process. But this table is based on some standard parameters.

So, what are those standard parameters this table is based on consideration of angular coarse aggregates in the mixture and a slump of 50 mm. So, if we are using other types of shape of aggregate let us say if you are using sub angular aggregates, so, the amount of force required to work will be less. So, you can reduce the water content by 10 kg if you are using gravel with some crushed particles, then you can go up to 15 kg reduction, then, if the target slump increases by 25 mm then for every 25 mm we have to increase the water content by 3 percent.

And if we are using water reducing admixtures say plasticizers we can reduce the demand by 5 to 10 percent. If we are using superplasticizers we can reduce the demand by 20 percent of these values which are considering to start the mix design. Again the requirement of water depends on the site conditions, let us say the plant where we are making the concrete mixture is far away from the site where we are going to place it then we have to consider this distance and accordingly we have to adjust the water content which means that probably at the plant, we will design the mixture corresponding to a higher slump value so that by the time it reaches the site where we are going to place it the slump will reduce because of this distance which it has to cover.

(Refer Slide Time: 31:56)



So, the next step now is to select the cement or the cementitious material content when I say cementitious material, it means that it can include a combination of cement and flyash or combination of cement and other mineral admixtures. So, that is why we call it either cement or cementitious material. So, how do we select it, we have the water cement ratio available with us which we selected in previous steps. After that we selected water content. So, once we have the water cement ratio and water content, we can calculate the cement content from this ratio.

But the value which we get can further be adjusted depending on several criteria's for example, if we are using more than 20 percent flyash then the amount of cement which we get from this formula can be increased by 10 percent, if we are using more than 30 percent GGBFS again we can increase by 10 percent, we can choose any other increment value also and the decision will always be based on trials so, that we are achieving the desired properties.

However, we have to ensure that the minimum cement or cementitious material content in the mix design should not be less than 360 kgs per meter cubed. So, this is the minimum cement or cementitious material content. Similarly, we have a criteria of maximum cement content, but that is not including mineral admixtures.

So, only cement the cement content alone should not exceed 450 kgs per meter cube, this is for normal PQC, if you are trying to design a high strength concrete then higher dosages may be used. Now, if flyash is blended at site then we cannot use flyash more than 25 percent, and in case we are using mineral admixtures then the minimum cement content should not be less than 310 kgs per meter cube if you are using flyash.

So, this is cement content not the cementitious material content. So, the cement content in the blended cement should not be less than 310 kgs per meter cube, if the admixture we are using is flyash if the admixture we are using is GGBFS, then the minimum cement content should be at least 250 kgs per meter cube.

Then we come to the final few steps. Now, we have to select the coarse aggregate and fine aggregate content. So, the coarse aggregate and fine aggregate content are chosen by the volume of the total aggregate mixture. So, we have a table here which gives us suggestive values. Now, again a point to remember that these values are corresponding to the nominal maximum aggregate size and the zone in which the fine aggregate falls.

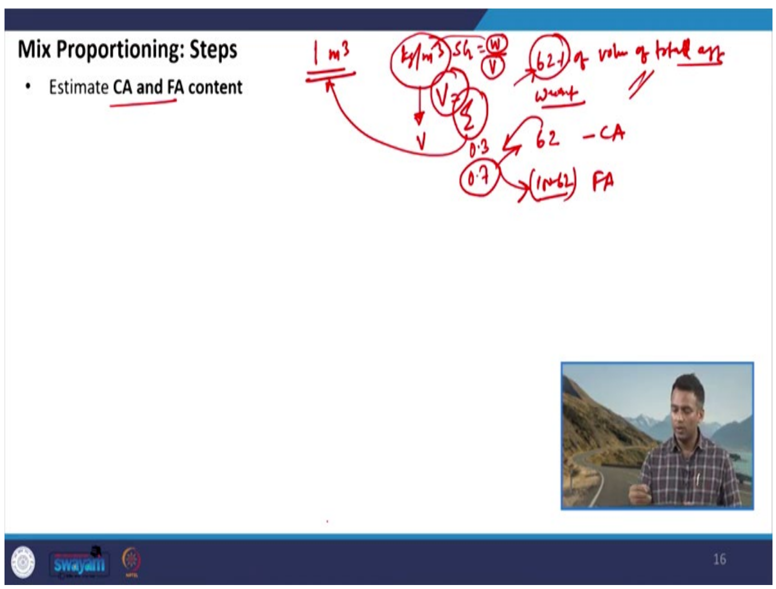
For example, if the nominal maximum aggregate size is 19 mm, it is a zone to find aggregate which we are using, then the amount of coarse aggregate by volume of total aggregate not by the volume of the entire mix by volume of the total aggregate should be 62 percent. So, the 62 percent of the total volume of aggregates should be coarse aggregate and the remaining which is 100 minus 62 percent should be fine aggregate. Again there are criteria's involved in the use of these this table.

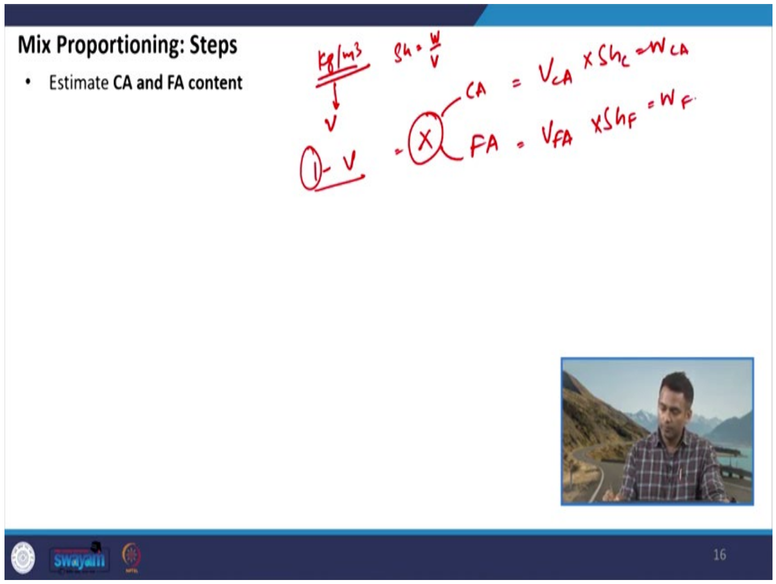
So, for example, this table is corresponding to the water cement ratio of 0.5. So, if the water cement ratio changes, this value which is given here should be adjusted. So, how we are going to adjust we will increase this value at a rate of 0.01 meter cube, for every decrease in water cement ratio by 0.05. On the other hand, we will decrease this at a rate of 0.01 meter cube for every increase in water cement ratio by 0.05.

Because you can understand an increase in water cement ratio means there should be more fine aggregate to weight the higher specific surface area in the mix. So, that is why it decreases with increase in water cement ratio and increases with decrease in water cement ratio. And this table again is based on the assumption that the aggregates are in their saturated surface dry condition.

We all understand what is a saturated surface dry a condition that the water has been absorbed inside the pores, but it is not present on the surface, it is not present on the surface. So, that is a saturated surface dry condition and it is again meant for angular aggregates. In other cases we have to do adjustments.

(Refer Slide Time: 36:50)





So, if you see the steps which we have talked about the water content, the cement content the admixtures they are all in terms of kgs per meter cube. So, usually we do the mix design of concrete considering a unit volume of 1 meter cube. So, and we have discussed about the proportions of materials in terms of kgs per meter cube.

But the coarse aggregate and fine aggregate which we discussed in the last slide, we saw the table where it was mentioned in terms of volume 62 percent of volume of total aggregate. So, we have to convert this volume into weight. First what I will do all the proportions which we discussed in kgs per meter cube, we will convert it into volume.

How, we will do that? For those materials, we know the specific gravity of those materials which we are using. So, we know that specific gravity can be written as weight by volume, we know the weight of those materials, which we have discussed here. So, with that we can calculate the volume of the individual materials.

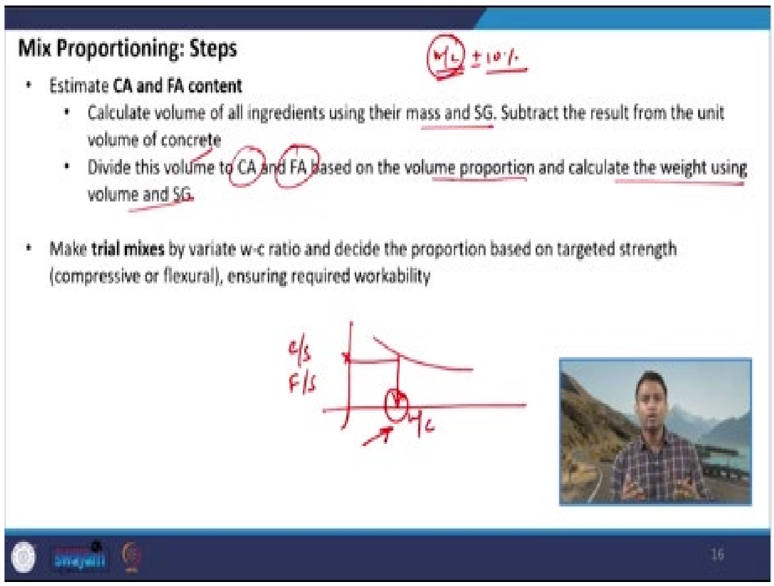
Once we have the volume of those individual materials, I will substract the summation of all that volume from 1 meter cube which is the bulk volume of the concrete. So, which means let us say the volume after we add all the proportion is somewhere around 0.3. So, 1 minus 0.3, 0.7 which means now 70 percent of the total volume will be occupied by the aggregates including the coarse aggregate and fine aggregate.

Say from the table depending on the nominal maximum aggregate size and the zone of the fine aggregate it says use 62 percent coarse aggregate. So, this 0.7 or 70 percent of the volume will be divided into two parts. So, 62 percent of this 70 percent will be coarse aggregate and the remaining will be fine aggregate.

So, as I mentioned first we will convert the weights of all the ingredients into volume, subtract it from the unit volume we are using. So, this volume let us say X will be shared by coarse aggregate and fine aggregate. So, we will get the volume here volume of coarse aggregate volume of fine aggregate.

Now, we know the specific gravity of coarse aggregate and fine aggregate and again what we can do we can just multiply this volume with the specific gravity to get the weight of coarse aggregate and weight of fine aggregate. So, this is what we are going to do.

(Refer Slide Time: 39:59)



To finalize the proportions in terms of kgs per meter cube. So, calculate volume of all ingredients using their mass and specific gravity subtract the result from the unit volume of concrete, divide this volume to coarse aggregate and fine aggregate based on the volume proportion as we saw in the last slide and calculate the weight by using the volume and specific gravity. So, this will complete proportioning of different materials that we are going to use.

Now, the final step is to make trial mixes, but if you see the selection criteria, we have selected one water cement ratio. So, usually what we do in the lab, we make samples with ± 10 percent water cement ratio. So, we vary the water cement ratio from our selection and then we see for different water cement ratio what is the compressive strength or the flexural strength? Similarly, we will see that for different water cement ratio what is a slump we are getting and so on.

So, say with increase in water cement ratio usually we will see a reduction in the compressive strength. So, we have some desirable strength here, corresponding to that we can select the optimum water cement ratio to finalize the mix design and at this water cement ratio again we will see whether the slump criteria or the durability criteria if there is any are satisfied or not. And this way we complete the mix design process.

So, as I mentioned that this presentation this class was more of theoretical only, we were trying to see the steps, we were trying to see those values that are prescribed by the chordal provision, but we have not understood it by solving a problem by seeing how the calculations are actually done. So, this is what we will be doing in the next class.

We will take up two examples one for flexural strength, one for compressive strength, we will try to understand the steps by referring to these tables by referring to these suggestions which are given in the specification. Thank you.