Basic construction materials
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Lecture 29
Cement and Concrete 3 - Part 1

Hello everybody, in the last couple of sessions, we saw the ingredients of concrete, primarily the cement, the aggregates and the chemical and mineral admixtures and what kind of impact they had on the concrete properties. Now another important aspect about concrete construction is the processes that actually make up the entire construction sequence. For instance, concrete has to be mixed, then it has been brought to the site.

It needs to be poured into the location where it is supposed to be going, like the formwork for instance. After it is poured, it needs to be compacted because otherwise it will not fill up the space properly. After compaction, needs to be finished and then, finally cured until it reaches the right level of strength. So let us take a look at concreting processes.

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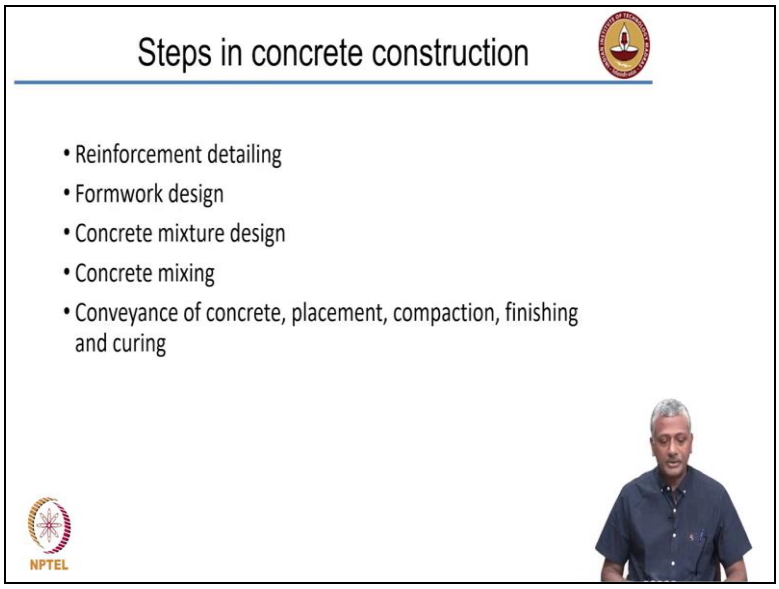

So, what are the important parts or steps involved in the construction sequence of concrete? First and foremost is the detailing of the reinforcement. This is followed by the design of the formwork which is going to be actually defining the shape of the concrete structure or structural element. Then, we have the concrete mixture design. Concrete mixture design involves selection of the right proportion of ingredients, primarily cement, water, aggregates in such a way that they give a concrete mix that has a sufficient amount of workability.

And of course, it performs to the satisfactory level in terms of strength and durability. Now the process of mixing itself is important because ultimately these ingredients that you put in have to be intimately mixed together to give you a composite material that is having a uniform spread of different phases across the volume. And then finally, after mixing, concrete is conveyed to the site, if it is far from the site, it is been conveyed with help of trucks for instance.

After it reaches the site, it is then delivered or placed, then compacted, finished and finally cured until it reaches the right level of strength. So these are the processes that are involved. Let us take a look, closer look at each one of these processes.

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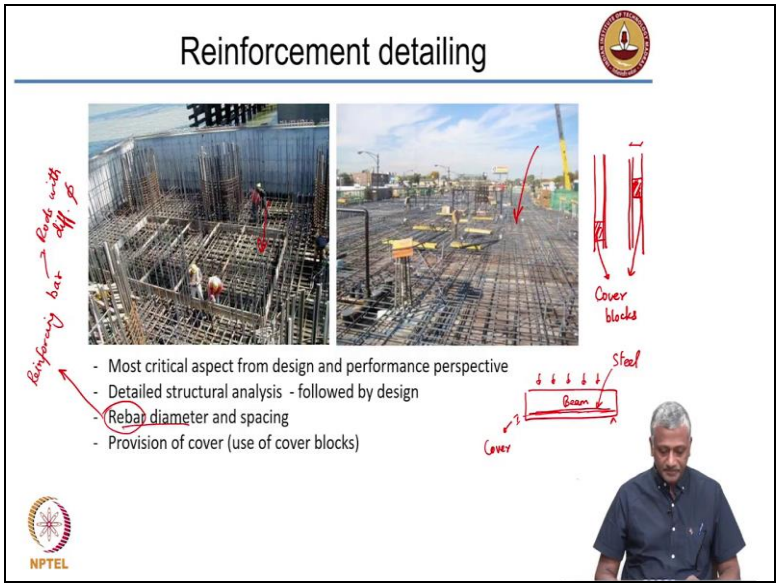

First and foremost is Reinforcement detailing. Now in terms of the behaviour of a reinforced concrete composite, the primary factor that controls the property of the composites is the way that the Steel is spread across the system or rather, in analysis you figure out what are the loads that are coming onto the structure, you need to figure out wherever tensile loads are coming and then make sure that you have sufficient amount of Steel in the tensile locations.

In most cases, from the design and performance perspective, in a reinforced concrete structure, the Steel reinforcement detailing is perhaps one of the most important aspects which will control the performance. Now as I said, you need to do a detailed structural analysis and determine where the tensile zones are, where are you getting tensile loading and

the design basically incorporates concrete and steel in such a way that the Steel is distributed evenly in the zones that need to carry tension.

Just for example, if you have a beam which is supported on the two ends and of course the Beam is getting loaded from the top. So, what will happen in most situations where it is simply supported is, it is going to bend like this. The beam is going to have a shape like this after it bends. So, this means that the bottom fibre where you have stretching, that is in tension.

And the top fibre, is in compression. So the Steel essentially has to be provided close to the bottom of the beam. Now reinforcement detailing is going a step further, not just understanding where steel is provided. It also means how much steel is to be provided in a given cross sectional area, how much area should be covered by steel.

So for that, we need to design the Steel in terms of the diameter of the rebar. Now, of course the Rebar is a term that civil engineers use to describe reinforcing bar. Because most of the steel rebar are basically rods with different diameters. Depending upon the capacity required, you may choose a larger diameter or a smaller diameter. So you have Rebar diameter and spacing. So how frequently are they placed in the given cross-section?

What is the spacing between the rebar? That will be determined by how much tensional capacity you need to bring in, in the cross-section. So all this of course you will learn in more detail when you actually encounter courses on reinforced concrete design. But it is very important to understand that before the concrete placement into the form work is done, the reinforcement has to be appropriately designed and laid out like you see in this pictures here.

Reinforcement is properly laid out before the concrete is poured, to ensure that you are getting reinforcement in all the zones, experiencing tension. Now, it is very important also to figure out how you can protect the steel from corroding. You know that steel left in the environment is prone to corrosion and that is a natural phenomenon, because steel is Fe, naturally stable condition of any metal is its oxide state.

So, Fe will obviously want to convert to the ferric or ferrous oxide states. In such a case, how do we protect the Steel from corrosion? So here I talked about the fact that the tension is

maximum at the bottom of the beam. But can we place steel exactly at the bottom, no, because they will be exposed to the environment. So what we need to do is, place steel in such a way that it is having a small covering of concrete around it.

So that covering of concrete is called the cover zone of concrete. It simply called the cover and how do we actually get this cover on site? What we do is, supposing this is your formwork and that is the reinforcing steel inside. To ensure that the Steel stays safe distance away from the surface, we place these blocks called Cover blocks. We place blocks called cover blocks which have a thickness which is equal to the thickness of the cover that you want to provide in the structure.

Again, if you go through design practices, you understand that the thickness that you want to provide as a cover is determined by the kind of environment that the concrete is in. For example, if the concrete is in coastal or Marine environment where it is going to be subjected to very harsh and aggressive condition because you know that there are a lot of chlorides and they can cause corrosion of your reinforcing steel.

So to ensure that the Steel does not corrode in the lifetime of your structure, you will need to provide a thick enough band of concrete around the Steel that is called the cover and that cover in most Marine conditions, for example, for structures like columns, which is standing in sea water could be as much as 75 millimetres. So how do we exactly provide 75 millimetres?

We have these blocks which are either made of plastic or they can be made of cementitious material like mortar or concrete of the same strength as the concrete in the structure and those are tied to the Steel reinforcement and kept in place between the formwork and the reinforcement so that when the concrete is poured, the steel reinforcement will be kept in place and will not go towards the corners.

You do not want the steel to come towards the corners, because then your cover becomes less than what you have designed for. So for example, if you do not do a good job of putting a cover block, you may have designed for a cover of 75 millimetres, but because I did not put the cover blocks properly, the steel may have come to the corner and you may actually get a cover of only 10 or 20 millimetres in some cases.

This means that you have designed your concrete structure thinking it is going to be durable, in a marine environment, but with a 10-20 millimetre cover, it is probably going to lose its life very quickly. So you need to be extremely careful about providing the right level of cover around the reinforcing steel

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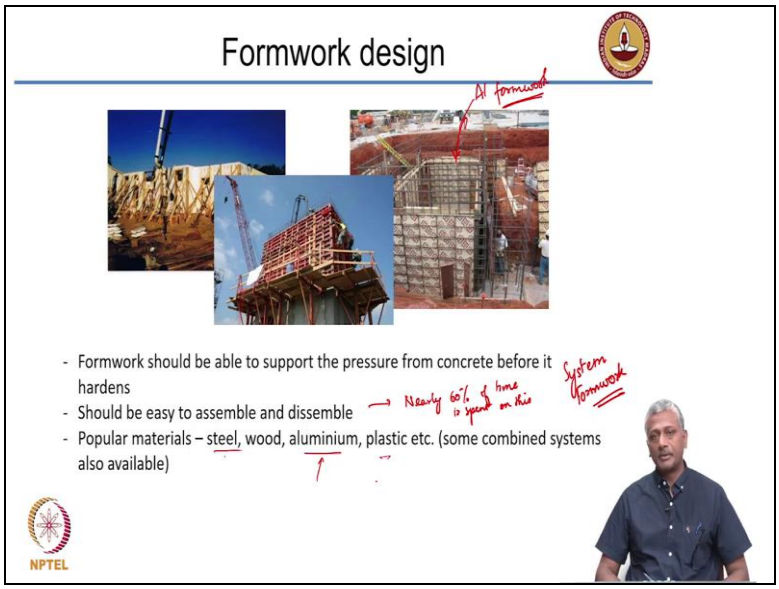

So, the next process of course, is formwork design. I am not saying that these are sequential. I am saying that all these processes need to be done for concreting to be completed. Formwork essentially defines the shape of the concrete structure that you are going to get. In most cases, of course we deal with rectangular shapes or cuboidal shapes, we do not really worry too much about curved sections. But indeed, there are several examples of construction where curved sections are also used.

So in such cases, you need to design the formwork more appropriately with the right blend of materials. There are different formwork materials. In most of the jobs you may see that formwork materials are made of plywood or other pieces of timber. In such cases, of course, you can imagine that the reuse is going to be limited, when we use timber formwork.

Why is that, because concrete, when it is placed as wet, and that wetness obviously will affect the quality of the wood so, the number of times that you reuse it, the number of time it is going to get wet and because of that the wooden formwork may warp or change its shape. On the other hand, when you have metallic formwork like steel or aluminium, you can retain the

form quite well. Today for many multi-storey buildings aluminium formwork, which is what is shown here, is quite highly preferred.

Because it gives an excellent finish on the surface and it can speed up the rate at which you build up floors. For many multi-storied buildings today, aluminium formwork is the material of choice because you can actually increase the productivity, the speed at which a given floor can be constructed. People are actually trying to cut down the time. So, today you do not find that you have frame structures with infill walls made of masonry.

Mostly you will find in multi-storey buildings that you have framed structures, with walls also which are reinforced concrete. It is totally different, the kind of construction today for multi storey building has become quite different as compared to what was there maybe even five to ten years ago. Now the formwork has to be easily assembled and disassembled, because if it is difficult then you have a lot of time spent on the site.

So in fact, nearly 60% of time is spent on this operation. That means assembling and disassembling form work on a construction site takes up 60% of the time that you spend in construction. So you can quiet readily imagine what kind of impacts the formwork would have. So you need to choose formwork systems that are easy to assemble and disassemble. So because of that today we have, what is known as system formwork available.

So for example, if you want to build a cooling tower. If you have to design formwork for cooling tower, it is going to take a long time. So, if you have system formwork, it can actually ensure that you are building this cooling tower and the formwork essentially moves up as the tower is constructed. So, System formwork is an innovation that is speeding up construction practices, concrete construction practice.

Of course, there are many materials with which you can make formwork. As I said, steel and Aluminium are highly preferred nowadays. Steel is heavy, so it is difficult to handle. So, aluminium formwork, which is light weight, has become a very useful material. Wood and plastic of course, can also be used as I said; wood is conventionally used in smaller residential job, you will see only wooden formwork being used.
Plastic or fibre reinforced plastic has also started getting used in many construction sites.
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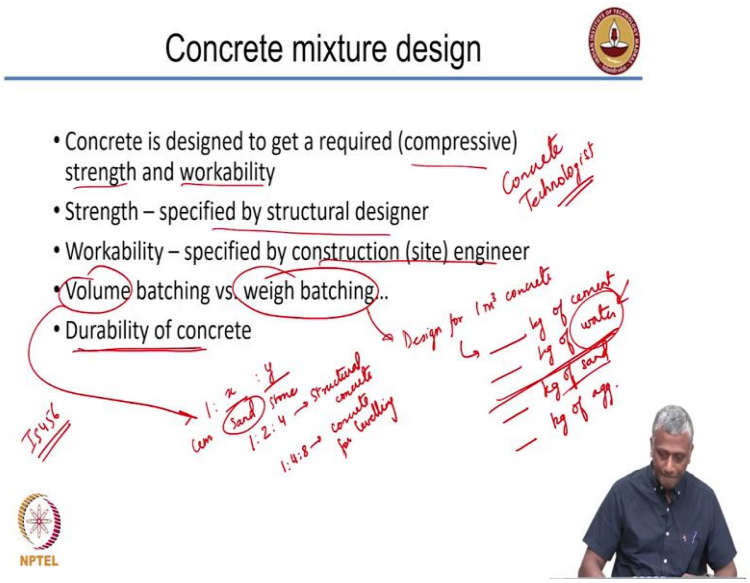

So, reinforcement and formwork are obviously not directly connected to concrete, but they are important from the perspective of designing the composite structure. Let us come to the concrete part itself. As I said, one of the most important steps is proportioning your ingredients that is, cement, water, sand, coarse aggregate, mineral admixtures and chemical admixtures in such a way that you get a composite material that is capable of certain levels of performance.

What is this performance? Generally concrete is designed to get a required compressive strength. Remember we talked about this that concrete is good in compression, poor in tension. So for tension, you need to provide steel. So, as long as you have concrete it takes care of the compression. So you need to design concrete for its compressive strength in most cases. In certain circumstances, the concrete resistance to cracking is also considered to be very important like the design of pavement slabs with concrete.

In those cases, tensile strength is also considered to some extent. But in most cases, concrete compression strength or compressive strength is what you need to design for. And the other aspect is the workability. How easy, is it for you to make it place, compact and finish the concrete? So, workability is a term that loosely defines all these processes coming together. We will take a look at these individual processes separately.

Concrete has been designed to achieve a certain level of workability. Now, just you can compare this to something that you see at home when your mom does cooking right. So, when you have flour and you mix water into it, if you mix just the right amount of water the

flour is nice and pliable. If you mix too much water, what happens? The flour becomes very sticky and starts flowing.

So that is what the same concept in construction is also. If you add the right amount of water, you get the correct amount of workability. If you add too much water, the ingredients may start separating out. If you add too less water, your flowability or your consistency may not be enough for the concrete to satisfactorily fill up the formwork. So who does the decision making as far as these characteristics were concerned?

As far as the strength is concerned, it is specified by the structural designer. So as I said in a construction sequence, the first is the analysis. That is followed by design. And in design certain material properties need to be attributed to the ingredients involved like concrete and steel. For steel, most often, they will be specifying something called the yield strength. Concrete, on the other hand, the structural designer will say, I need to have a concrete of a certain compressive strength.

Now this compressive strength is specified by the structural designer but has to be ascertained by the person who is supplying the concrete for the job site. What about workability? It will be specified by the construction engineer? Why because, the construction engineers knows at the job site, what are the conditions, how concrete needs to be placed and compacted and finished. And for that operation what the level of workability desired is.

So, construction or site engineer specifies the workability that is needed for the concrete mixture. Now, concrete can be mixed by batching the constituents or measuring the constituents either by volume or by weight. In all controlled concrete operations, it is better to go only with the weigh batching. That means you exactly measure the quantities of ingredients by weight. And typically we do the design for a certain volume of concrete.

Let us say cubic metre of concrete and we say it needs to have so many kilograms of cement, so many kg of water, so many kg of sand and so many kg of aggregate and of course you can also think about kilograms that you need to add per cubic metre of the other additives like chemical and mineral admixtures if you need them. So, that is what you do, typically in a weigh batching, that you design for a 1 cubic metre concrete, but of course, depending upon the capacity of your mixer, you may want to reduce the quantity.

So let us say 0.5 cubic metre or 0.3 cubic metre. There are certain well defined sizes of concrete mixes available in most cases. You will need to then design appropriately for the amount of material that can be mixed in that mixer satisfactorily. So that is called weigh batching. So volume batching is what you see being practiced in many residential sites. So what they do is, they have a measuring bucket or a measuring cuboid in which they actually measure the quantities by volume.

So they generally say, one part of cement, to some x parts of sand, to some y parts of stone. So when the mix design is present in terms of one is to x is to y, typically, we want to mean it by volume. So that is by volume, so that on the site, you do not need to have the capacity to measure these things. You can just have this volumetric bucket which measures exactly one proportion and then proportion your materials accordingly.

So cement of one part, sand of x parts and stone of y parts. Typically, in most construction sites, where they do volume batching, you will see that this sort of a volumetric ratio is 1:2:4 for most structural concrete. For most concretes that is used only for filling and levelling applications, you will have something like 1:4:8, Concrete for levelling. Why do we need less cement in the case of levelling concrete?

You do not rely on the strength; the concrete simply forms the base layer on which the main structures going to get constructed. So that we basically concrete for levelling and there you are you going with 1:4:8. What is interesting is, in the weigh batching, you clearly had an indication of the amount of water that you are adding to the mix. What about volume batching?

It does not say anything about the water just say cement, sand and stone. What about the water now? That is where volume batching becomes a difficult thing to practice, if you want to control your concrete well. The water in volume batching is decided by the mason who is going to be mixing the concrete together. So if the mason feels that so much water is enough that is the level of water they will have for the concrete mix.

So there is no control on the amount of water that you add in Volume based batching. Next, please remember that we talked about this pack called bulking. So if you are measuring sand

by volume and sand has gotten wet the previous day because of rain, the volume that you measure will not actually have the right quantity of sand that you want to use. Lots of that value may be filled with water.

So you are not going to be able to compensate that features doing volume batching. In weigh batching, you can simply take a part of the sand and dry it in the oven and find out how much water is actually there and remove that water from the water that you have calculated for the mix. So weigh batching involves a lot more control, you can design concrete with a very clear set of characteristics.

In volume batching, you do not know what you can get. It all depends on the mason on-site, how well they are able to mix up the concrete and produce the concrete of the right strength. So, if you are an Engineer, please do not support volume batching, go only for weigh batching. It just require some additional facilities for weighing things and ensure that you produce a concrete of the right level of strength and that is determined exactly or almost entirely by the amount of water that you put in the mix.

So, ensure that you have some way to dispense water to the right level of accuracy. Now, of course, I have not said something about the durability here. I said that mostly with design the concrete for his workability and strength. But if you look at our design codes IS 456 - design code for plain and reinforced concrete, it tells you about the conditions of exposure of a concrete structure and the need to design concrete with a certain set of characteristics to match the requirements of durability in that exposure condition.

For example, if you are designing a concrete structure for the coastal area. The requirement of the concrete to survive in its given environment is going to be quite different from the concrete that is designed in an inland environment which is 3,400 kilometres away from the coast. There the requirement of concrete to survive in that environment will be quite different from what you have in the coast.

So that is another consideration that you need to have while selecting the mixture proportions or mixture ingredients to design concrete for a particular structure. So workability, Strength and durability. So, what is happened over the years is that structural engineers who define the strength have been having the say in the kind of concrete that you actually get. But today

increasingly people have realised that it is the durability of concrete and the associated aspects that come with that which govern the performance of the structure much more than the strength.

In most cases strength is not really a consideration, because we usually over design the structure with respect to strength. But with respect to durability, if we do not have a clear understanding of the environment and what can happen in that environment, we could be in for a lot of problems with respect to concrete structure. So, today increasingly, the focus is shifted to durability and because of this, there one more additional person that needs to come in for large projects and that is the Concrete technologist.

You have Structural Engineer, have a Constructional Engineer, but you also have a concrete technologist who can actually give a clear distinction between the qualities of materials required for the given performance that is expected in a particular environment. So, a concrete Technologist can actually have a clear understanding, is the person who has the clear understanding on how the concrete would behave in a given environment, what would be the characteristics of the ingredients designed to produce concrete of the right quality.

So, if the emphasis is on quality construction site, you need to have a Concrete Technologist, because structural engineers do not understand concrete very well, construction engineers usually want to get the job done, they do not really think too much about the material. We need to have somebody who has an understanding the material and is able to practice the material properly and that is the concrete technologist.

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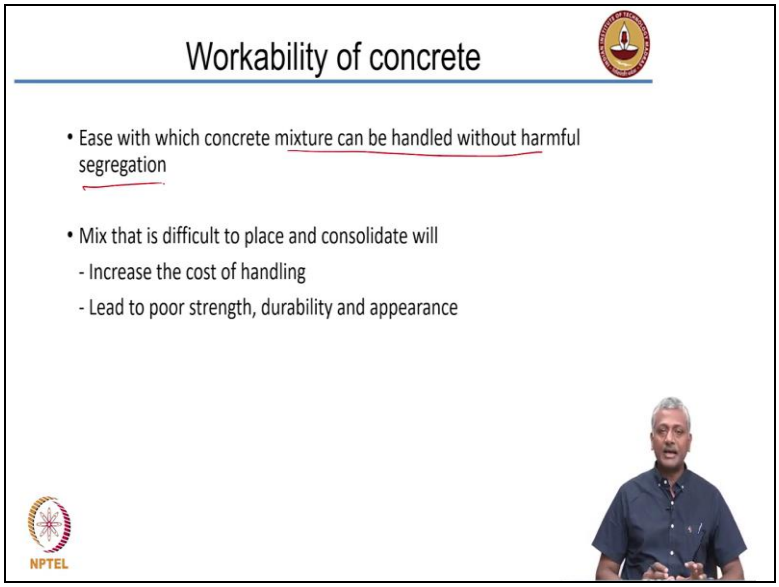

So, workability as I said is the ease with which you can handle the concrete and place it in, compact and so on. So, generally, what you say is, the ease with which concrete can be handled without harmful segregation. What is Segregation? It is the separation or the constituents of the concrete. As I said earlier, concrete is a very heterogeneous material. It has got ingredients which are at completely different size scales, cement particles are a few microns.

You have sand which is ranging from 75 microns all the way to 4.75 millimetres and have coarse aggregate which is going above 4.75 all the way to 20 or 40 depending upon the kind of content that you have. Because of this, because of the relative sizes and differences in densities and because of water is involved in the scenario, you can have separation of the constituents.

So, workability is defined as the ease with which you can handle the concrete without causing segregation. Now, the mix that is difficult to place and consolidate will increase the cost of handling and also lead to a poor performance in terms of strength, durability and appearance. So we need to provide concrete of the right level of workability. It is very important that you do so.

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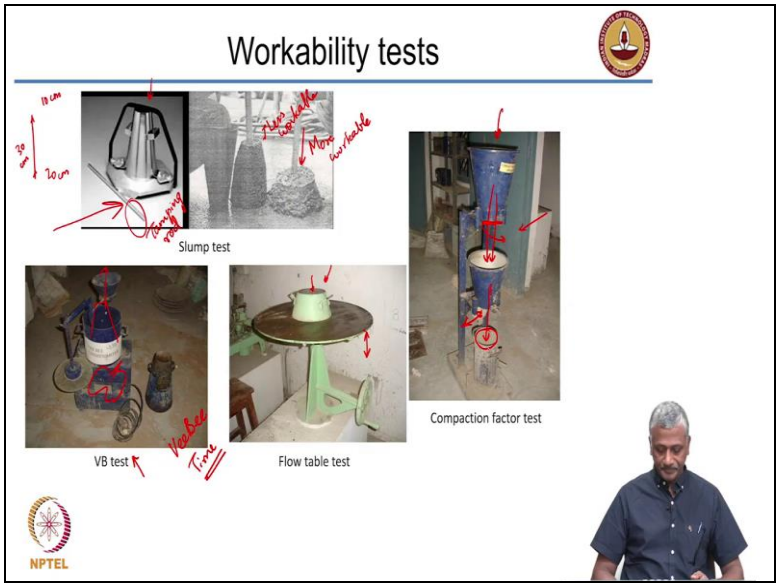

Now, there are several measures of workability that are used at construction site. Many of you will be doing experiments in your college, which deals with determining the workability of concrete as per one of these methods. Most common test and a test used everywhere is the slump test. As the diagram indicates, this is nothing but a cone which has an upper diameter of 10 centimetres, lower diameter of 20 centimetres and height of 30 centimetres. What you are supposed to do is fill up your concrete into this cone in 3 layers or 4 layers depending upon what standard you follow.

And each layer needs to be compacted by this rod called tamping rod. So you give compaction to each layer, fill up till the top and then you remove the slump cone, what will happen is the concrete that is nicely workable and flow-able will start slumping down like this. That means because of its self weight, it starts settling. That settling is called the slump. A concrete mix that is a lot more cohesive and less flow-able will slump less.

This is more workable, this is less workable. We have workability test, like a slump test which defines the workability or consistency of the concrete mixture. There are other test that is also can be used for stiffer mixtures, slump does not work very well. So, you may want to use something called VB test. In this case, what happens if you have a cone which is sitting in the centre of the cylinder?

If you fill up the cone the same way as you fill up the slump cone, then you lift the cone and you vibrate this entire apparatus so that the conical shape of the concrete assume the cylindrical shape of the container. So, the amount of time it takes for that to happen is called

the VB time. That is again the indicator of the workability. For example, for a concrete mixture that is highly flow able as soon as they remove the slump cone, it will start assuming the cylindrical shape of the outer container.

Another test which is commonly used is the flow table test. So here you put your concrete inside this frustum of a cone, lift that and then you have the table which is jolted up and down a certain number of times, what will happen because of this jolting? The concrete will get vibrations and it will start spreading out. Then you measure the total spread of the concrete and that spread is basically called the flow table spread and usually measured in millimetres.

Another slightly complicated test is the compaction factor test, where you fill up the concrete in this top bucket, you have a trap door here which will open. What happens is concrete falls into the second bucket and then you have another Trap door, you open that and the concrete fall into the cylinder. So, what is this trying to measure? It is trying to measure time to make sure the ability of the concrete to compact, so a concrete that is highly workable will be easier to compact.

So, in other words, when you open this door and the concrete falls here, and then you open the door in the concrete falls in the cylinder, a lot of the cylinders volume will be filled up by the concrete. On the other hand, what will happen in the case of concrete mix treatment that is stiff and less workable? What falls into the cylinder will fall with lot of voids inside. It will not get compacted properly.

So you can measure what is called the compaction factor. But in most construction sites what you will see being used is only the slump test.

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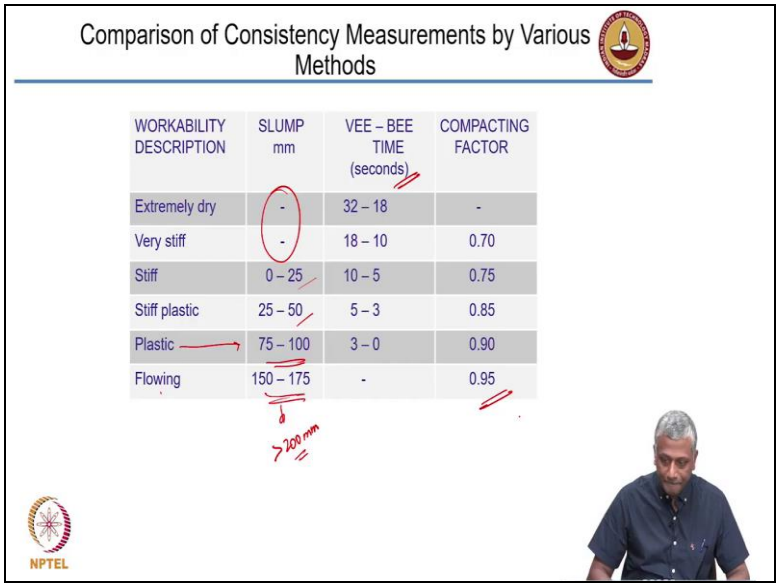

Now, this is just an indicative, qualitative classification of the concretes based upon the performance in different workability test. So as I said, when you have a floating concrete, you have a very high slump, concrete that is very plastic and flowing. Sometimes, you get slump of more than 200 millimetres also. Please recall as I said, the total height of the slump cone is 30cm or 300 millimetres

The maximum slump that you can typically have is only about 250. Because we have aggregates inside so the concrete cannot slump to more than 250 millimetres. So, in some cases flowing concrete can 200 mm. I will also talk about a concrete that is only flowing in, that does not really show a slump but it shows more of a flow. That I will talk about later. A plastic concrete is 75 to 100 millimetres.

A Stiff plastic is less than that and stiff concrete is 0 to 25 mm. When you are talking about extremely dry concrete. For example, when you are doing a pavement construction with concrete, I do not know many of you may have seen, that for pavement construction concrete, they make the mix extremely dry. It is not having lot of water. It will not be flowing; it will have an extremely dry consistency.

When they place it, they will pull a roller above it and compact. That is one of the ways in which they do it. The other is they will push through an extruder or a paver and then get the shape of the slab perfectly made. In such cases, the concrete is too workable, the Slab will collapse and you do not want that to happen. In such cases, you need to mould it properly.

Again when you want to make concrete blocks, we talked about concrete blocks in the masonry chapter. Most of these concrete blocks are poured through the block making machine and extruded out. They are extruded through the block making machine. In such cases the workability need to be very less. It needs to have a stiff or extremely dry consistency so that after that is extruded, the block will maintain its shape. Otherwise it will start collapsing.

In such cases, as I said you need to measure the VB time in seconds and that defines the workability of such extremely dry mixtures. Again, the relative values of compaction factor given here as I said, for a highly workable concrete you will have a very high compaction factor.

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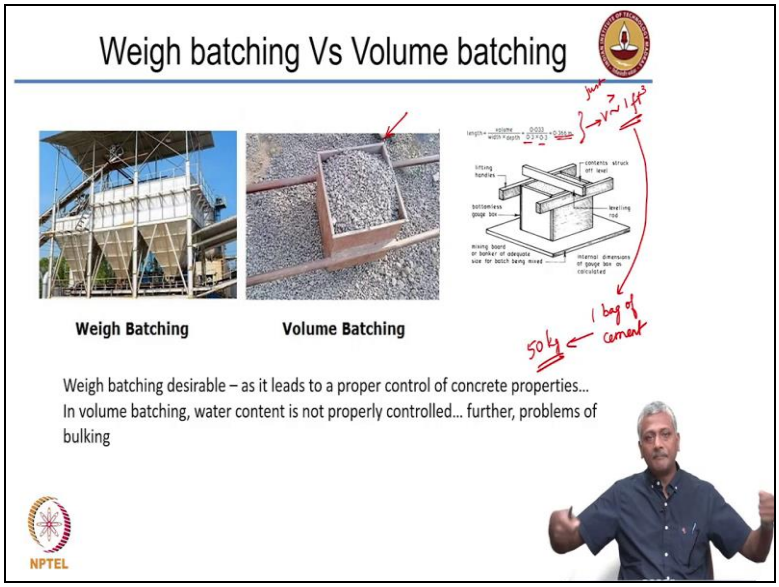

Now, again just coming back to this weigh batching vs volume batching aspect, as I said, in volume batching, you basically need to have a container either a cylindrical or a cuboidal container which contains exactly one part of the material. So, when we say, 1:2:4, 1 part of cement, 2 parts of sand, 4 parts of stone. So what happens is this width and depth are typically 300 millimetres, 300 millimetres and the length is 366 millimetres.

So that what happens, when you totally measure the volume, it is close to 1 cubic foot. The volume is close to one cubic foot or slightly more than just 1 cubic foot. And the advantage of this using 1 cubic foot or just more than 1 cubic foot or design this container exactly like that is that it can exactly hold one bag of cement.

So if you pour the contents of one bag of cement, they will exactly fit this volumetric container that we use in our job sites where volume batching is practiced. What is the advantage of that? The advantage is now in your mixer, you do not need to measure the cement in the volumetric bucket and pour it. You can directly pour the cement from the bag itself because this bucket is exactly measuring a volume equivalent to one bag.

So, you only need to make measurement for sand and stone. So that is why, one bag of cement typically weighs 50 kilograms for the purpose that this 50 kilogram bag will exactly fit in into the volume of this container that is used for volume batching. Otherwise, 50 kilograms is not something that one person can lift. I do not know if you have tried lifting 50 kilograms not that easy.

Even 25 kilograms is not that easy. When you lift a bucket of water which is filled up entirely that is about 25 kilograms, you know how difficult that is. So, imagine one person lifting 50 kilograms, not possible. I mean, possible but very difficult. Usually what will happen is 2 people will lift it and place it next to the mixer and use some sort of a knife to cut the bags so that the cement falls in the mixer.

Next time, when you are at a construction site, please observe this very carefully. A lot of the discussions that we are having in this class dealing with materials and the way that the materials are processed in site, they will be understood much better when you actually visit construction sites. And you do not need any official notification making your Intern to really visit these sites.

In most cases, you can simply observed from a distance also and see the goings on, on a construction site, as to how they deal with the materials, how they understand or how the materials are being put into the containers, how they are actually being applied to the form work and so on. In such cases, make sure that you are just observing these practices. You will be able to correlate things much better with what you learn in class.

So volume batching is done with volumetric bucket and this bucket is entirely filled up by one bag of cement which weighs exactly 50 kilograms. So, you can completely overlook the measurement of cement volume, when you doing volume batching, you just have to measure the sand and stone volume. In a weigh batching, what will happen is, you have systems that

are capable of measuring the accurate quantities of cement, water, stone and sand that come into the mixer.

So in a weigh batcher, you need to have arrangements for measuring the weighs. In most cases, when you are using concrete that is supplied from a centralised batching plant, this is the kind of arrangement they would have. I already talked about the fact that when you have volume batching, you cannot control concrete properties well enough not because there is no clear measure of the amount of water that you add.

And secondly, you will have problems of bulking when sand stored out to be open. When moisture affects the sand, it will increase the volume of the sand without really having that much sand, you might think that you have enough sand but in reality they will be lot of moisture present inside.