Building Materials and Construction
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Module - 5
Lecture - 1
Fresh Concrete

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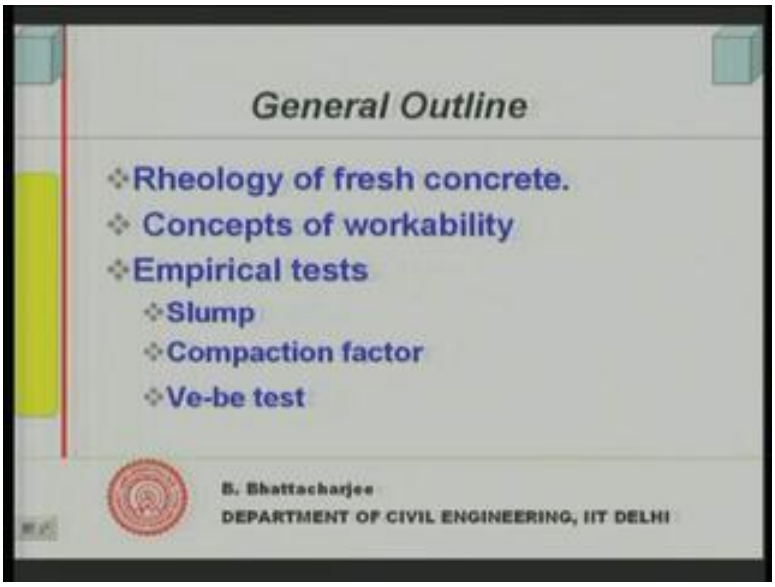

In module 5 we will look into, Fresh Concrete. To start with we will look into what is called Rheology of fresh concrete. Then, we will discuss about concepts of workability and some of the tests which we define workability. Followed by this would be the discussion on parameters that controls the workability, and finally role of admixture etcetera in control of workability that is what we will discuss.

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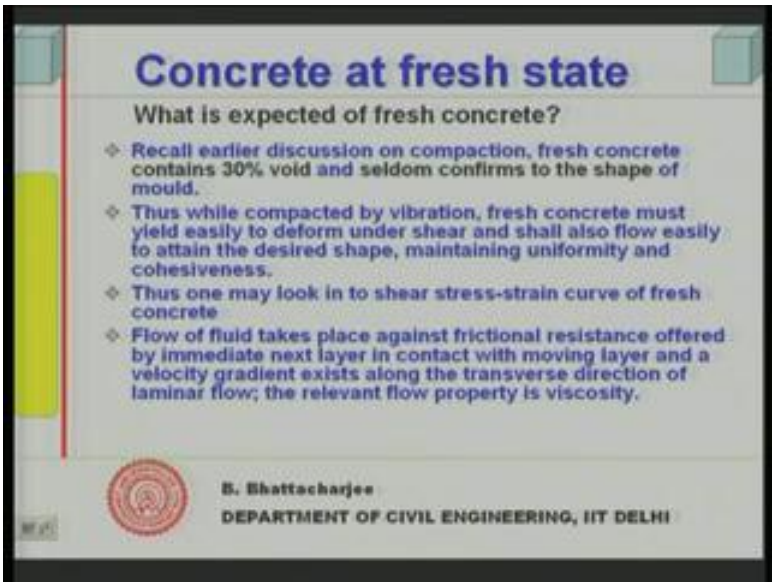

So, you can start with first what is expected of fresh concrete, if you recall our earlier lectures in 1 of the earlier discussion related to compaction we said that, fresh concrete contains about 30 percent pores voids and its seldom confirms to the shape of the mould. So, what 1 has to do 1 has to compact it to remove this voids and also; ensure a little bit of mobility, so that it moves it flows and then attains the shape of the mould itself.

Right thus while compacted by vibration, fresh concrete must yield because if it has to you know settle by itself under gravity that is what discussed earlier. Then, during compaction it must yield and then deform after yielding it must deform and must also flow to attain the desired shape. So therefore, these are the 2 major requirement of the fresh concrete.

At the same time it should not separate out, not segregate out and should remain as a cohesive mix. So, 3 requirements from fresh concretes are: number 1 it should of course,yield and deform to become you know to get into new shape and then. So, that the voids are removed also flow and thirdly it should not segregate.

So therefore, first point one may look into shear stress strain curve of fresh concrete because it should yield under shear it should yield when you are trying to compact it you are applying some vibration. So, it should move horizontally and also vertically. So, it should yield actually. So, shear stress is an important dominant factor there, while it should flow is always against the resistance afforded by another layer of the liquid.

In case of flow of liquid, 1 layer of the liquid offers resistance to another layer against the flow and therefore, there is a velocity gradient normally exist in a pipe. Let us say, if you are considering the pipe flow velocity gradient would exist along the transverse as a normal to the direction of flow. Because, 1 layer if flowing at a faster speed than the immediate next layer and there is a resistance between these 2.

The property that governs this is, a property through which we define this phenomena is the viscosity. So therefore, viscosity and shear stress behavior of concrete fresh concrete is important when you are looking to it you know concrete property of the ease with which it can be compacted. So, these 2 properties are important: that is first the shear stress strain behavior, shear stress with respect to shear strain rate we shall see this behavior is important.

The other property which is important is the viscosity because the flow is involved and lastly since it should not segregate, it should remain cohesive what is important here is tensile strength, fresh concrete it should not separate out. So therefore, tensile strength of fresh concrete is important. So, these three properties are very, very important of concrete from fundamental principles of science.

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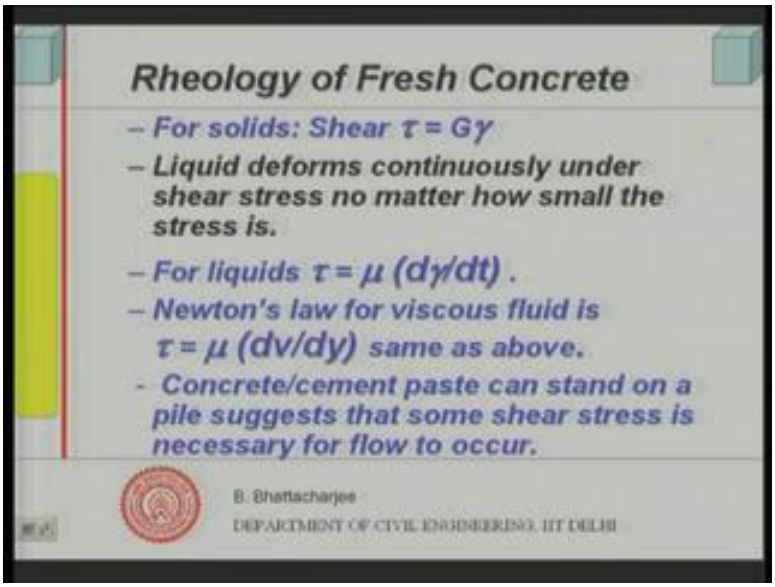

We will see that how 1 can model concrete with respect to these properties a little bit. You know for solids: shear stress is proportional to shear strain and if you look at fluid it deforms continuously under stress well no matter how small the stress is... So, solid does

not deform you know shear stress is proportional to the shear strain; liquid it deforms continuously under shear stress. What about the plastic material which are somewhat in between?

Well that is what we will see concrete is somewhat in between. So, for liquids then therefore, 1 can say the shear stress is proportional to rate of shear strain, shear deformation rate of shear deformation and the constant is viscosity. For Newtonian liquid tau is dv dy, which is same as above these 2 are same. So, tau is proportional to mu into rate of shear deformation.

Right that is what is for liquid and in our case plastics. So, concrete and cement paste is somewhere in between and initially it is in a pile as I mentioned with 30 percent void and this voids would get actually deduced under compaction. So therefore, it must yield it must overcome some shear stress. You know some shear stress is necessary to apply, some shear stress and which will overcome the resistance offered by friction etcetera.

So, it will yield, and then flow to attain the shape and then also remain cohesive if its tensile strength is sufficiently high you know to maintain a void segregation. So, these properties are important and that is how these equations are like this.

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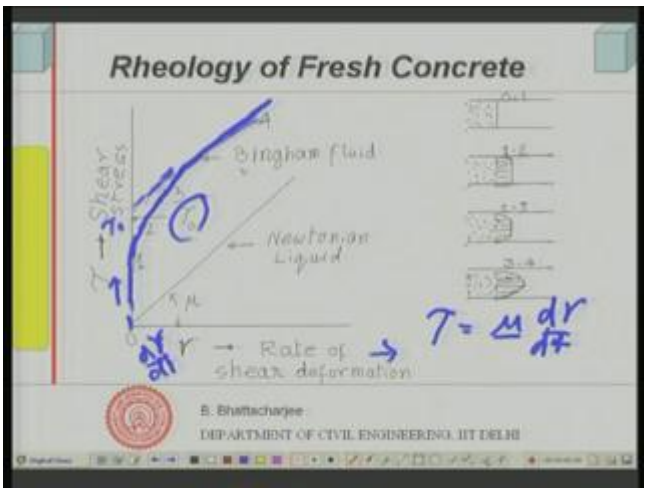

Now, let us see what happens in case of plastic concrete how does it behave. The plastic concrete is considered to be what is called a Bingham body. Now, if you see if you plot rate of shear deformation in fact, this should be d gamma dt rate of shear deformation

know this is the shear strain. So, rate of shear deformation if I plot along this direction again shear stress or Newtonian liquid for liquid.

Because, we wrote tau is proportional to mu into d gamma dt shear stress is proportional to rate of shear strain and this is the viscosity. So, you get a linear line simply for Newtonian liquid. It will actually be something like this, the velocity profile within the pipe say if this is the pipe velocity profile looking the pipe will be something like this. Butfor a material plastic material like concrete, you can see from 0 to here this behavior is something like this.

So, this behavior is for concrete the behavior is something like this, is not straight line initially it is actually rigid does not move and then attains a straight line. So, initially it is something like this then there is a curvature and then it attains a straight line.Now, this portion 0 to 1 portion it is solid; there is no deformation at all. There is stress shear stress no deformation, increase the stress somewhere it starts yielding and then there is a deformation like this.

So, if you try to see this flow or velocity the movement you know deformation well this very little the velocity is gradient is not there. Between 2and 3 there are some amount of flow possible, because there at the periphery there is very little resistance. But the velocity is constant here and 4 is linear which is Newtonian liquid you know like something like this.

So, it this plastic material can behave like this initially there will be no flow, when you apply some stress it will yield and then there is some flow possible. But there is velocity gradient and does not exist throughout the cross section of the flow, but will be existing only close to the boundary of the pipe or similar pipe or something like that. And finally, if you apply high pressure or high stress it will flow almost like Newtonian liquid.

So, concrete this is a Bingham fluid this is a behavior of a Bingham fluid and concrete is suppose to are fresh paste is suppose to close some resemble this behavior. And if you extend this line backward you get what is called tau 0; that is identified if extend this line backward. So, this is what is defined as yield shear stress of such material. So, this is what the fundamental principle, behavior of concrete under shear stress when in its fresh state could be something it can be defined like this.

So what do we see is, this tau 0 is an important property, because you must cross this value in order to make it to flow in fact, this can be expressed as a straight line. So, this is what is known as rheological behavior of the fresh concrete. Let us see something more with respect to this something fundamental.

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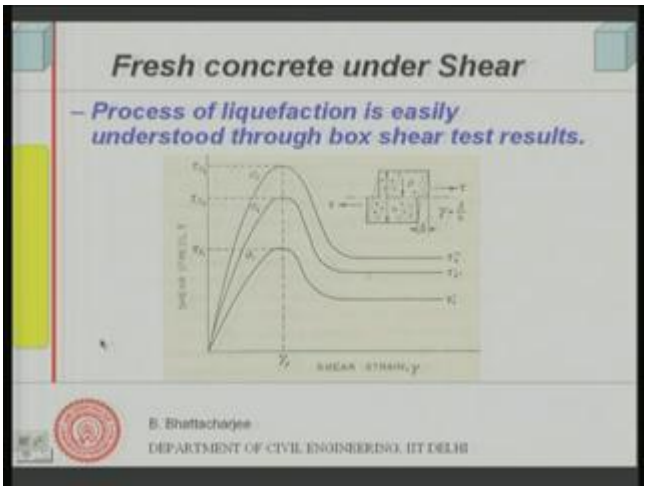

Now, supposing I tried to do box shear test on concrete which was done on all cement paste orvery early in 50s similar test were done which I mentioned that earlier in connection with compaction. So, box shear test is done and then in box shear test what we do we have 2 boxes I think I must mention this earlier, 2 boxes and you pull it from both the sides and it actually the shear deformation takes place here.

So, 1 plots the shear strain versus the shear stress 1 gets it the curves like this normal stress. As the normal stress increases, the shear load getting capacity increases or yields shear stress would increase. This is the maximum stress it can take here this we know, this is known to us.

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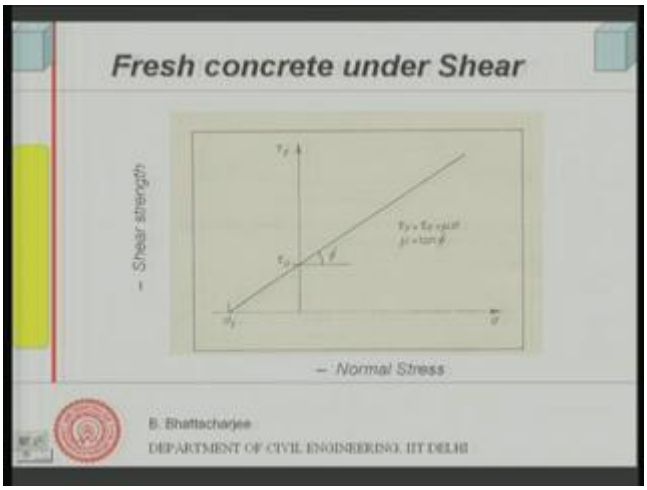

Now, follows from that is this relationship if I plot the normal stress versus the shear stress I get tau 0 here; that is at 0 normal stress this is the value of tau 0 and beyond that at higher normal stresses tau y and you know at any point yield stress is a function of tau 0plus mu sigma. So, what do we see is yield shear stress depends upon the normal force as well.

In our case it should be the self way to the concrete, if you have high mass of the lift thickness is very, very high. If you high lift thickness, possibly you will require most stress in order to cause the concrete fresh concrete to yield. So, tau is proportional to mu sigma plus you know it is the constant the intercept at y x is tau 0.So, this is this is important as far as fresh concrete is concerned.

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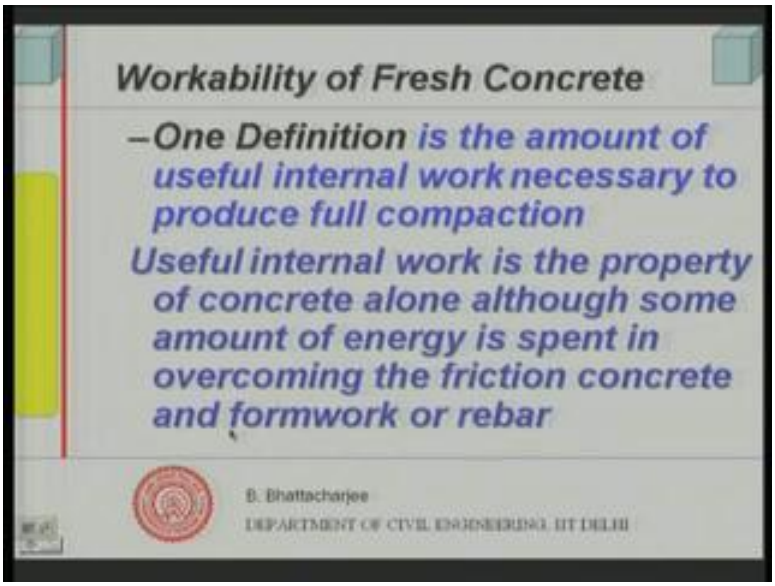

Now, this is fundamentals as far as rheological concern you know from the rheological fundamentals from science; rheological behavior of concrete some studies have been done on those. Now, this we must be able to translate to some sort of ease of working with concrete ease of compact the concrete. So this finally, what we want to do we expect that concrete should yield and it must compact into the right shape.

So, density must be sufficiently high, because if the density is less the strength would be lower. We understand that the voids are the 1 which is essentially will bring down the strength because; whenever we are talking of capillary pores in correction with cement hydration we said that higher porosity in the concrete results in lost strength.

We will discuss this in more details, but finally, we would like to have avoid any kind of compaction pores. So, compaction pores should be avoided therefore, it should be dense. So, that is how much how easily I can do I should be able to do it with normal or conventional compacting means, not by very high force then it will become uneconomic or you know that is the main main concern.

So therefore, ease of compaction is what is require such ease of compaction defining them in terms of the fundamental parameters like: yield shear stress, viscosity is relatively difficult not at the moment. Models are not available at the moment and especially when early days of computing technologies are definitely not available.

Similarly, tensile strength of fresh concrete relating this to the segregation is relatively difficult you know particles should not separate out.

So, it is the tensile strength of the cohesive mix that is very important, but relating to this segregation is difficult. So, but you know if this difficulty if the modeling or the understanding is not fully clear we cannot wait for that, we have to make concrete and use them. So, empirical properties were actually developed or a terminology empirically defined terminology was established and that terminology is called workability. So, workability of fresh concrete is a terminology.

Now, again this definition of workability has been a little or problem, but1 you know more expected definition is: the amount of useful internal work amount of useful internal work necessary to produce full compaction. And it must be property of the concrete itself now, this useful work of course, if you look at it may not be necessarily all works that you do internal work, you do goes in moving the concrete or giving the concrete or compacting the giving the concrete right shape in compacting the concrete.

But some energy is also lost in the process of you know, loss due to movement of concrete across the formworks some friction on the particle. The formwork friction of the particle reinforcement, there is some energy is lost there you cannot separate them. So, still the better you know this is the one of the better definition that amount of useful internal work necessary to produce full compaction that is what 1 can understand as a workability of concrete.

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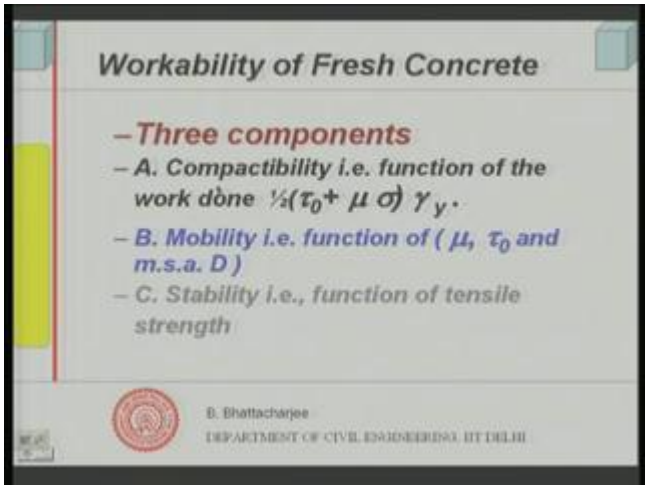

There has been a slight difference in other kind of definitions, but it was understood and it is it was pointed out that perhaps workability can be better understood in terms of 3 components. These 3 components are called compatibility number 1A, is compatibility and this is nothing, but the work done associated with compaction is the function of the work done.

Now, how is the work done? Work is done, because it has to yield. So, some work is done once it is yielded it would get into a new shape, so that is amount of work done. So, it has got one component a will call as compatibility how easily it can be compacted and that is related to work done.

If you remember, if you recall our earlier discussion actually when you vibrate concrete the particles the friction between the particles inter particle friction is reduced and then the get is lost from the local position. In other words, it starts yielding and then it gets settled by the gravity itself.

So, the work done to compaction you know and work done, in case of when you are applying some stress to it the work done is given as stress strain energy is given as half stress into the strain.

So, this strain energy can be thought of something like this, where tau 0 mu sigma that is what I mentioned earlier, that the shear stress can be depend upon the normal force that is when applied to it the viscosity. And the yield shear stress that tau 0 half of that multiplied by the shear strain. So, this measure of this compatibility could be something like this.This is the closest one can come, but you know there are problems determining this mu or determining tau 0 at the movement.

We are it is not very clear you know, but this is only one component like solved by shear stress 1 can determine, but this is only one component of the workability. The next component of course, will relate to flow and this is called Mobility. So, 1 is compaction; the other is mobility it should be able to move easily it should be mobile and that mobility is flow characteristics. And therefore, you know it is a function of the viscosity of course, it is a function of this yield shear stress.

Then this is also then observed that this is a function of the maximum size of the aggregate what we call as m. s. a nominal maximum size of an aggregate; m. s. a stands

for maximum size of aggregate and it's been observed that mobility is function of all this. But again quantifying mobility is not easy, although compatibility can be quantified relatively easily.

At the moment there is difficulty in determining this viscosity by various kinds of viscometer this in the developmental stage. So therefore, although this understand this is the components of workability, but we will see that we actually measure it by some simple empirical means.

Right followed from this is mobility and then the third 1 is a stability. Now, I mentioned three things must happen in case of concrete you know expected of fresh concrete number 1 it should yield and then get into new shape should be easily deformable. And it should also flow a little bit, and then it should not it should remain cohesive and should not segregate.

Now, this stability is related to the resistance to segregation function of tensile strength. So, it is the tensile strength is high then obviously, it will remain stable it will not actually yield shear stress should be low. So, that will requireless energy consumed in deformation, but tensile strength should be high. So, it does not actually separate out or segregate out.

So, this is the fundamentals some definition of workability I have given it is actually the useful internal work required to a actually compact. Right and compact the concrete get into right shape, but 1 can understand the basic that this could be 3 components of this particular workability as I defined.

Well today we understand them in fact, of some empirical properties and not really through those fundamentals, but they are good from for overall basic understanding. But reality in real life we apply only some empirical terms. So, let us now look into those empirical test; empirical measures of workability.

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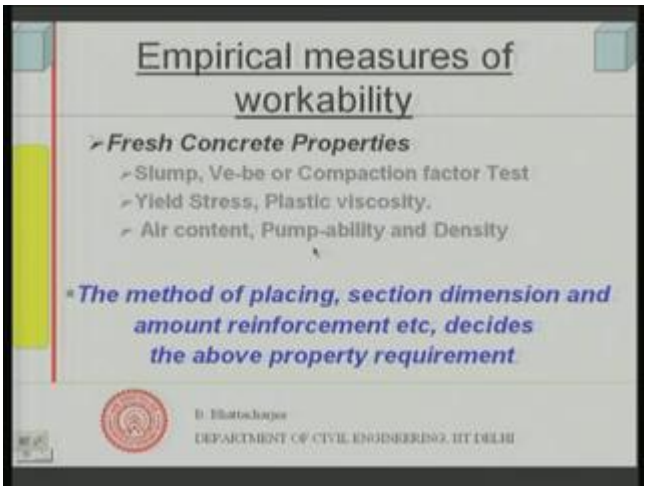

There are several such measures developed, because they are empirical.Now, first 1 that was developed was slump 1 I will discuss what this is and then there is 1 which measures the compatibility actually the first a I mentioned earlier is compaction factor test.This is a modification of what is earlier known as, Remoulding test and the measure of actually mobility isa main test later used today empirical test used today.

There are other tests like: flow test, ball penetration test and other there are some other empirical tests available, but they are not as popular as this 3. So, we will discuss this 3 mainly from fundamental principle of course, yield stress should have been what 1 would look into and plastic viscosity. But at the moment, considering the difficulty of application in real field practical field and some of the tests being very, very easy to do in real field this is not involved at the moment, but there are some other special tests could be there.

Air content in concrete related to air containment, pump ability I mentioned of pumping of concrete. So therefore, pump ability some tests could be there for pump ability although crudely pump ability can be related to slump and density. Density I mentioned earlier in connected with compaction the density would get etcetera.

So, density is important parameter in case of dams or similar mass concrete structure density is quite often measures particularly with what is known as roller concrete. So, many other situations density is measured to find out the degree of compatibility that you have attained. So, this could have been several tests possible, but actually most commonly used for structural grade of concrete are this sought of these tests.

So, these tests you know this structural grade of concrete are this sought of this this tests this test you know this tests most commonly, but this is what used because of its ease. So, slump test is 1 of the empirical tests; there are several other empirical tests I have mentioned. So, slump is a most commonly used test I will discuss this 3 I said in stresses and plastic viscosity they are more fundamental in nature not at the moment, not used at the moment.

So, these are some other tests like pump ability tests when you are pumping the concrete. Density is particularly useful in case of mass concrete and pavement concrete or roller compacted concrete and air content is measured in air concrete. So, there are some specific tests, but most commonly common workability tests is used; we will discuss them now 1 by 1.

Before that of course, let me mention that the values of slump or compaction factor that we specify for a given concrete depends upon how much I should be specifying, depends upon the method of placing, section dimension and amount of reinforcement etcetera. And these values are specified in code.

Now, what does it mean for example, if you are pumping a concrete therefore, how much work ability you need that will be decided by the placing method. Because we said that, pump able concrete will have something like 130 or 120millimeter of slump. Section dimension is important if it a very thin section, you require high flow able concrete or high possible high value of workability slump or similar sort of thing flow able characteristics has to be more.

Now, I will define the slump a little bit later and I will use of course, the earlier with respect to pump ability. So, by this time perhaps it is clear that higher the slump flow ability it has got better you know ease of compaction is more. So, high if the section dimension is very thin lot of enforcement is there possibly very high slump concrete.

So, these are specified also it will depend upon maximum size of aggregate and other factors and codes gives you these values. Sometime later on in connection with mixed design we will talk about, how much should be the value of the slump depending upon the section properties and method of placing etcetera. But at the moment we understand, that it is a method of placing section, dimension amount reinforcement present actually govern the high you know slump of the concrete.

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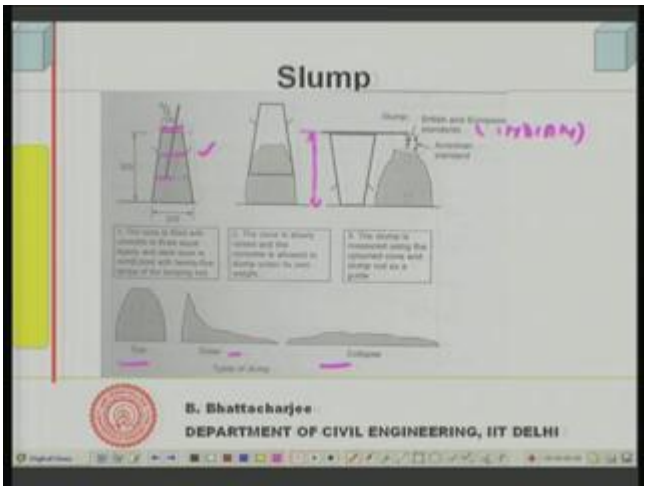

So, this is what it is, so you follow from here slump test. First test is the slump test and remember this is the easiest test and most of them is used in sites and laboratory and elsewhere and developed around 1930s.Now, this is a very simple test if you see this there is a simple cone here this is called slump cone this is the slump cone here. And if you see this dimension of the cone, this is been this is about 300 millimeter and this is about 100 millimeter right you know in good old days about a foot and this is foot. So, top is say truncated cone shape of a truncated cone and this is 200 millimeter base you know 8 inch by original standard.

So what is done? Concrete is actually compacted in 3 layers compacted in a standard manner. So, you put four concrete and then compact in approximately 3 equal layer compact by a temping rod. So, this is been standardized you compact it by a temping rod and then fill it in and then simply lift it just lift it up.

So, what will happen this concrete will settle on its own like this. So, original height is something like this just put it reverse or there can be a scale or something like that place slump cone here; original height is something like this. And you see, the depression of the concrete or in other words, settlement of the concrete. So, this settlement is called the Slump.

Now, there is slight difference in Indian standard, British standard and this is, so Indian standard also same thing. Indian or other many other European standards follow this; this is the slump American standard follows this as a slump. So, slump is simply the

depression or settlement or the concrete on its own way, a truncated cone of the size that is given this we call as slump.

So, you can understand that higher the slump more is the flow ability; less is the effort required to compact it. There are what kind of possible slump there? This is called a true slump, where it has just got this kind of a shape it has got a shape of this kind it has got a true slump; this is called shear slump.

Right and this is called collapse, this is called collapse of course, in modern concretes you can have what is called slump flow. We will see that, later on sometime. So, this this is the slump test this is a very very simple test easy to do hardly requires any time at site for quality control this is very much used. Also you can use this in laboratory and useful for most of the concrete will see, that is possibly used for most of the concrete except for very stiff concrete where the slump would be very very little. So, not measurable slump may be there it is an absolutely stiff concrete. So, we will discuss the situation. So, a slump test is possibly difficult to do. Right this is this is 1 important test.

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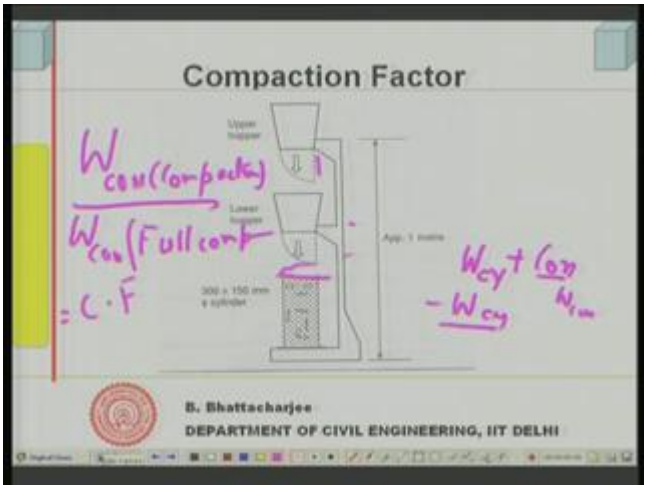

The next test which is quite useful in the laboratory and also used sometime in the site also, but then it must have site laboratory. Now, this is called compaction factor test so what, you do in this case? You actually have a hopper you know it is a truncated cone again, but it is a hopper right its bottom is closed.

So, you fill in the concrete in this 1 in a particular manner temping with rod etcetera, etcetera. Now, allow this to fall open this bottom you know this bottom can be opened

simply take this shape or bottom can take this shape and it falls onto this this is now closed. So, this concrete from here just falls and this height is standardized. This is about 1 meter this drop is standardized.

Now, what you are doing you are actually compacting this concrete because; this can be filled in by different person differently. The different you know they might achieve different compaction here; they might achieve. So, to avoid that different compaction, because you will loosely fill in it is not very very fill it fill this 1 quite loosely not in a highly compacted manner.

Now, this compaction ensures that there is a standard compaction. So, this is compacted this is drop after this drop it is compacted in some manner; subjectivity of the person doing the test is deduced somewhat by this. This is lower hopper and once it has reached to the lower hopper, open the bottom of the lower hopper then it falls into this. Right this is simply as cylinder a 300 millimeter by 150 millimeter cylinder and here it fills.

So, whatever excess concrete is there at the top you just remove it trial it out and then remove this cylinder. So, you have a standard drop of the concrete and it is compacted by that drop at the moment, now it is compacted and filled in here. So, compacted by a standard drop; drop is fixed, so standard drop and it is compacted. Then, you take mass or weigh this cylinder find out its weight and note that weight down.

So, that weight of the cylinder with concrete cylinder plus concrete minus simple weight of the cylinder will give you the mass of the concrete you know this will give you w concrete. So, you subtract the mass you know weight of the cylinder from weight of the cylinder plus concrete, because this is weight of empty cylinder.

So, this is cylinder plus concrete, so you get the weight of the concrete compacted in the standard manner under you know this compaction. Then, you take this cylinder and fill in concrete and vibrate it in a standard manner to achieve nearly full compaction. So, w of the concrete again you can find out in same manner that is empty cylinder weight is known, weight of the fully compacted concrete.

Now, this compaction you do under vibration in a standard table vibrator or whatever manner full compaction you should get and once you have done this full compaction you

find out the weight difference of full compaction and the compaction by standard drop. The ratio of this 2 is called compaction factor.

So, what is compaction factor? It is the ratio of the weight of the concrete I mean mass essentially; it is the ratio of the weight of the concrete compacted through a standard fall divided by the weight of the concrete compacted by you know nearly fully compacted concrete by some standard compaction means.

Now, as you can see if this is high it means the concrete is easily compactable. A flow able concrete or a concrete which is fully compactable will get compacted more, under this drop. Compared to a concrete which is stiff, which does not want to compact soeasily and then this is constant in all cases, because you have full vibration to ensure that nearly full compaction you are getting.

So, how close you can achieve to the full compaction by this drop is compaction factor. So, this is compaction factor and higher the compaction factor it is more workable; lower the compaction factor it is less workable. Usually you cannot get a compaction factor less than 0 6 and you cannot get of course, compaction factor 1 only for water you will get a compaction factor 1.

Because, water or some liquid because if you drop through its weight would not change it will fill in completely and do vibration ideal compaction factor 1 is for water.For very flowing concrete are very close to that right. So, in case of stiff mix this will show very little value, so that is what compaction factor is.

And highest code for mix design used as this compaction factor values, as the indicator of indicator of workability of concrete right. This is slightly more difficult as you can see compared to slump; slump is very easy you just to and its fairly easy way to test.

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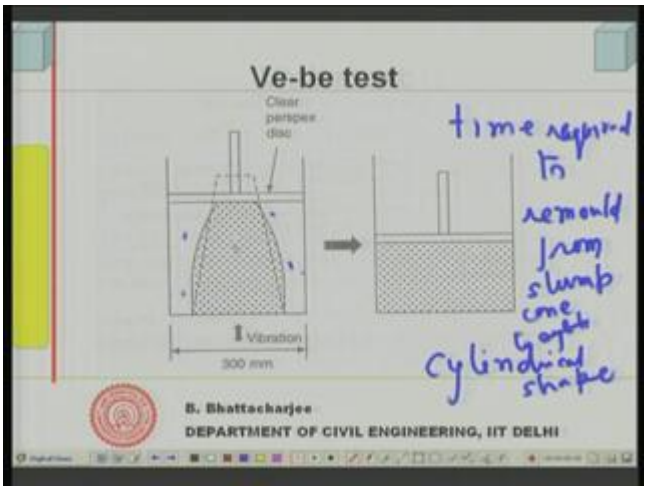

The third popular test is called Ve be test and this is as I told you, it is a original it is a modification of the original remolding test you know what you do is you have the same slump cone again. And on top of that you fix a perfect disk on top of that, so this is your original slump cone filled in with concrete in the same manner and put the slump cone here; remove the cone.

So, it will attain this kind of a shape too slump say this kind of a shape; it will attain this shape. Then put a perfect shape, which is a part of the machine actually clear perfect shape over this. And vibrate this in a standard manner now, what will happen the slump will then attain the shape of the cylinder. This is the cylinder this will attain the shape of the cylinder under vibration.

So, this when you vibrate it will attain the shape of the cylinder; that means, what you are doing? You are remolding it from a slump shape, cone shape to a cylindrical shape. So, this is as I said it was the earlier remolding test that was there. So, it is a modification of the remolding test. Now, this remolding test what was done? The force required to remold it from this shape to this shape, was measured the force required.

But in Ve be test you do not do that, rather you vibrate it and find out the time required to vibrate it from this shape to this shape, so it is the time required. So, what you measure is the time required time required. So, what in the process you know what you do is time required. So, required time required to remold from slump cone shape cone to cylindrical shape cylindrical to cylindrical shape.

So, if you need higher time it means that it is a stiff concrete it requires a lot of effort, because the vibration is same standardized. So, it is been vibrations is been standardized,, so it you know it requires higher effort is required if the time required is more; lesser effort is required if time required is less.

As you understand this concrete is suitable this test is suitable for supposing it is a flowing concrete. So, you won't require any vibration, so time required for remolding to from this shape to this shape is very little under the standard vibration. So, if it is a very flowing concrete then this test won't be sensitive, because time required is very small.

So, 1 microsecond or less than a micro second it is very difficult to measure that time, because you would be normally measuring this with stop watch, which least count in terms of second. So, you cannot have something less than second quickly, if it quickly it gets remolded you won't be able to measure it. Therefore, this is good for only stiff concrete, where the concrete is stiff this is useful; right for flow able concrete this is not, so much useful. So, this is the Ve be test this 3 tests are the most popular test as far as work ability is considered.

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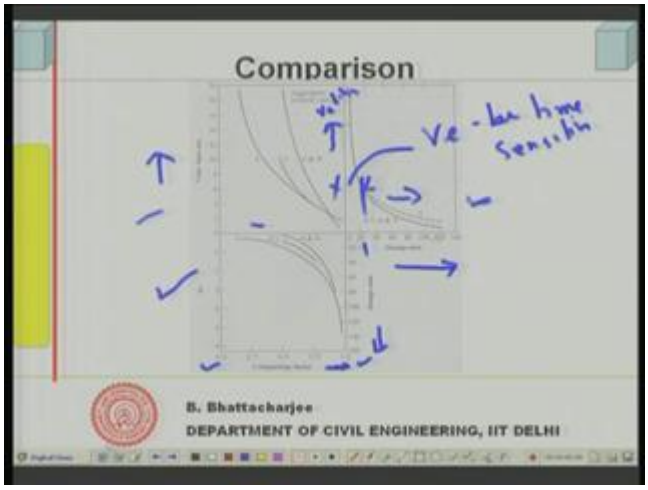

But out of this slump test is the easiest 1 and most commonly used in the laboratory, whereas, Ve be test is used possibly in case of site, but for fibre reinforced concrete has got very little work ability. Because, you have introduced fibres and this fibres stop increasing the inter particle friction and do not allow concrete to move or flow very easily and thereby, it is Ve be time is relatively large.

So, very stiff concrete there, so where your concrete is very very stiff you use this test while. This is a comparison you can see this, if you look at this this axis isthis is the slump axis and this side is the Ve be time this side is the Ve be time. So, if you look at this is Ve be time this is nothing, but Ve be time.

So, when the slump is very small Ve be time is quite a big; you know Ve be time is sensitive in this zone. In this zone Ve be time is sensitive in this zone Ve be time is sensitive, because you can have large variation in Ve be time. But you come to this zone this side you will find that slump increases, but Ve be time is nearly remaining same.

So, you cannot distinguish between 1 Ve be time to another Ve be time if the slump is very large. So, that is why Ve be time that slump increases, but Ve be time is nearly remaining same. So, you can distinguish between 1 Ve be time to another Ve be time if the slump is very large. So, that is why Ve be time is useful only for very very stiff concrete.

Then, if you look at compaction factor the second test that we talked about which actually measures compatibility, you know a that was out of the 3 components of workability a. Compaction factor actually measures compatibility there is no work done required to compact it whereas, Ve be time is you are remolding into shape. So, it is related to flow ability.

So, this this Ve be time is related to actually to flow may be it is it will measure the second component right.Slump is also flow under or in itsown way right. So, anyway, so this is slump versus Ve be relationship. Let us say slump bus has compaction factor relationship. So, this is your compaction factor and you can see the highest value here is 1; this value here is 0 6.Highest value is 1. So, usually it varies between 0 6 to 1 less than 0 6 is very unlikely, because then it is not a normal concrete right.

So, it is 0 6 to 1 it will vary and corresponding slump is you can see a slump is higher here; slump increase around this direction. So, for lower slump compaction factor varies, but in the higher slump zone compaction factor is relatively less sensitive. But not as much as this. So, in fact this is somewhere in between, it can be used for concrete and not very stiff not very flow able again. So, this is somewhere in between and compaction factor is you know measure of the compatibility.

If you come to Ve be time and compaction factor; obviously, you can see that at compaction factor at very high compaction factor Ve be time changes, but relatively lesswhereas, at low compaction factor Ve be time changes more. So, that is why it is in between the curve is quite stiff you know, if you see the nature of the curve here; this curve is relatively more flat compared to this.

So, with reference to compaction factor at high compaction factor it is still sensitive, butat high slump Ve be test is not at all sensitive, because variation of the Ve be time is very very little.So, that is why we said that compaction factor is somewhat in between, because here still it is sensitive right. And if you see this, this is relatively more sensitive than the nature of the curve of course, this depends upon other parameters like: aggregate, cement ratio, etcetera, etcetera you know paste content and soon.

This different curve for different mix or different combinations, so we are not really interested at the moment to look into this. We are just trying to look into the type of you know variability associated with different types of tests. So, here by going by this compaction factor versus Ve be time, Ve be time you can see that this I said the aggregate to cement ratio varies aggregate to cement ratio.

We will see that how aggregate affects workability at the moment, we are not really interested; only we are interested in the nature of this curve. So, nature of from this nature of the curve we can say that compaction factor can be used for relatively a moderately stiff concrete whereas, for very stiff concrete it is actually Ve be test. And that is why, we use for fibre reinforcement concrete practically you can use only Ve be test.

So, for pump able concrete you can use slump, you cannot use this Ve be test compaction factor is in between test eventually IS code uses this test for mix design calculation. And slump is used by Ve be t sometime Ve be test could use not of course,Britishpractice use as this as well asthis.

Slump is more common, but this is the most popular slump is the most popular test right. So, that gives the comparison of this three test, but remember they are all empirical test designed by the engineers, for the purpose of field use and not really based on fundamental principles of science. In the sense they do not come from viscosity, shear strain or rheological properties, etcetera, etcetera.

I will discuss about segregation the tensile strength part of it, I have not talked about right now, but does not be talked about much later this is something different. At the moment we are trying to look at ease of compaction; later on sometime we will look into the segregation properties that which we should not separate out right, so that is what it is.

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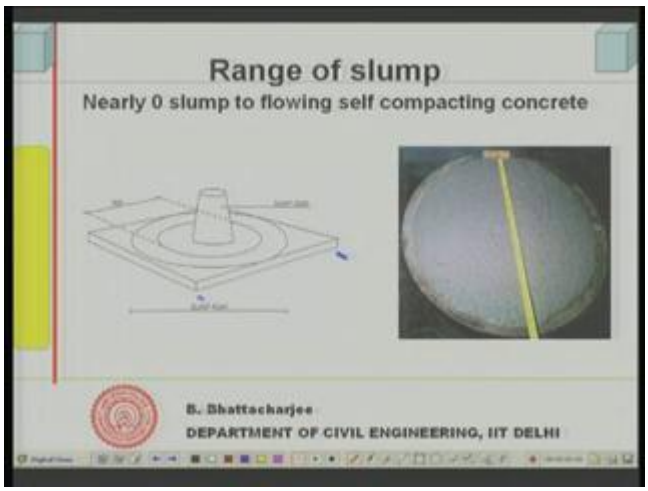

Now, what could be range of slump? Slump can very nearly zero to completely flowing self compacting concrete. Now, what is 0 slump concrete? Well, 0 slump concrete it is essentially meant for what I said roller compacted concrete. Now, roller compacted concrete may be discussed in some time.

But basically this concrete is used in dams usually not very high strength, but interesting feature about that roller compacted concrete is that as the name suggests compacted by road rollers. So therefore, it has to be relatively dry very very dry nearly 0 slump should be there, because it has to be compacted by road rollers. All road compaction machineries that is used for path work or road compaction purposes otherwise, is used for roller compacted concrete usually low as.

So, that concrete has got a strength I mean you know it has got a slump nearly 0 and one of the measures that is used for necessarily 0. So, slump test is not really used for compaction or compaction, whether it has attained full compaction or not, but what is used here is the density. So, use density instead of using any one of the measure, because finally, we have achieved the compact or not that can be decided by density.

So, that is what is done in such kind of concrete. So, you can have nearly 0 slump concrete that is the roller compacted concrete.

To another concrete which is completely which does not require any compaction; that means, it flows on its own. It has got practically very little, yield shear stress and viscosity is such that it can flow very easily of course, without segregating. In such sort of cases, we use what is called slump flow test. Now, in slump flow test what you do is, well there are several other tests and this is also in the development process.

So, in the sense that actually this is being this is still being standardized is yet to become completely standardized. So, one of the test is slump flow test just modification of the slump test.

Now, same slump cone you have you have the same slump cone in this case and what you do fill it up with the concrete that is, self compacting concrete that is what it is. So, you will fill this up completely with the concrete and then just lift it up. Now, what will happen it will get spread like this shown here.

So this is about this, you know this is a slump flow that will take place this is 500 to 500 meter this is about dimension of the 1 meter; this dimension will be some meter. So, slump flow, so the range of the slump that you can have is from complete self compacting concrete to 0 slump concrete. So, you know this shows that slump is out of all the tests that we have looked into slump in some form or the other possibly is most versatile.

Of course again in the low range we prefer not some, but density. In the higher range course we modify this as there are several other tests to govern you know define self compacting, we are not really discussing this here at the moment. Right few points I would like to mention related to the test of work abilities y like, ball penetration test is another kind of test penetration which tells us how workability is.

If it is easily penetrable it is more workable, if it is less easily penetrable this is not so penetrable. But this test has got importance, because we do we talked about box setting characteristics of the cement, but we did not really talked about the setting characteristics of the concrete. In case of concrete the setting characteristics 1 can measure in terms of slump loss, how the slump is changing with time. You perhaps would remember, when

you talked about ready mix concrete I gave a figure showing the slump loss with hall time.

So, with time actually slump loss takes place and that tells you, beyond of when the slump is quite low you cannot walk with it. So, there is a minimum limit penetration test also you can serve the same purpose. So, when you want to measure let us say setting characteristics of the concrete, slump test, slump flow or loss of slump time is what you can actually measure.

So, these are the test essentially popular tests which we have discussed at the moment and segregation is another 1, which I mentioned the tensile strength should not be lost should be sufficiently high. So, it does not separate out; this is another property and we will discuss this out sometime later on. Because, segregation tendency of concrete is very much there let me repeat, which I repeated perhaps earlier that concrete is made up of materials of different densities.

The least being the water and the maximum being the cement. So, when you mix these materials together cement to water and then some inert stone and find aggregate or course aggregate which are actually inert in nature, inert particulate material you know natural particulate materials either obtained by crashing or simply natural gravels as available in nature.

So, when you mix them up together they would not level never like to meet together. The heavier material will have a tendency to go down and the lightest material will have a tendency to come up. So, water will have always tendency to come up simply, because of the buoyancy effect and cement would have a tendency to go down. So, this 1 kind of segregation would be separation of the water coming out of the mix and that could be in form of bleeding or in case of pump ability the water might go away right.

So, it might bleed and result in choking of the pipes and things like that. So, segregation 1 kind of segregation is that bleeding the water moves out from the rest of it. The other kind of segregations would be separation of the closer aggregate from the finer aggregate or motor and closer aggregate get separated. Some aspect of this we discussed earlier, in connection with placing of concrete.

So, when you have you know wrong methods of placing of concrete it may, so happen that large particles system would be separate from the motor system. So therefore, that is another kind of segregation. This issues how we measure segregation, that 1 we will look into later on. At the moment we have looked into, how easily it can be compacted; the workability is concerned that is related to how easily we can compact and then use in how we can measure them and also we have seen the ranges of workability.

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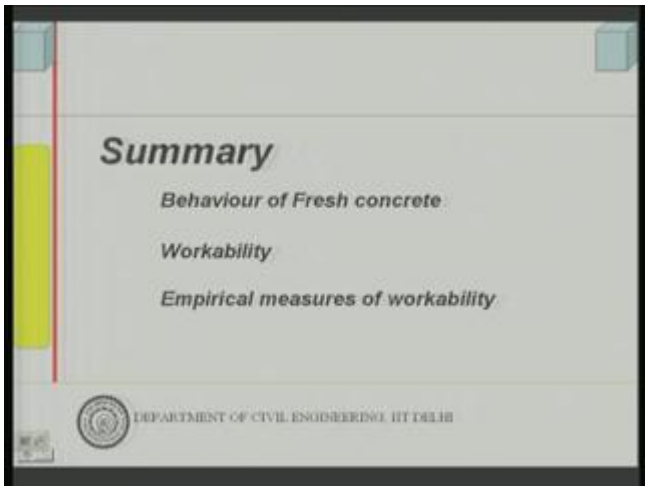

So, then we can summarize our discussion we have looked into behavior of fresh concrete or behavior as, we require not you know behavior under stress and behavior under flow condition that is what we looked into. You can recall some of the earlier discussions with reference to pumping also at the moment. Because, we have seen that the pumping takes place as plug flow.

So, you can see that it does not purely behave like liquid, but does not behave like solid either and it is somewhere in between. So, that behavior we have looked into and we tried to relate this behavior to the requirements of the fresh concrete. The main requirement of the fresh concrete, that it should be able to cause make able to deform it and then it should move to attain the shape of the mould itself.

So, this is the requirement and this requirement should be we should be able to relate to the behavior; while from fundamental principle at the moment it is not possible. To directly define relationship between the fundamental properties like, viscosity as well as yield shear stress, etcetera. But we have some empirical we have defining, the ease of

compaction and that is what we call as workability. Most close definition of workability is, useful internal work that we mentioned.

Then, we have looked into the various kinds of empirical measures of workability namely the slump the Ve be test and the compaction factor test. And also we have tried to find out which is the most you know which is suitable at what location. Since slump is you know is relatively easy and is relatively versatile and used over a wide range can be you know range of slump can be very very wide.

So whereas, Ve be test be only used mould for only for the stiff mixes. So, fibre reinforce concrete for example, you cannot use any other thing whereas, slump is very difficult to use, because the slump variation of slump would be very very little. So, such concrete we use Ve be test, but we can use for another concrete also, but it has to be stiffer.

So whereas, compaction factor is somewhere in between and how you choose the slump depends upon the section, the congestion of the fibre reinforcement or how we choose the workability will depend upon the concrete itself, the kind of concrete that is there. And also it will depend upon the section, the mode of vibration and mode of placing.

For example, if you are vibrating you do not ever vibrator, you expect no vibration possible for that particular concrete say example is under water concrete. In case of water under concrete you do it through, a pipe will be pipe system or similar sort of thing such concrete cannot be compacted below.

So, it should be a concrete which should be flowing on its own, it should be compacting really it should be really as flow able as possible. So therefore, you will require high slump. So, depending upon the method of placing, method of vibration other section properties the amount of reinforcement 1 would choose how much is the workability required, in terms of the measures namely the slump and sometimes, of course compaction factor and Ve be time as well .

So, we will discuss this issue related to selection of the slump as given in the code in or reference to mix. The last aspect related to workability is what we will look in the next class. How the mix parameter governs workability? Since now we have discussed about,

the empirical properties we will continue only with empirical properties and not with the fundamental properties anymore.

Because, that is not useful in field what is use are the empirical properties. So, we will try to see what governs this workability what factors for example, how does the aggregate system or other ingredients of the concrete governs this parameter, how does it governs the slump. We will also look into how additional materials such as admixtures of the kind of the chemical admixtures and mineral admixtures governs.

So, this you know rather controls this workability namely the slump, Ve be etcetera and then finally, of course, we will look into how they are useful in our designing the material that is the mix design of concrete. So, I think with this we generally would like to conclude this lecture; next we will look into the effects of you know ingredients on to workability of concrete.

Thank you