Concrete Technology
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Lecture - 25
Strength of Concrete: Factors Affecting Test Results

Welcome to module 6, lecture 3. If you recall, we discussed about factors affecting strength of concrete. In the last two lectures of this module and we also said that it is, you know test condition that has a role on the value or on the estimated strength that we get estimated cube strength or cylinder strength, that we get from our tests. So, what are the factors related to test condition that affects? This test result you know is what you are going to look at today, right? So, it is essential we are looking at what are the factors and how do they? How do they factors? What are the factors, how do they affect the strength the test condition, test related factors that affects the strength.

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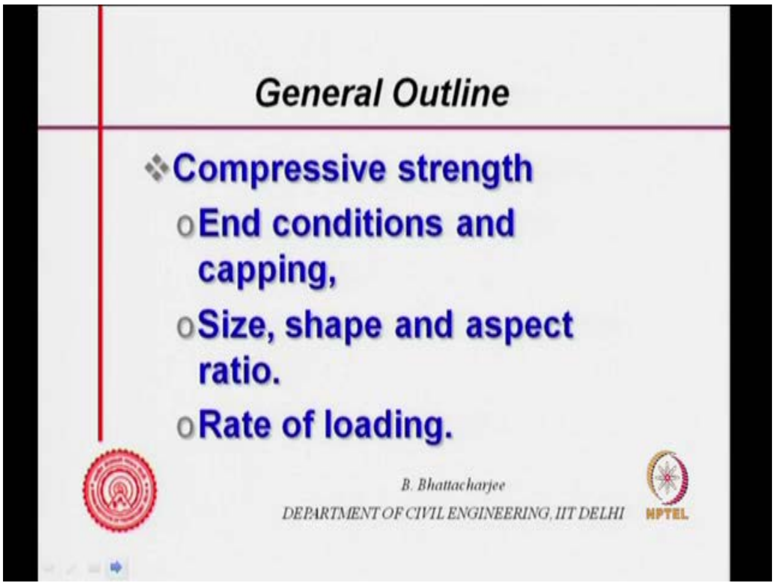

You know such a factor those will be affecting the strength. So, general outline compressive strength. The factors which affect the compressive strengths are end condition and capping of the sample or the specific, you know sample of the specimen that I take, size and shape and aspect ratio of the specimen rate of loading, and then will look into some of the aspect related to tensile testing some of the aspect related to tensile testing.

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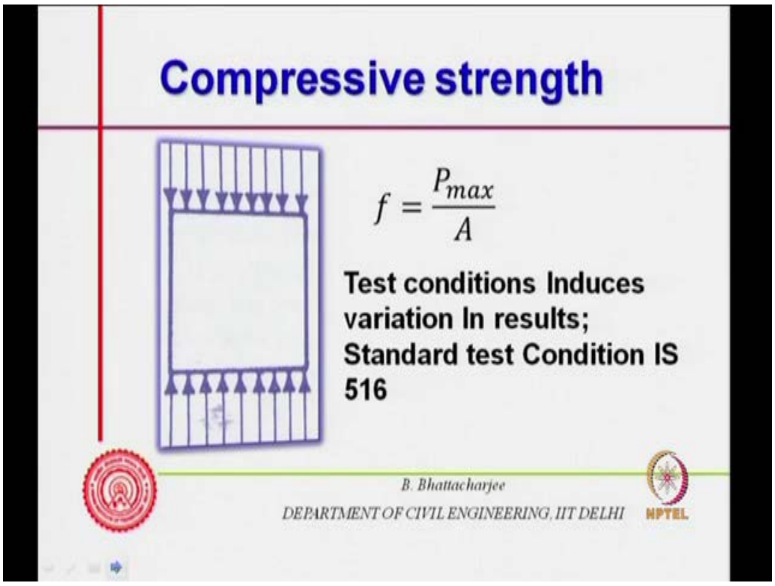

So, compressive test, compressive strength test for compressive strength actually what you do? Let us take a cube and we apply load from top and bottom through a machine, testing machine where this load is applied through hydraulic system, and we can also control the rate of loading etcetera, etcetera. So, we apply load like this and we define the strength as P max by A that is the simple way of doing that, and test condition induces variation in results. That is what we are going to see of course, the strength. Therefore, I must have a standard test condition.

Now, if you recall sometime earlier we talked about that the cube strength that you get actually is not a really a measure of strength, that you get in the structure because several factors will be affecting the strength in the structure, as well as that obtained from the cube test and they are not the same. The factors values of those factors or levels of those factors are not same, but then it gives us a relative measure. It gives us a relative measure of the materials that has gone in concrete making.

Since, the test condition affects my strength, I must standardize this test condition and use the same condition for all the cubes, so that I can only compare the materials. So, standard test condition is given in courts, in Indian scenario it is given in I S 516, originally framed in 1959. Also, but then it is been reformed past possible from sometime in 2009 or so.

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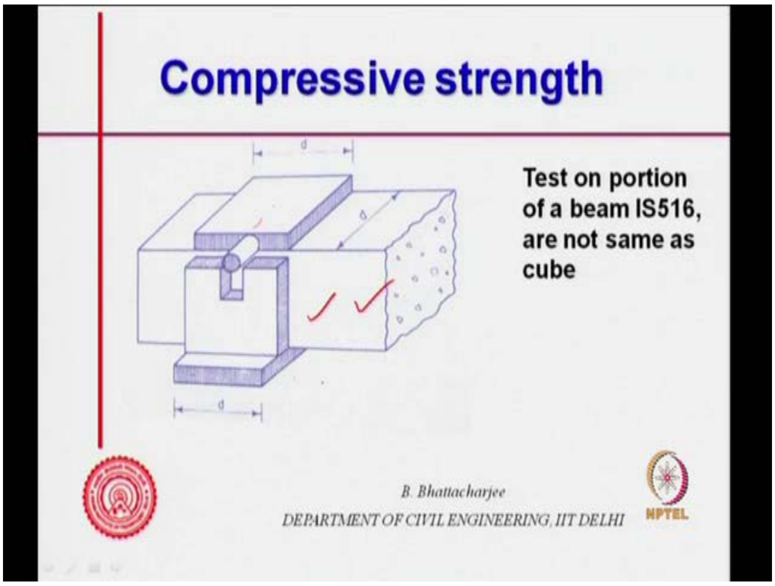

So, test condition it remains same still it remains same. So, what you do you apply load? From the top uniformly distributed load on the cube surface, and bottom there is an uniformly distributed. Assume that the there is uniformly distributed reaction from the machine frame or machine plate as we call it, we apply the load also through the machine plate and as we apply the reaction comes from the bottom, and the cube concrete cube is crushed under those two loads all. So, that is how test cube, but we can test part of a beam as well, you can test the part of beam as well all right, you can test the part of beam as well.

So, for example this is the whole beam, this is the whole beam, this is the whole beam, this is the beam, part of a beam, after doing fractural strength on the test fractural test for fractural strength on a beam will discuss. This test for fractural strength sometime later after doing that test the remaining portion the unbroken portion. Actually, I can test under compression, so the load is a applied through this and bottom plate is here. So, applied to the top plate and then as we press it goes down and I get some results.

Remember this results, it is not the same thing I S 516 gives text on portion of a beam is not same as the cube. It is not same as, you know these are the, these two things are not same, they are not same. They give you some, this gives you some strength, the other one gives you some other strength, but anyway that is good enough for our purpose we are because we are relatively comparing. So, compare this results with only the beam results, compare cube strength result with only the cube strength result. Now, this is not so popular while cube is very very popular. Cube is most popular commonly used this is this is rarely used actually.

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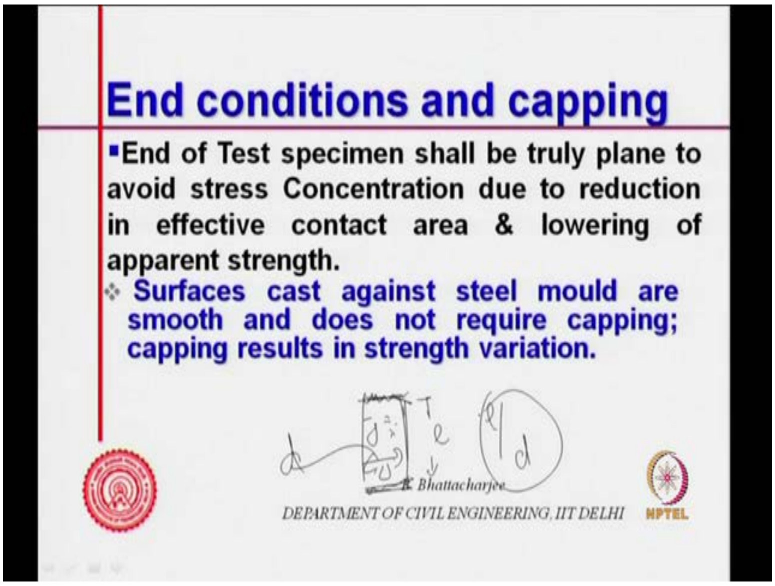

Now, end condition and capping, end of test specimen shall be truly first of all you know it should be truly plane, this is what we talked of now this should be truly actually, this should be truly plane, this portion should be truly plane, this should be truly plane. Otherwise, the undulation the contact area would reduce, and there will be stress concentration, you know effective contact area will reduce, and apparent strength will reduce.

Therefore, this must be the first thing is it must be plane and to do that what we do, what you do is we cast surface cast against steel mould are smooth and therefore, it does not require any treatment. I will talk about capping a little bit later on, but it does not require any treatment there is very smooth and I put that below the loading plates, what we call loading patterns. You know, I put the this one this top portion this portion, this portion is the this portion, you know this portion, this portion I am talking of it, is that one which is which was in contact with the steel mould during casting and not expose to air?

So, this will remain by enlarge plane by moulds are standardized properly made within tolerances, this will remain plane. While we can do this for cubes, while cylinder actually you cannot cast in this manner, cylinder you cast like this, you know this surface is always exposed. So, this surface, this surface is always, this surface is always exposed this surface is always exposed, this surface is exposed. So, we apply load to have through this and we cylinder scenario we cannot apply, but we have to see that it is sufficiently smooth there is no variation.

Now, let us say for as a cubes and cylinders largely cubes are concerned, but if you cut it core from actual structure sometime we do that, we will not be, right? Now, we will not be discussing this, but sometime we cut a core from the cut a core, cut a core and from the from the structure. So, this is the core actually so is a core cut you know, cut core from the structure, which we have seen in the beginning first lecture, if you remember? I actually showed you a core. So, you cut a core from the structure and this core sometime might may have rough surfaces and or length may not be sufficient you know, you have to have a specified length, depending upon the diameter d. So, l by d.

So, there is a minimum l by d, which is 1 but suppose you have got slightly less than I might do some sort of capping here. That means, put some material put some material and do capping, put some materials and do capping. So, if you do this kind of capping, you we will see that the results in variation in the strength. So, that is what we are saying. So, capping results in strength variation right and capping results in strength variation.

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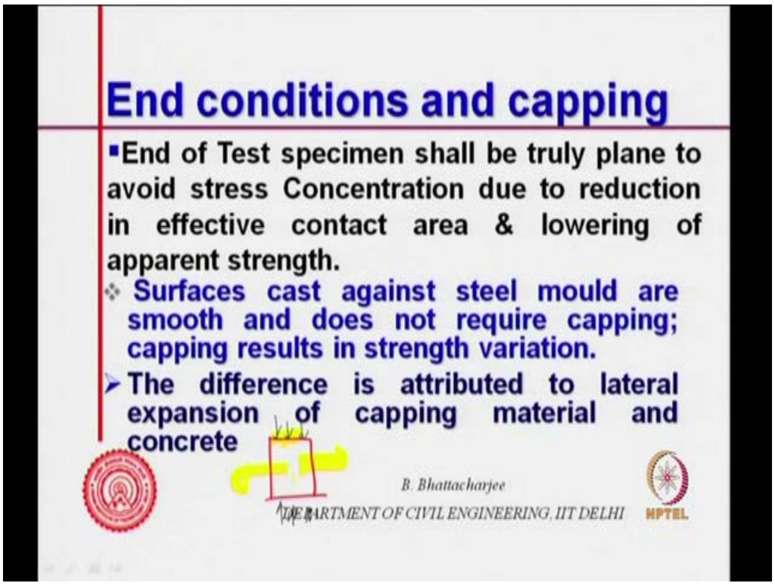

Now, this variation or the difference we get is attributed to lateral expansion of capping material and concrete, relative you know is both will be the capping material would can be expanding. So, what we are doing when we are applying load like, when you are applying load like this on this one you are applying load like, this material here would be actually expanding material here would be actually expanding. So, if you put a capping material, this will also expand and concrete will also expand. So, this is related to this sort of expansion of this capping material and concrete. Let us see how it is? So, see just see that right now, we will see that right now, we will see that how it affects.

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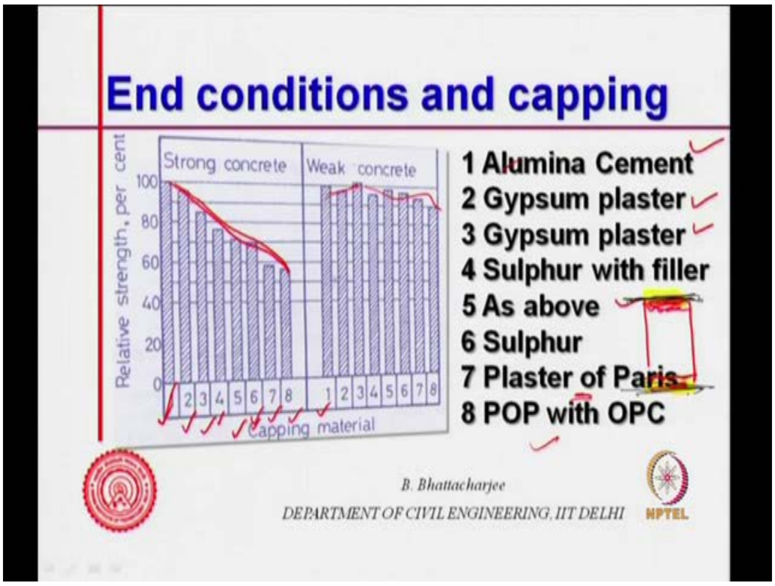

Suppose, if you have put different capping material, I put different capping material. Let us say first is one is this is alumina cement, first one is a alumina cement, this is one is a alumina cement. So, I have made actually cubes or cylinder like this and I am using different capping material here, they might be this might be rough, this might have not been smooth etcetera. I may bring different whichever way, this is the result of experimental results.

So, I am actually doing some capping and capping here put this capping and first material that I am talking of is alumina cement. So, this is alumina cement and second one is gypsum plaster, third one is another gypsum plaster, fourth one is sulfur with filler sulfur concrete with some filler. Sulfur you know actually colloidal sulfur E L O sulfur you might have seen actually melts. So, you put some aggregate into with some filler it becomes almost concrete when it solidifies.

So, the sulfur concrete you can put some sulfur plaster of Paris, calcium sulphate to 2 H 2 O that we know and P O P plaster of Paris with ordinary Portland cement. So, plaster of Paris is this ordinary Portland cement is here. 6 is sulfur, 6 is sulfur, 5 was same as sulfur filler, and it is pure sulfur is 6, all right? So, see if you have different capping materials, same cubes or same cylinder if you look at relative strength. If I assume that high alumna's cement gives me 100 percent strength for strong concrete, it goes on reducing with the capping material, it goes on reducing with the capping material, it goes on reducing with the capping material.

And for weak concrete the affect is somewhat clears affective increase, this is the qualitative statement not doing qualitative statement, quantitative statement, qualitative statement. So, what we observe is that there are variation and it depends upon the type of capping that you are using. So, end capping has an effect on you know end condition normally, if you do not have a capping the machine plates are straight away coming in contact with, machine plate is straight way coming in contact with top and bottom which are usually steel.

So, you have steel patterns plates patterns they come in contact with the, they come in contact with the specimen survival sample, you know specimen itself all. So, specimen itself so that comes in specimen itself all right not samples, specimen because sample would be couple of specimen makes sample, so it specimen from the sample actually so specimen cube use specimen itself.

So, this is what is happening machine plates coming and if you put depending upon strong or weak concrete, the f factor will depend. So, you see depends both on the strength of the concrete the quality of the concrete as well as, you know the affect of the capping material is a function of the strength of concrete again, say kind of non-linear situation so that is what it is.

And therefore, this is an important issue, so end condition capping this is an important issue. Now, what is the mechanism, what is the mechanism? Let us see if I have some diagram some diagram, some diagram right? Now, I do not have perhaps. So, no problem what explanation is there? Let me have use my own diagram, let me use my own diagram the observation is I mean more or less first use this my diagram, again I will come back to…

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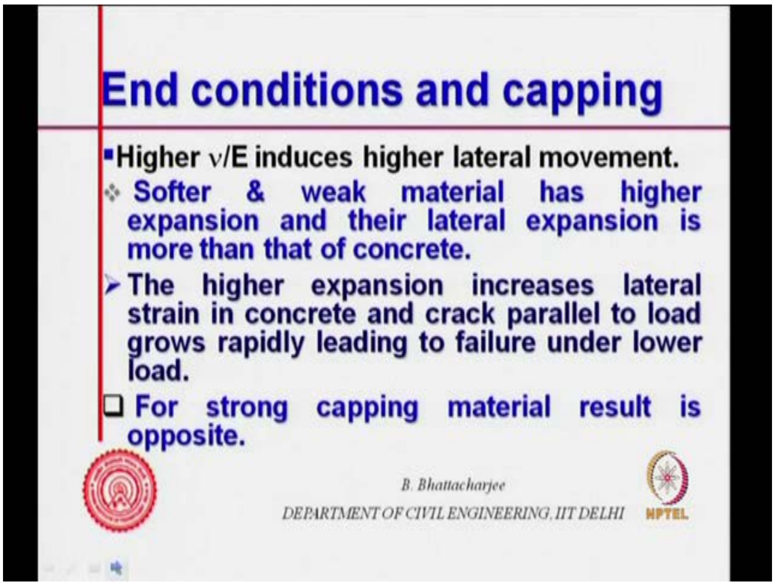

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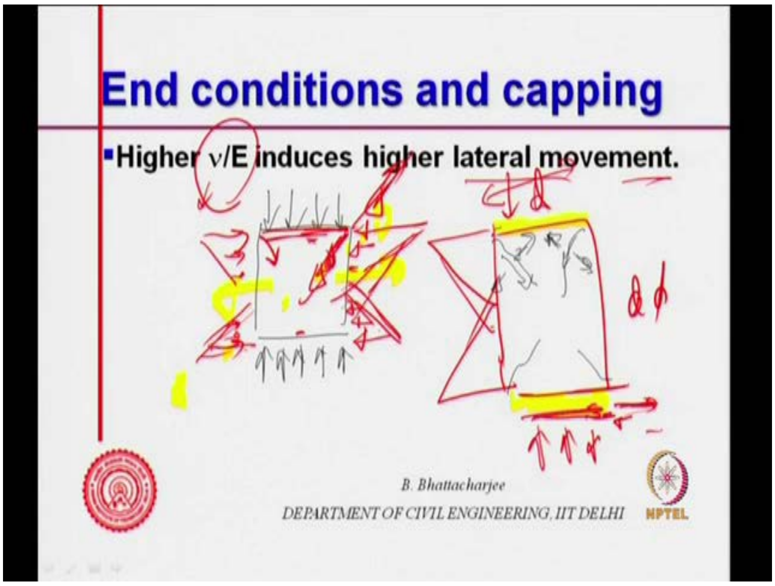

Now, this is your cube you are applying load like this and we have discussed that my material, my material will have a tendency to under this compressive universal compressive situation. It will have tendency to move along this direction, as well as along these two transverse directions. Now, if tries to tend along move along this direction that means it finally, the failure is because of then the movement is important movement of this material along this direction is important. Now, this point the movement of the material is restricted by the friction between the machine plate, and the specimen.

So, there is a kind of force acting like this frictional force, which will not allow this movement. Similarly, here this is a kind of a frictional force which will not allow you to move along this direction. So, this is the surface, but then surface material is in contact with the just bottom next, layer of the concrete. So, if there is a force acting and it is the time to contract it is the time to expand it also tries to take the material below, but if it is if there is force opposing this. This also will be opposed somewhat, but it would get gradually get reduced, you know there is some sort of opposition to the movement here also, but gradually it get reduced.

In other words, your this force is resisting forces, I mean it would get reduce somewhat. So, you do not have really purely uni-axial situation, you have a situation where there is some sort of a force acting on to the specimen depending upon, you know depending upon the type of specimen or l by d or up to some height. This there is a force acting like this also height force acting like this also this will depend upon. This is your l and this is your d, if I say this is the d dimension of the cube. So, if it is d and d there is somewhat overlap is there, we will come to that just now.

So, you see there is an opposing force or to the movement horizontal movement or transverse movement, this opposing force to transverse force both this direction as well as in this direction there will be an opposing force. So, this opposing force actually what it would do it would actually, you know net effect is a force compressive force acting like this, net effect is at this point compressive force acting like this, compressive force acting like this.

So, tension force will be acting normal to the tension force will be acting normal. So, it will act like this and here also it will act like this tension will act like this. So, tension acts like this because compressive is along this direction, compressive along this direction net force because of the resultant of the frictional resistance and the applied load. So, net compressive force will be along this direction, which means there is a tensile force the transverse tensile force because of the (( )) act like this.

So, you have crack in this direction in your crack in this direction, you have crack in this direction and you have crack in this direction, this is called platen effect, this is called platen effect. Now, supposing I put a material here I put some material here, I may put some capping material here. Now, machine plate is not in direct contact with the specimen, machine plate causes the friction is between this and the friction is between friction is here. Now, between the machine plate, your load is coming from here and friction is somewhere here. So, this material would try to you know expand in this manner, but would be resisted by the friction.

So, it is Poisson's ratio which causes to deform along the transverse direction. Poisson's ratio along the transverse direction and it is stiffness right is an important issue. So, if it moves high, moves quite a bit compared to the stiffness resistance to move is stiff is as a material property, for a given force. Then for different capping you know it is, suppose I have two different capping there movement along this more quite moves, it will cause the concrete to move more along this direction. If it is stiff then the strength, this directional strain will be low the personal affect will be minimum.

So, more the Poisson's ratio of this capping material and less the modulus velocity of that material, it will tend to actually nullify the platens effect more. So, in other words just let me now put it here higher, higher nu where nu is a Poisson's ratio divided by E modulus of velocity stiffness, more modulus of velocity. You know more modulus of velocity is then less will be the movement.

So, nu by u E is important if this is less this term is going to be higher and if this is more this term is going to be higher. So, this if this is higher. So, the higher nu by E induces higher lateral movement, higher lateral movement higher nu by E induces higher lateral movement. So, that is what we have understood that is what we have understood I am just erasing it out now right, I am erasing out.

So, softer and weak material has higher expansion and their lateral expansion is more than that of concrete. So, softer and weak material has higher expansion and their lateral expansion is more than that of concrete. So, therefore this will cause if that moves concrete will automatically, will also move platens effect will get reduce significantly. Softer and weaker material will get reduced, the higher expansion increases lateral move straight in concrete, and crack parallel to the load grows rapidly leading to failure under lower load.

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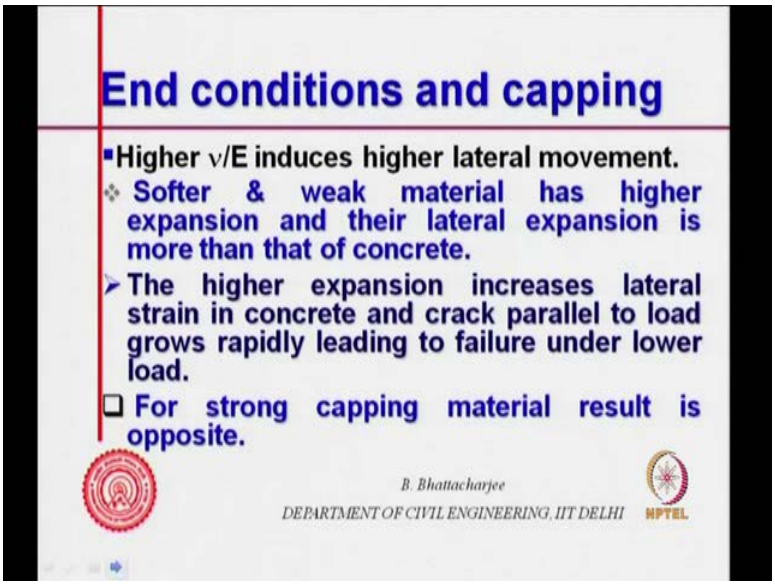

So, you see higher that means higher nu by E material as a capping material that is softer and weak material. You put it in the capping material it will cause it itself expand and we will not restrain the expansion of concrete, under then you know Poisson's effect. Therefore, concrete vertical cracks you will see possibly crack parallel to the load that is downward load. So, crack will be parallel vertical load, vertical cracks and that would failure would progress under that kind of load.

For strong capping material result is opposite obviously, so if the nu by E is small. That means this material itself has low present ratio and E is high very stiff therefore, stronger material has this kind of behavior and that would actually restrain and therefore, it would have showed higher strength, compared to the one with higher value of nu by E because it will restrain. So, the net effect is you know the material is not into expanding in the transverse direction it is restrain to that. So, net effect is it will you will require higher load to cause it to now failed. So, this is the affect of end capping as you have seen.

The end platens of the machine produce same effect as strong capping material. So, the capping you know end platens machine, platens because steel is a material it is a strong material and its Poisson's ratio is divided by modulus velocity is relatively low. If there is no capping material. Therefore, plates restrict the movement and increases apparent strength and the degree of restraint depend on friction between plates and the concrete surface.

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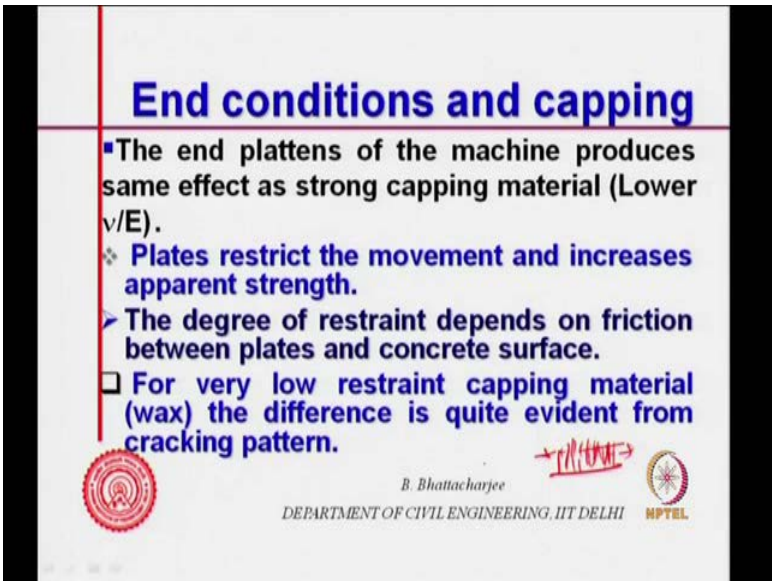

So, that is why everything has to be standardized, you see you have to standardize your plate and whether, you go to use a capping material or not, that has to be standardized. Normal cube stress we do not apply any capping material, but varying this capping material we did not, understand? You know why possibly a specimen, which has got high l by d fails at load compared to a specimen, which is l by d goes to 1.

So, the degree of restraint depend on friction between plates and the concrete surface, and for every low restraint capping material wax, let say if we put wax, the difference is quite evident from cracking pattern. We put wax which is a very low restraint, it does not restrain because it is very low restraint, weak material expands very quick a lot. Therefore, you can find an almost vertical cracks right something similar.

For example, rubber of teflon, if you use it has got a high strength, but low stiffness. So, it allows expansion, but it does not fail itself. Therefore, you will find again the affect of the plates are gone there is something called brass platens made of platen plates made of brass, you know brass clothes brass platens. So, then you use below the plate a brass. So, brass can expand easily it is a brass steel brass. You just put the platen, it can expand. Although, it will not fail, so that is it that is you know platen effect.

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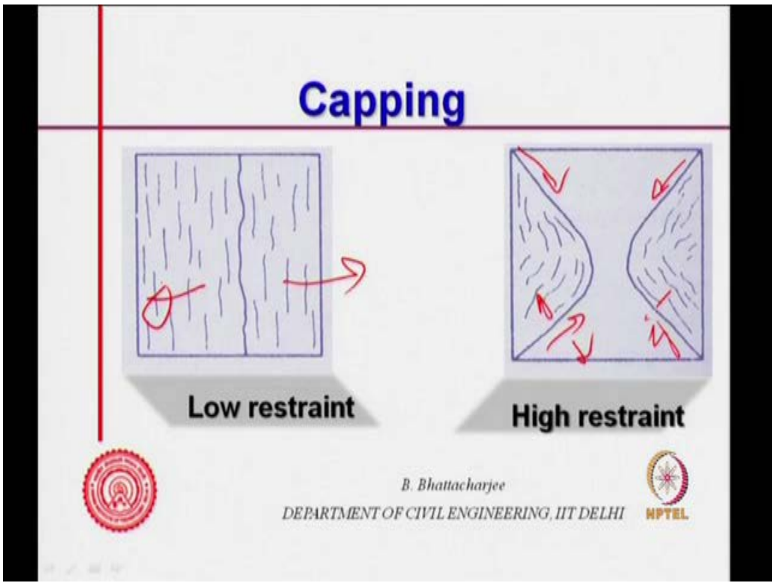

Basically, so if you see if no effect, no capping, no restraint practically and if you have high restrain, then these are the scenario, low restrain, high restrain, high restrain you will get because I told you net compression. Net compression will be along this direction resultant force. So, transverse tension will act like this and you have something of this kind while, if you have low restraint basically you ask something or teflon or brass platten affect, brass plate. Then cracks will be vertical because of the filler due to Poisson's effect. So, these are accepting to taken into account.

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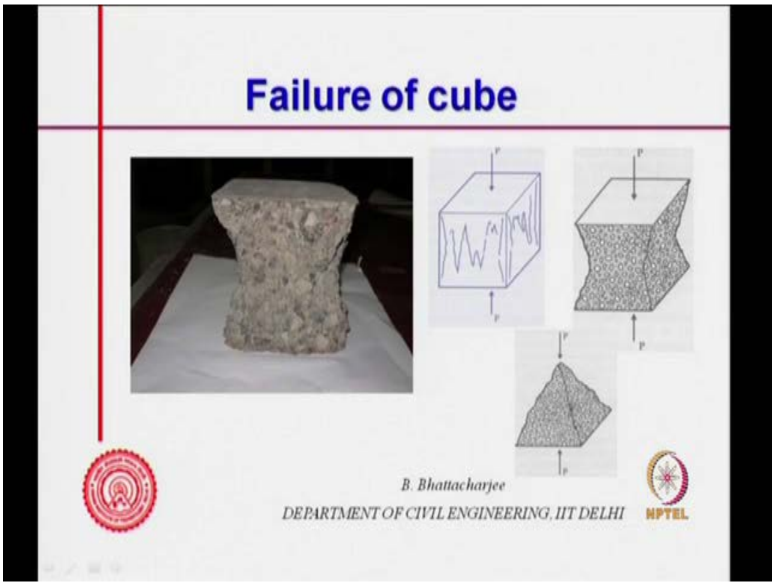

Therefore, you know we got if we recall failure of the cube like this. This is the cube failure, if you remember this is what you should. Earlier in the beginning cracks will come like this, then this is the shape that you get and some cases. Further, you might get shape like this; this is the portion which does not get fail, right? So, this is the final portions platen effect like this.

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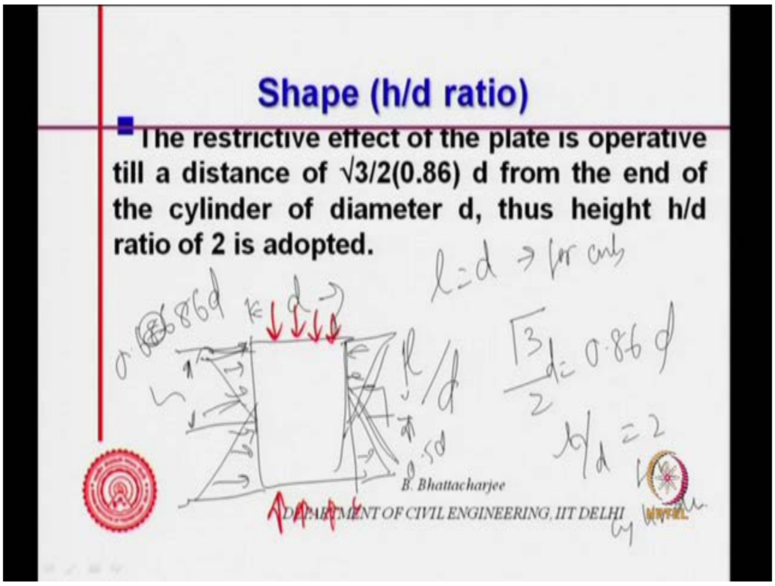

Due to the platen effect it is like this, but then restricted affect is limited up to certain distance from the plate. As I said it is limited, if this is your you know specimen, what is important is l by d? So, up to certain portion this is effective this platen effect, you know this will certain point, right? It will act into certain point, does not act full length. So, this is acts on certain point, right? This is act up to certain point, so in this direction it will be there. So, it will act like this, now how much is this distance? This distance seems to be it is related to d, this can be related to this d. So, it is been observed that up to about 3 by 2, you know 3 by 2 may be 8, 6 d 3 by 2 d up to this d, the end of the cylinder of diameter.

So, it is actually you know estimated actually up to 8, 6 d this affect will be there. So, if this is d 0.86 d this distance will be 0.86 d sorry 8, 6 d 0.86 d this side also 0.86 d this side also 0.86 d. So, you have l is equal to d which is in the case of q for q actually there is an overlap of the platen affect because this is 0.5 d and this side 0.5 d, it goes up to 0.86 d specimen platen effect. Practically, this affect of restraining affect of the plates works as the whole of specimen, but if you have a cylinder with h by d is equal to 2, h by d is equal to 2 for cylinder.

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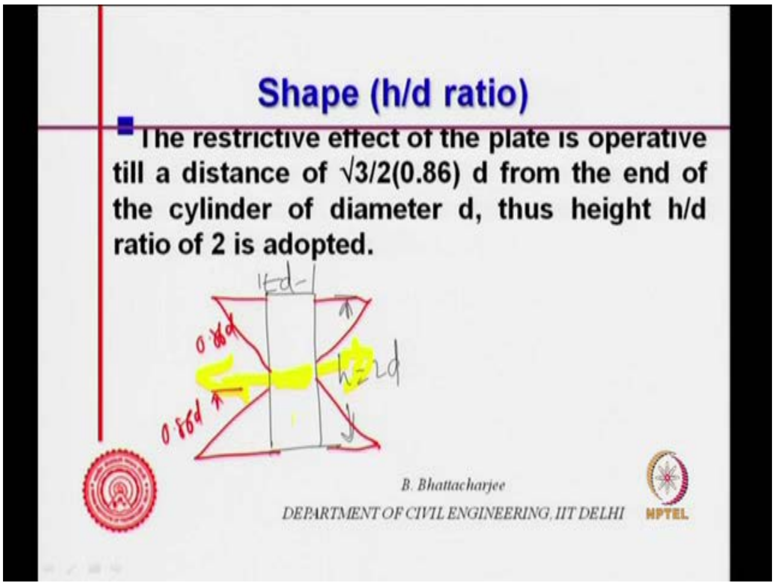

So, in that case what is happening? In that case what is happening? A cylinder h is equal to 2 d at least this is 2 d, d the latten affect will finish up to 0.86 d. So, this is 0.86, 0.86 d and so on. So, there some portion, there some portion where you have no platen affect that will expand easily, it will expand easily along this direction. Therefore, we adopt actually h by d is equal to 2 and we find the strength is lower, strength is lower in case of cylinder, strength is lower in case of cylinder right strength is lower in case of cylinder. So, that is it strength is lower in case of cylinder.

Strength result differs for specimen having h by d lower than 1.7, when we ask a question sometime you know it is lower, but why it is lower? Some people say buckling, while buckling occurs when h by d is greater than phi. So, it is simply because platen effect cylinder. Strength is lower than a cube strength, right? Cylinder strength is lower than cube strength, effect of h by d ratio decreases with increase in concrete strength as nu by e increases decreases sorry nu by e decreases.

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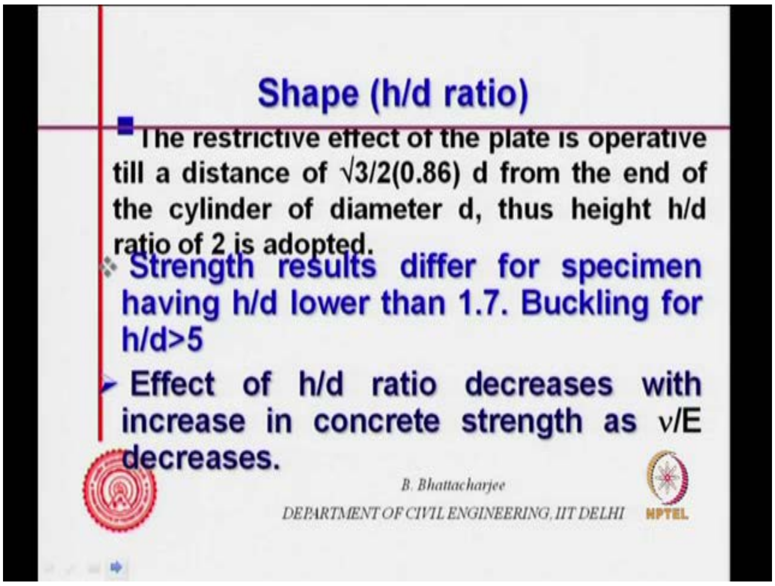

So, if you have higher strength concrete is more nu is, nu is you know nu is relatively nu by E will be higher for higher strength concrete. So, this nu by E increases you know basically, depending upon this concrete itself because expansion of concrete is important, right? In weak concrete restraining affect will be more because it wants to expand, but then if you are not allowing it. So, this affect will be more and you can see the how, how the capping material is actually affected it. So, that is why this depending upon strength of the concrete relative motion of the concrete with respect to capping material, that would differ and that is what it is.

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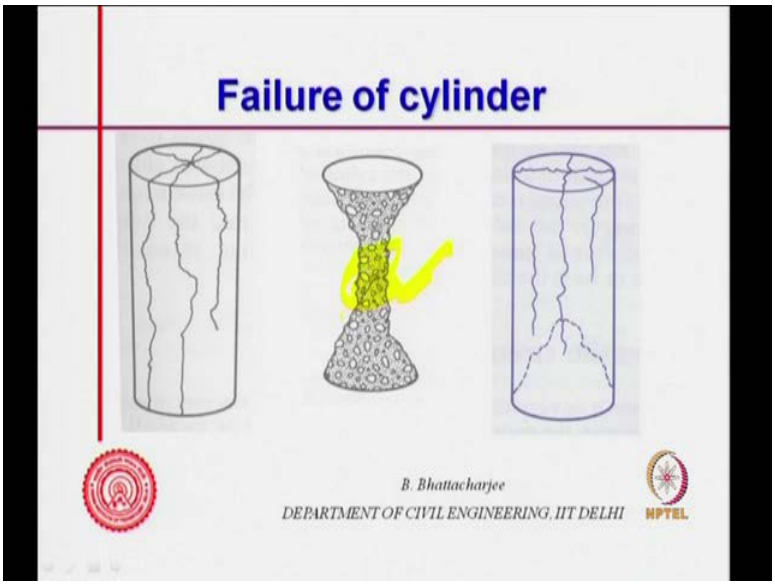

So, cylinder then failure of cylinder will always see vertical cracks, somewhere you might see something of this kind, right? You might see something of this kind and you might see something of this sort of you see cylinder failure pattern, something of this kind cylinder failure pattern is something of this kind, all right? So, that is because same because same this portion does hardly any platen effect and therefore, it shows vertical failure platen.

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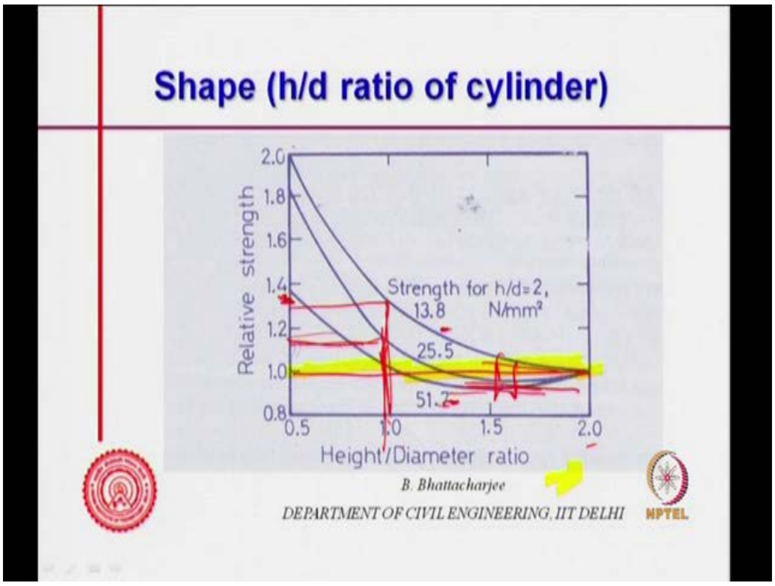

People have done some experiment and it is been observed, as you increase the h by d ratio height to diameter ratio. Relative strength if this I am calling 2 I am calling as 1 at 2 is 1, 2 it is 1 at 2 at 2, it is 1 sorry at 2 it is 1. This 1 at 2 at 0.5, l by d ratio it is something like this and it also depend up on the strength. For example, higher the strength behavior is somewhere here lower strength is somewhere here. So, this affect you know 1.4 l by d equal to 1, let us say l by d is equal to 1 you get about one point depending upon the strength, you get one point some cases might get 1.3.

Some 3, 5 or something cases you get very close to 1.2 and so and so for. So, depending upon the situation depending upon the strength, this ratio this is for cube what cylinder having l by d ratio is to 1 cylinder having. So, experiment shows how it changes actually, but beyond what is observed is a beyond certain point, the variation is very little this variation is very little, right?

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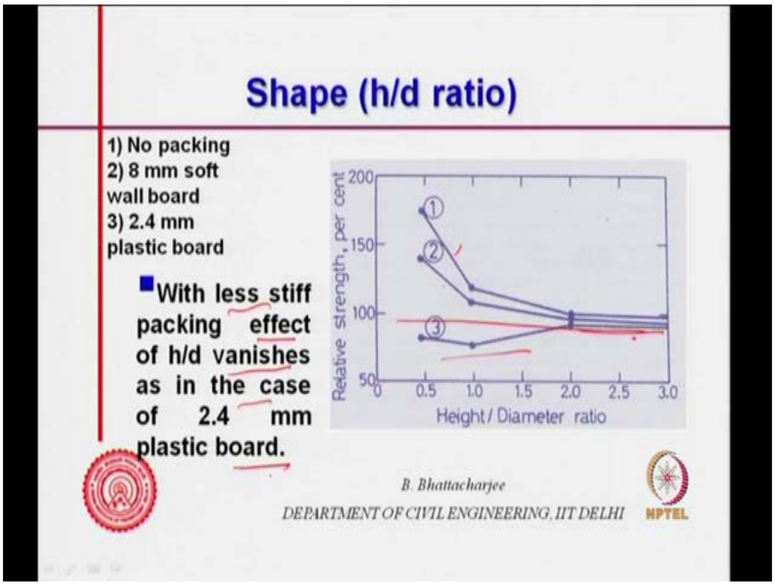

So, that is because of that is because of the l by d ratio effect. Similarly, if you have no if you just have just kind of a situation, where you put in some packing between earlier one is h by d ratio, related to h by d ratio earlier this was related to h by d ratio we have changed. So, we have said that if the h by d ratio is high platen effect reduces. Therefore, strength tends to become similar and now, if I put some packing same aspects of capping actually, first case is more packing second case is 8 millimeters of 2 volts, and this is 2.4 millimeter plastic volt.

So, in this case there is no effect practically, you do not see relative strength almost similar 100 and in case of 1 no packing effect is there. So, packing would affect this now packing would change, packing would change because change you know some cases l by d ratio affect could be nullified by putting right kind of packing, but one does not want to do that we want to standardize everything, and use the rest I mean use compare for, comparing you know tests are for comparing only.

So, with less stiff packing effect of h by d vanishes, as in the case of plastic board because plastic board has got low modulus of elasticity and high present ratio. So, nu by e is now actually large. So, it can deform itself and allow the concrete to expand and therefore, this effect is merely is simply not there you know it is very little may be. So, this is what l by d ratios cylinder to strength and all that.

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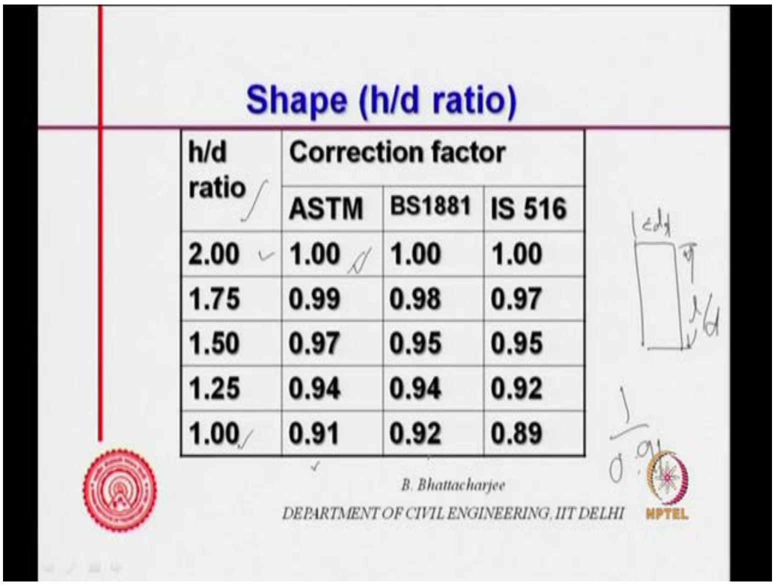

So, therefore there is when you are measuring cores let us say, if you are measuring core as I said sometime would be testing of core. So, you are measuring the strength of the core and different h by d ratios is there. If you consider this as 1 American society of testing material factor correction for 2 is if it is 2 is 1 correction factor for 1 is 0.91. That means, the cylinder with a l by d ratio is equal to would exhibit nearly 90 percent of strength sorry exhibit, sorry not nearly 90 percent, exhibit higher strength. So, multiplying factor is 0.91.

So, convert the cylinder cubes convert the cylinder cubes l by d ratio 1 l, this is l, this is d. So, convert l by d ratio 1 cylinders strength obtained for l by d ratio, 1 cylinder to l by d ratio 2. What you do? You multiply this by 0.91, so you can see the strength is high here by 1 by 0.91 around 10, 11 percent higher according to A S T M code. I mean this is of course, judgmental if you see British code it is 1 by 0.9 to Indian standard 516.89. So, you know everybody takes somewhat normal that is for of course, core.

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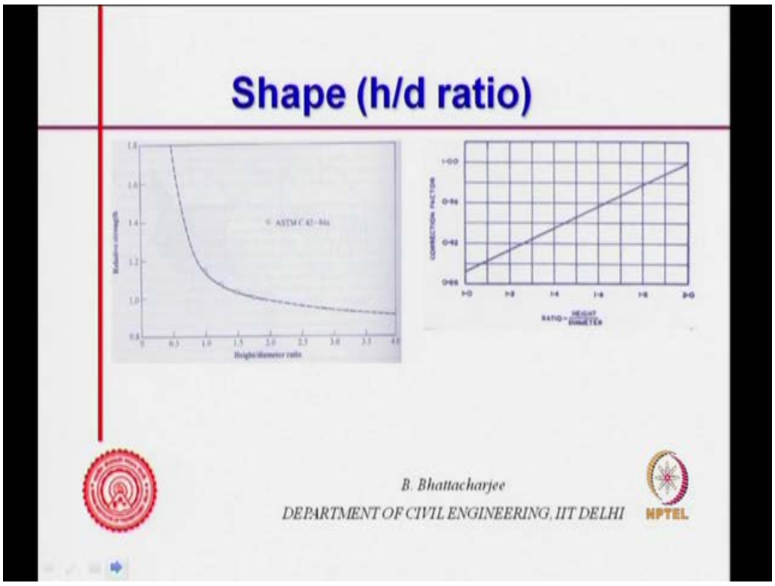

Now, A S T M gives you the same thing if I plot it, I get A S T M and this is Indian standard 516 same thing given in the curvature form, this is an Indian standard 516 same thing given in the curvature form 2.5 above, and all that you find much over variation, above two practical there is no variation and that is it.

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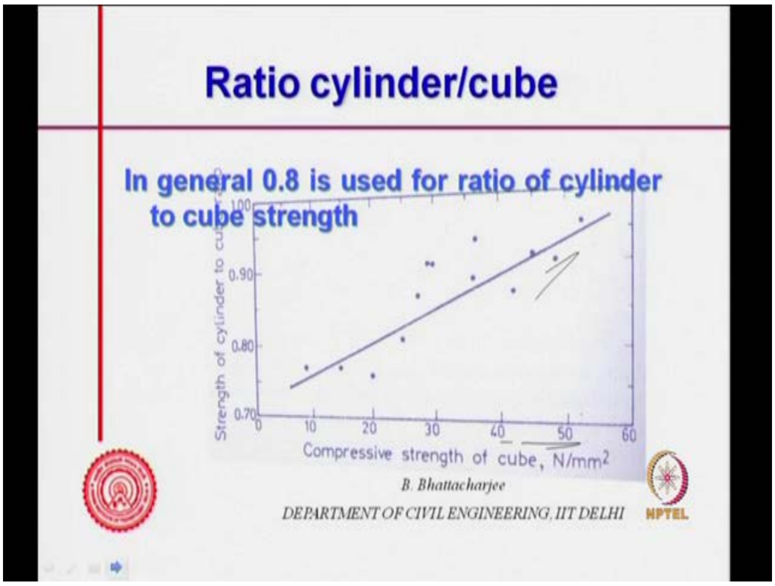

Now, lot of people have actually tried to find out ratio to cylinder, ratio of cylinder strength to cube strength, right? So, strength of the cylinder to cube strength on this side and at what point they are same. Obviously, it will show scatter large scatter, but typically what we do is it would vary up with the strength higher, the strength the ratio is increasing actually relative cylinder to cube strength because we said that the capping and platen effect all these are functions of the strength as well, but what we do is normally in generally we use 0.8 as a ratio to cylinder to cube strength. So, specimen shape has got role capping has got a role. Therefore, while Indian standard uses cube fifteen centimeter of the side length, some other places they use 15 centimeter dia cylinder the strength would not be same so it depend upon specimen type.

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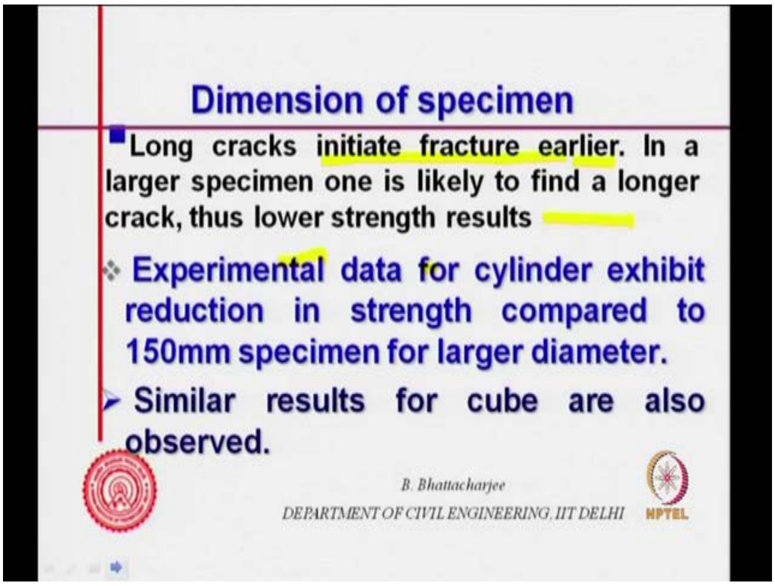

L by d ratio and you also seen what kind of capping is there. So, long cracks initiate fracture earlier in a larger specimen. Therefore, now size is other issue, dimension of the specimen if the specimen size is large then it fails at lateral load. Why? Because long crack can long crack initiate, fracture earlier. So, in a larger specimen you are likely to find out a longer crack or longer fisher, right? In the beginning and therefore, in a larger specimen one is likely to find longer crack, thus lower restrain results.

So, this is somewhat something called size affect sort of thing, larger the size lesser is the strength. Experiment data for cylinder exhibit reduction in the strength compared to 150 mm specimen for larger diameter. So, if one does systematically, but then the error is so much in our normal testing the variation, capturing the variation is not very easy you have to do lot of test actually.

For example, just doing 3 cube of 10 centimeter side length, 3 cube of side length 150 mm and 3 cube of side length, let us say 200 mm. So, 9 cubes you test, 3 of each size and find out the mean you may not find the variation because the error in the test. Otherwise because of all those all the factors that is involved merely is simply mass, the effect of this size, but if you do large number of test then this effect you do see.

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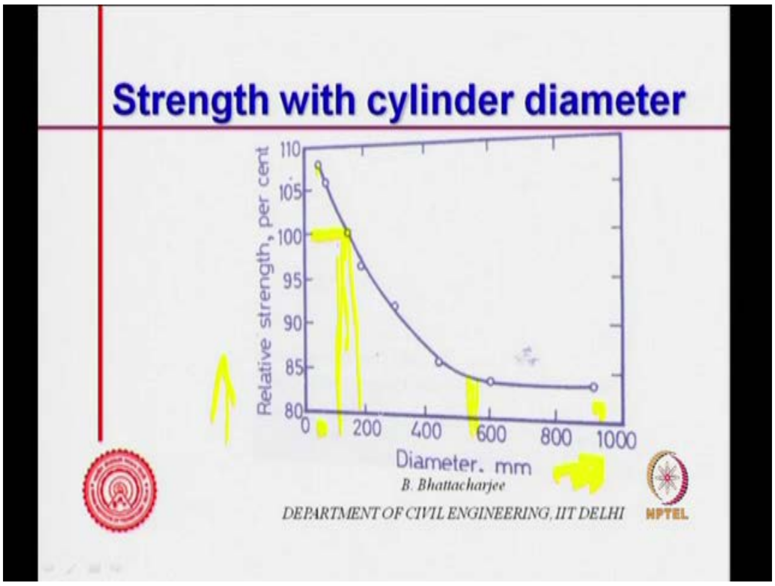

So, people have done some testing and they have observed for cylinder and cubes, as well let us see what are these for cylinder, it is been observed that if you have larger diameter, if you have diameter increasing along this direction in millimeter, diameter in millimeter the relative strength assuming that you are, you know 100 corresponds to somewhere 200 I mean 150, sorry 100 corresponds to 150 mm cylinder. So, relative strength if the size is smaller strength is higher size is larger, but beyond 400 and 500 mm diameter strength has been not changed because you know, the crack sizes are likely to increase this is observation for cylinder so you can.

So, that is why size is standardized again cubes of course, people have some results are available. Say size of side length if it is 70 mm then relative strength is 1.0, 100 to 150 mm people have seen that it is 1, 200 mm 0.95, 300, 0.90. So, you can see the size of the cube is important. So, if you are using 150 mm cube size, which standard we use that cannot be compared with any other size.

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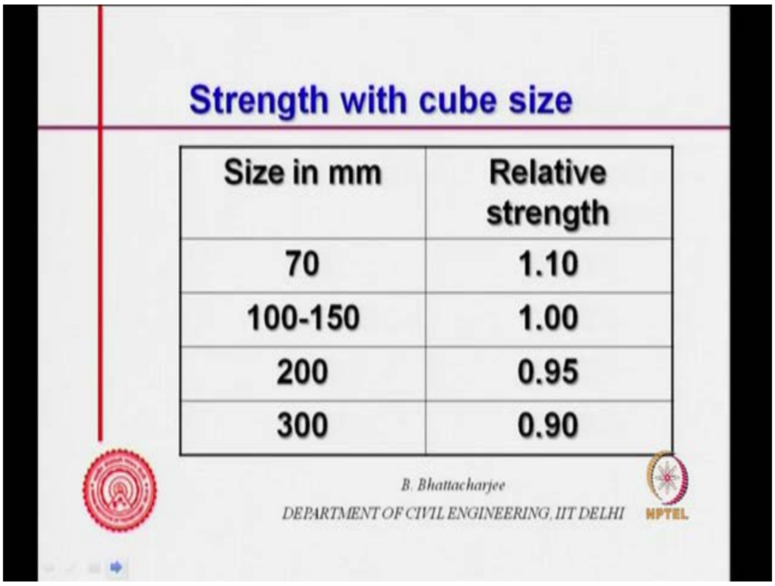

Now, some of the codes some of the European codes or euro codes actually which allow you to test different sizes. Many, many countries allow you to test actually different sizes of the cubes, but one thing, but it is only for comparison purpose and same size. Suppose, I am comparing 100 I am using 100 mm cube, then I must be comparing different concrete, with 100 mm cube only laboratory standard of course, standard for quality control and acceptance etcetera. In Indian scenario we use 150 mm cube, but in laboratory sometime people might do it 100 mm cube, but then 100 mm cube has to be translated to 150 mm cube results it is not same.

Similarly, cylinder somebody might use 100 by 200 mm dia 200 mm length equals 200 or somebody might use 150 mm and 300, which is standard in many countries. But then comparison will be 100 mm dia to 200 mm dia, 150 mm dia to 250 mm dia. So, that is size is important so this is the other test factor which is very, very important.

Then next important is thing is rate of loading, higher loading rate yields higher strength quickly you load it, loading is the faster phase the fracture do not transmit so easily, it takes time. While you would just put a sustain load, there will be affect of creep in extreme case. So, some deformation might occur with time, all right? So, see sustain if you monotonically increasing at very slow place, the strength observed will be less compared to if you are doing at a faster rate.

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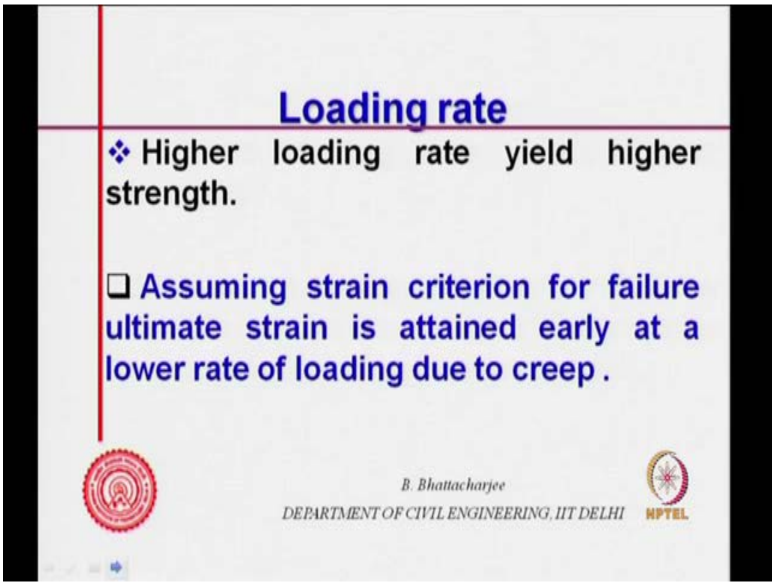

So, loading rate is also important and this many people seem to be seen so your test specimen cube, test specimen used in concrete construction when tested the testing machine must have a mechanism to control the rate, right? So, ultimate strength this attained early at a lower rate of loading, due to creep that is what we are saying suppose you assume that strain is where it fails, fracture occurs.

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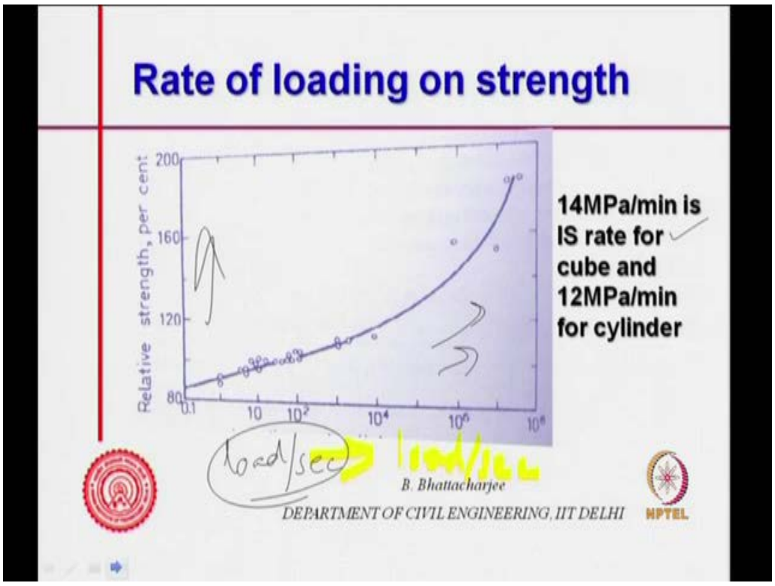

And rate of loading has a relation kind of effect on strength. For example, strain day per second if you put it then measured strength. So, higher strength strain rate strength increases lower strain rate strength decreases. Similarly, loading if you see relative measures, relative measures higher rate of loading load per second, let us say load applied per second or you put it this way load per second, relative values the relative strength increases. So, at higher rate of loading whether it is strain controlled situation or you are controlling the load the rate of load, load application because they are not same thing load control and strain control is different.

Load is easily controlled by hydraulic system, while a strain controlled would require you are finally, applying actually applying load, but then you want to control the strain. So, you have to measure the strain and there is a feedback loop through which you see the load is changed. So, it requires a kind of controller we will not go into that right now, but whatever it is rate of loading is important higher rate of loading tends to show higher strength. Higher rate of loading tends to show higher strength.

Therefore, what codes have done Indian code user 14 M P A per minute as the rate for cube and 12 M P A per minute for cylinder. So, basically this is by enlarged worldwide similar sort of things are used 14 M P A per minute rate of loading is used, and this is very important in quality control because must have this capability to control this, and that is quite often honest to check this, in case of you know acceptance of concrete etcetera.

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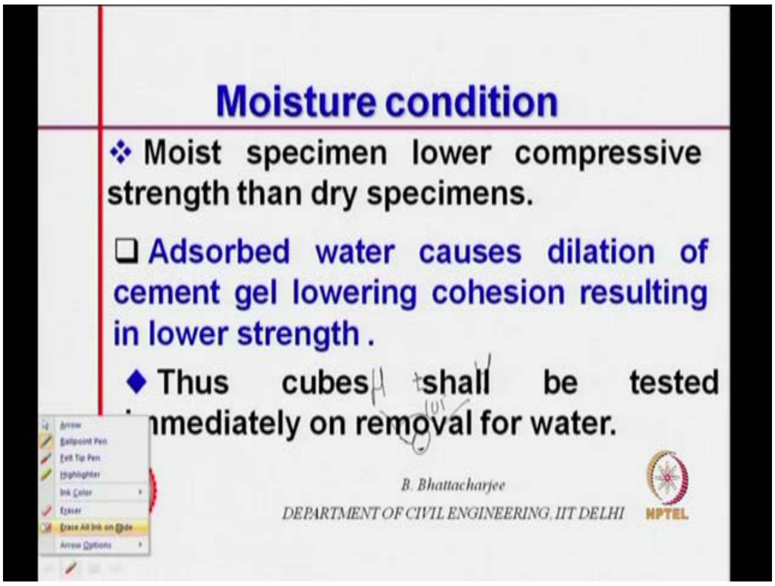

Moisture condition moist specimen lower compressive strength, than dry specimen I just mentioned it at the other day because you know, if there is an adsorbed water. What is adsorbed water? Adsorbed water vapor can be adsorbed that forms actually, a layer as you know water is a dipole you know H O H. So, central positive charge is here negative charge is here, this is 105 degree or some such angle you know whatever the angle is, this is not 180 for surely, so H here. Therefore, it can form a dipole and this water can get attach to the charge solid surfaces in fine, in case of very fine particle like clay or cement gel, cement hydrate gel that adsorbed water, we talked of this sometime earlier in the beginning.

So, this adsorbed water causes dilation of cement gel lowering cohesion resulting in lower strength. So, it is absorbed water if you moisture water adsorbed, water adsorbed water is by capillary section even capillary section, adsorbed water that water which goes in that also results in lowering of cohesion because it is gets adsorbed by surface tension forces. So, change in the surface and all occur and that is result in lower strength. So, that is cubes are to be tested at a standard moisture condition.

So, you have saturated surface wise situation and a code tells you within how much time, you should wipe off the surface and then tests put in a wip off the surface, put it on to the expose for certain period of time and within how much period of time should be testing. So, moisture condition is an important issue. So, that is what that is what we have seen, what we have seen for cube first of all we have seen, the capping and size I mean aspect ratio.

I will say l by d, l by d or h by d, then we have seen rate of loading, rate of loading moisture condition size of the specimen. So, all these factors affects the strength therefore, codes standardize those conditions and accept the material, the composition, the concrete that is produced. Therefore, I can compare relatively to control this and that is quite often honest to check this, in case of you know acceptance of concrete etcetera.

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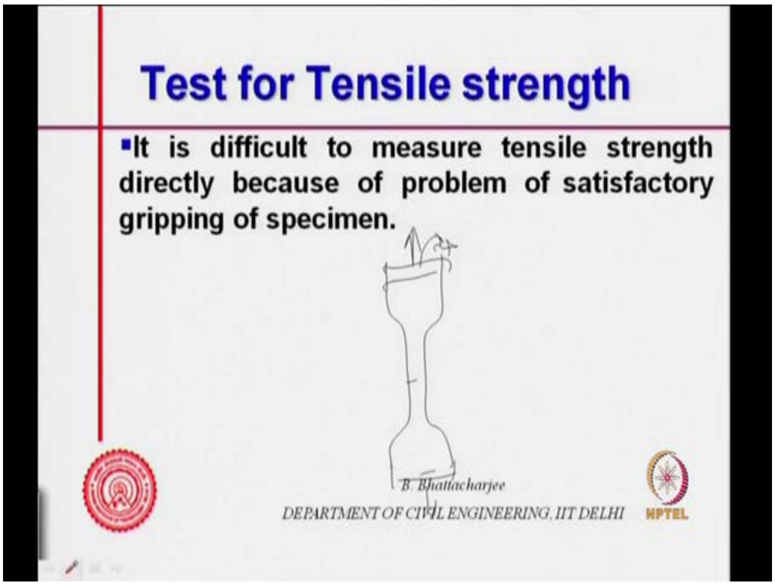

How do you measure tensile strength? It is actually difficult to measure tensile strength directly, I mean one can use what is called one can use, what is called a gripper test something of this kind specimen directly, but gripping this specimen is very complicated you have to grip it here, and pull you know if there is any horizontal load or any movement or anything kind of coming in that can create problem, and just cause it to failure may not be failure tensile failure. So, pulling it and all that so there are some amount of complications involved, therefore this test is not done, this test is not a preferred test, this test is not a preferred test for concrete tensile strength.

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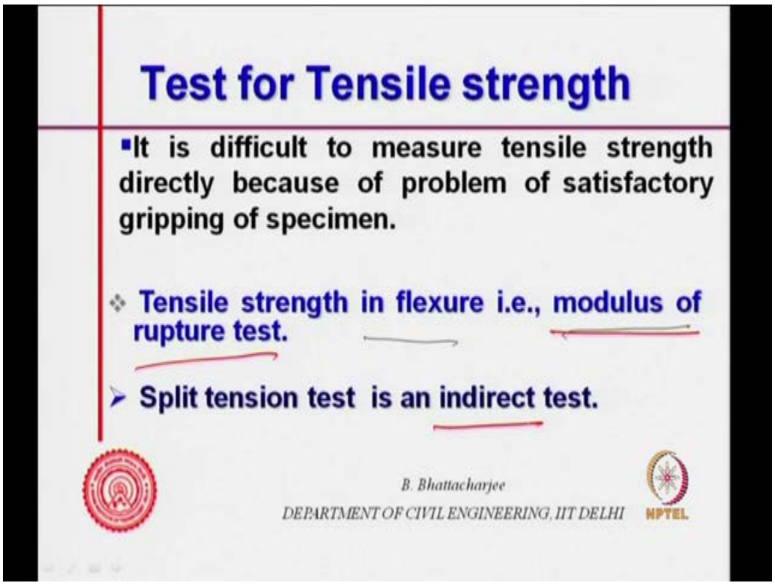

And direct tensile strength is rarely used also, what we use. Of course, sometimes we use, but let us see we have better method. Since, we have better method we use that better method or easier method I will say. In case of fracture of course, it is not direct tension, tension in some part compression, in some part all right direct tension is full specimen is under tension. In case of fracture full specimen is not under tension only a part tensile strength also varies we will see that.

So, this strength tensile, tensile strength in failure we test by what is called modulus of rupture, test modulus of rupture, test modulus of rupture test, right? We do modulus of rupture test then for direct split tension test is done, but this itself is an direct test you know indirectly you measure the direct tensile strength of concrete. So, this is called split test split tension test Brazilian test, Brazilian split tension test so and so for.

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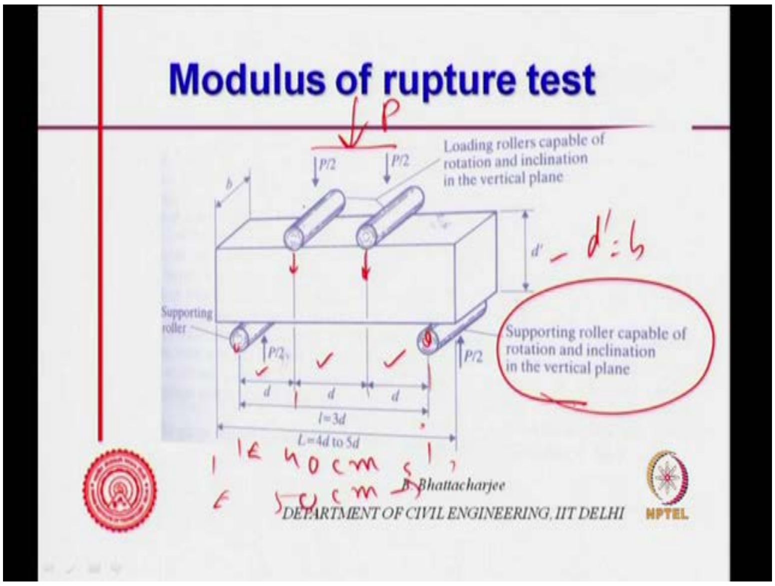

In case of modulus rupture what you do, we have the beam specimen right and then this supporter on 2 rollers. So, this is 3 D so this spacing is same and load is applied to 2 rollers p by 2, p by 2. So, you apply actually p here generally, this 50 centimeter, total 50 centimeter as per I S this is 40. So, 13.3, 13.3 you apply the load and this is d dash, then you know this is some dimension depth, this is d, this is b and this is d dash. Usually square 10 by 10, so d dash is equal to b you can apply sometime, but not necessarily you can you know by the principle does not require this.

So, loading rollers capable of rotation and inclination in the vertical plane. That means, you are only transmitting downward force because there roller point, point loads you are only transmitting point roll loads. So, in case this bands you know this is capable of rotation and getting inclined in the vertical plane. Therefore, this is will not apply any other kind of force except for this type force and these are the supports. So, supporting roller capable of rotation and inclination in the vertical plane, same thing, so it will only give you point load. So, actually you are trying to put a point load and that is how it is?

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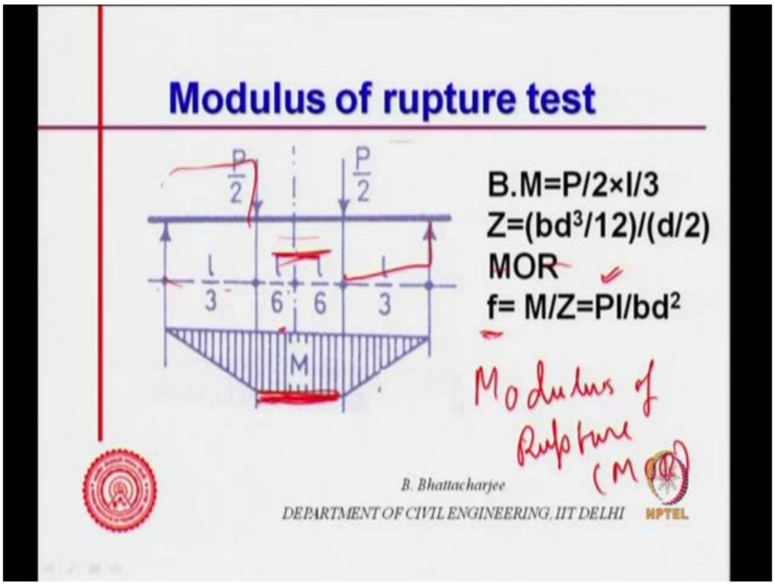

So, what will happen? I will have a bending movement diagram of this form p by 2 p by 2 here l by 3 of course, this from the centre l by 6, l by 6 and 3 by l. So, your bending movement here is l by 3 into b by 2. You know this will be bending movement will be simply p by 2 into l by 3, which is equals to p l by 6 and the maximum stress z value is given as, you know is movement of resistance will come out to be p l by b d square because this will be z the that section modulus is b d cube by 12 and d by 2.

So, this will be simply b d square by 6. Therefore, mortar by z will be p l by b d square. So, that is the failure you find out, what is the p value at the failure and the corresponding f value is called modulus of rupture M O R, modulus of rupture of rupture. It is actually a measure of the flexible strength M O R modulus of rupture is a flexible strength, right?

Now, why do we choose this bending movement is constant here simply 0 shear stress, you know shear diagram if I look at it, it would be something like this or you know there will be no shear stress, shear force here there will be no shear force here sometime to actually minimize, the shear stress and only bending movement. So, it is a pure fracture within this zone, then also if it is the single point loading, you will have only one point failure may not have occurred within that. So, here you are increasing the chance of failure due to pure fracture by putting two point loading. So, no shear boards pure fracture and so and so forth.

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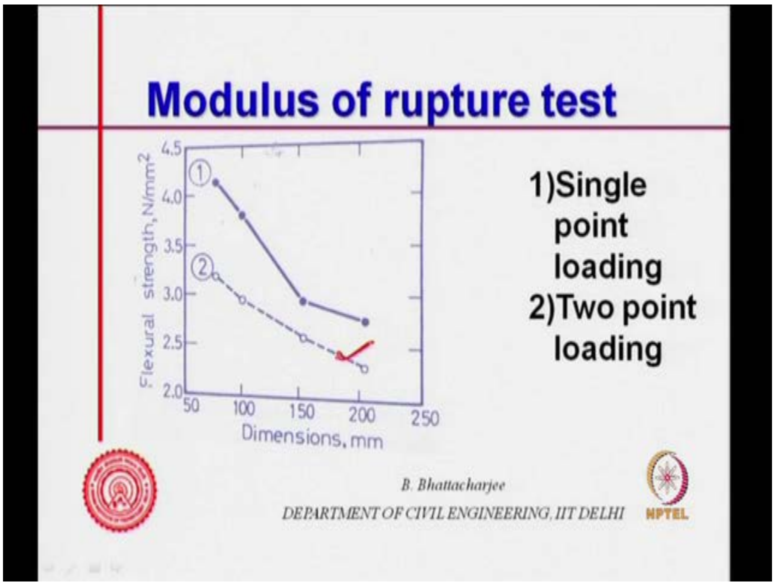

Now, people do of course, if you have different dimension case one is single point loading, case 2 is two point loading. The variation is there, but I said this is what is standardized, two point has been standardized obviously it will change with the dimension like we did for we said for cubes.

You see modulus of rupture value that I am calculating, I am assuming the stress diagram is like this, you know that p l by b d square that I obtain, I assume the stress diagram is linear, but real stress diagram will be something like this. So, you see M O R actually over estimates the result a little bit.

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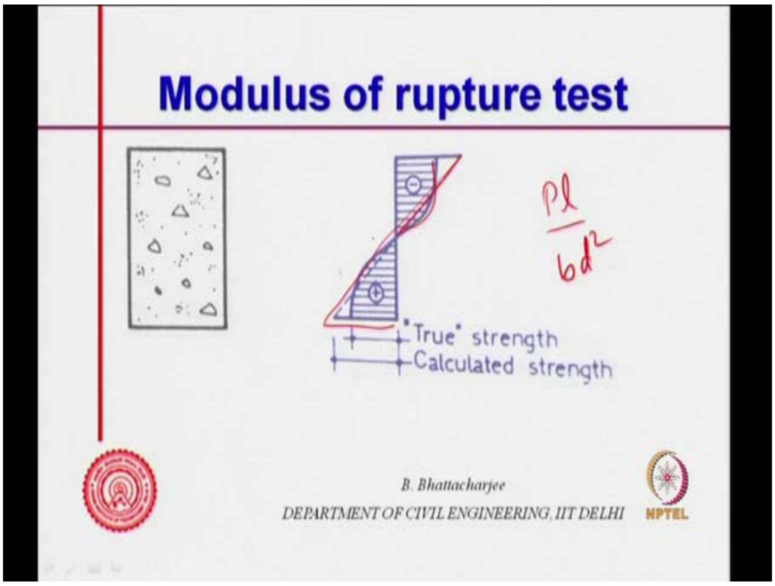

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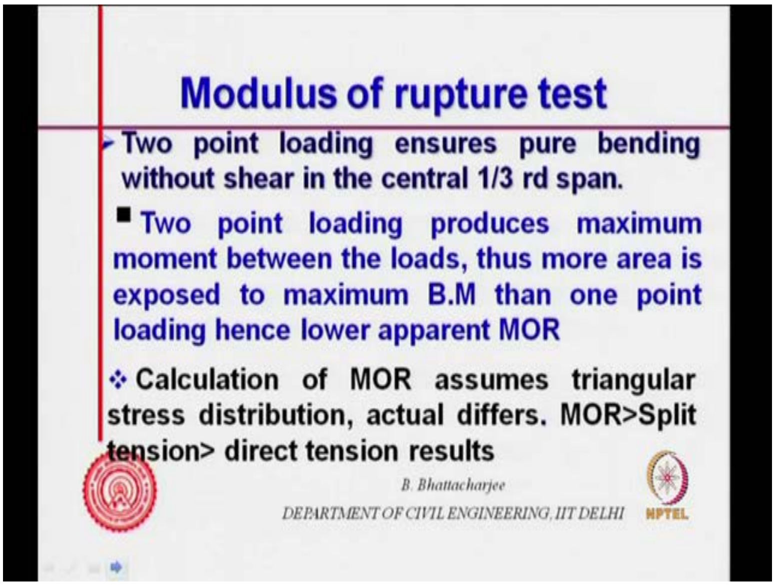

The two point loading ensures pure bending without shear in the central one. Third span that is what I said and two point loading produces maximum movement, between the loads thus more area is exposed to maximum bending movement, than one point loading. Hence, lower apparent M O R modulus of rupture calculation of M O R assumes triangular stress distribution, actual stress distribution is different. So, modulus of rupture is therefore, it over estimates even the flexible strength, but will see the other kind of test results that is split tension test that will do, that we will just discuss gives you lower strength than modulus of rupture. But if you are able to do direct tension that will give you still one, all right?

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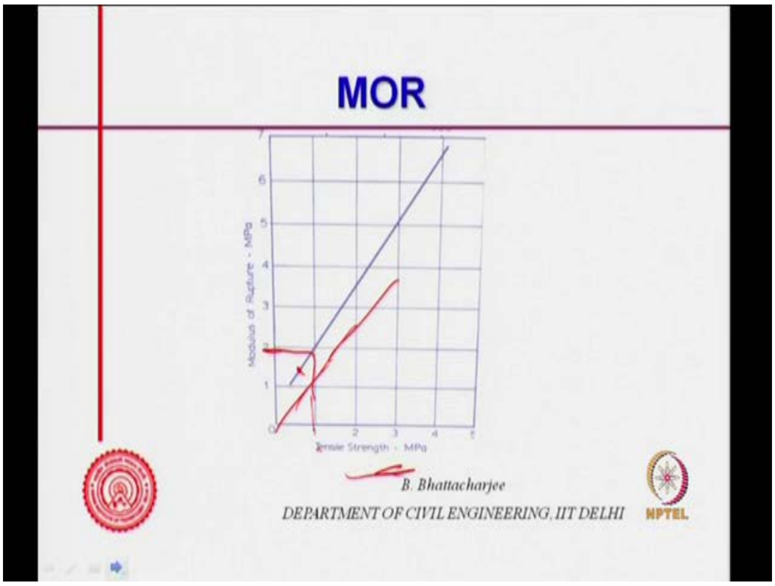

So, what is split tension test? Split tension test this is what it is tensile strength modulus of rupture you know this is of course, direct. So, this in linear of course, they are linear, but this is always lower you know this is not line here not this is somewhere here. So, when this is one this gives you somewhat higher value. So, this direct tensile strength or tensile strength is pretty lower.

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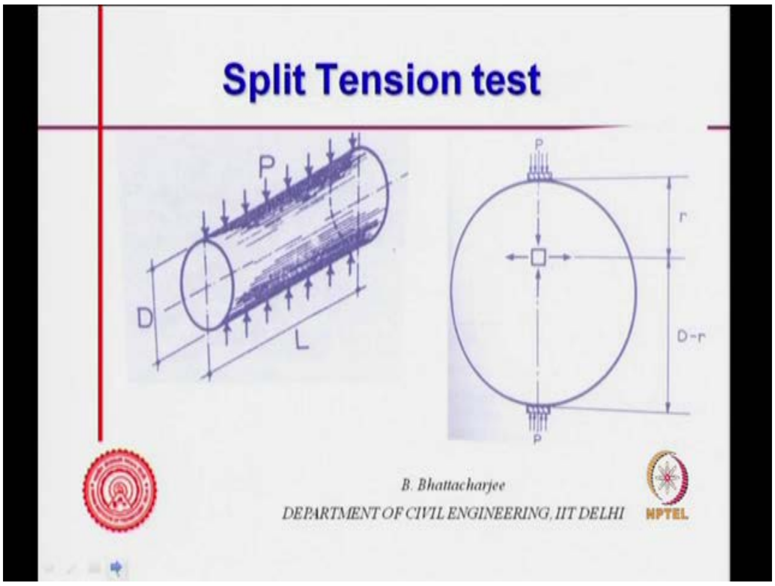

This is how we do split tension test, you apply load like this on a cylinder point along the line, along the line or I can say something like this sort of load here over smaller area p. And if you take the stress at any point, at stress can be drawn from various velocity stresses are these are available concepts are available.

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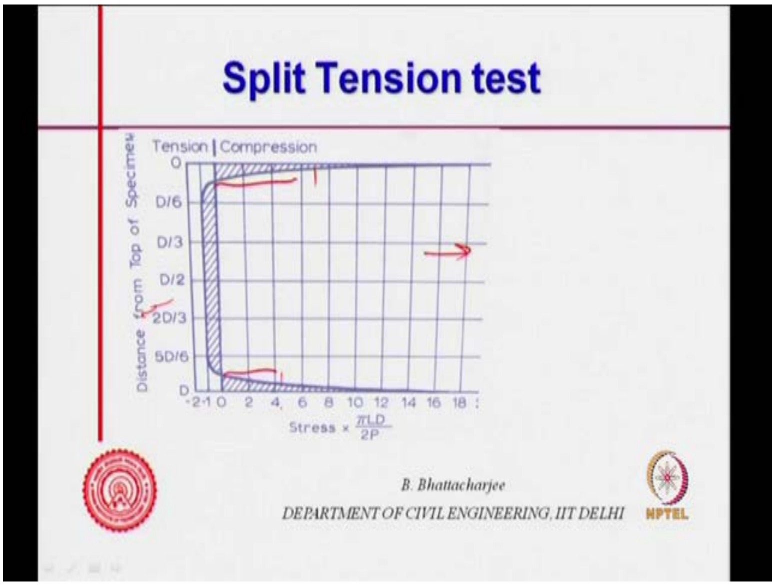

And this stress diagram one would look like this, where this is your compression, this is the tension. So, only top small position there is the compressive load, we are applying compression here.

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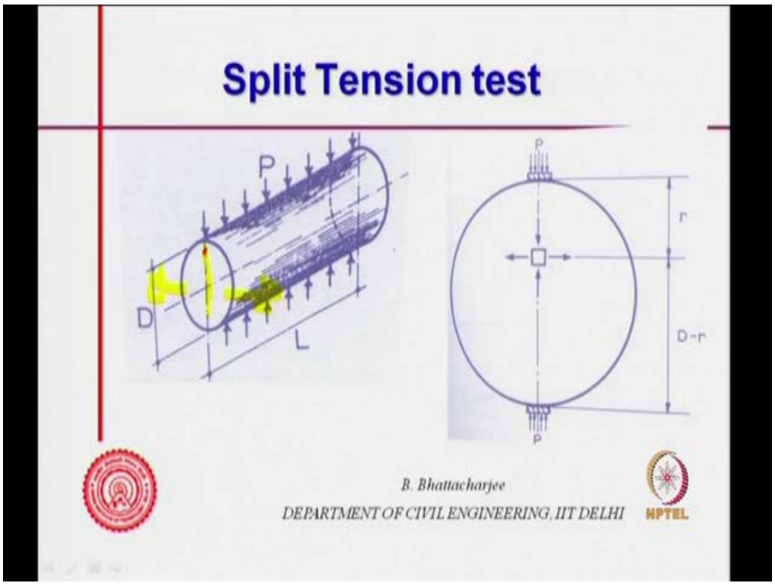

We are applying compression here so only small portion, there is compression rest of the portion it is actually tension. So, it is trying to split along this direction. So, this portion is only tension compression and you can see this is it is because of the shape of it, or the kind the load you have applied.

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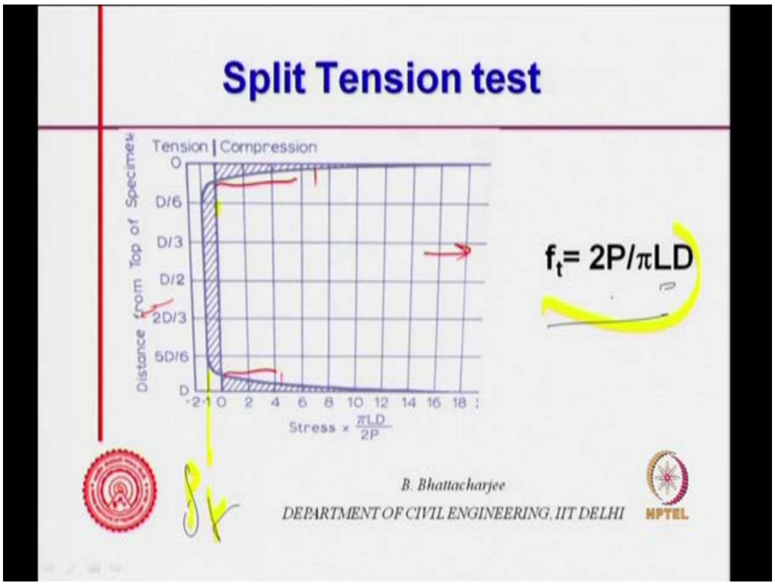

So, it is seemed that this is only the portion that compression is applied most of the portion, you apply actually tension trying to split. So, d by 6 d by you know may be d by 0, 2, 6 and 12 d by 12 or something d by 12 or somewhere close to that all other places, it is actually tension. So, the tension f t this is f t, f t is given as this is f t, f t is given as twice p by pie l d. Where p is the load that you have applied pie l is the length is this length l is this length l is this length l is this length. So, this l this is d so 2, 2 p by pie l d is a at failure p failure to take p maximum, this will be your tensile strength, this will be your tensile strength. So, split tension test gives you know you can do it on a cube also in that case, it will be like this you apply p here and the formula is f t is equal to twice p by pi d square.

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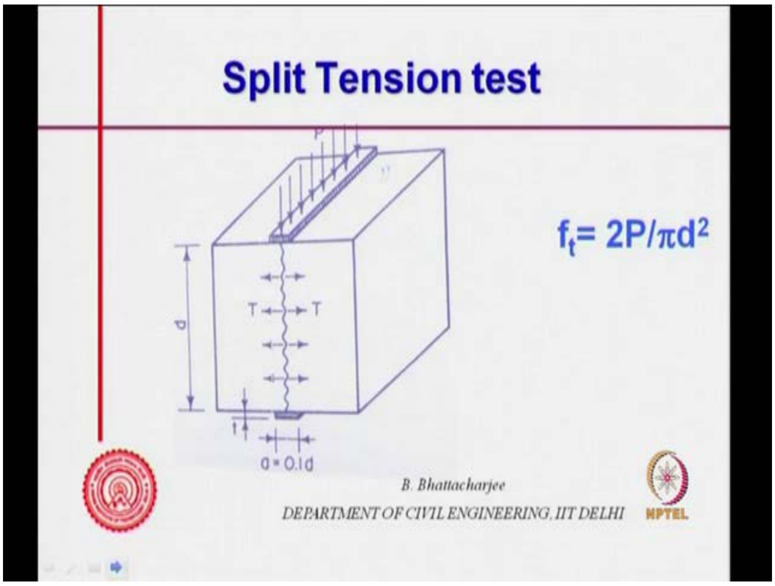

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This gives you lower strength than modulus of rupture, this gives you lower strength than modulus of rupture because in case of modulus of rupture, only the bottom fiber is subjected to maximum tension other are not besides that. You are actually over estimating, you do not take actual stress strain diagram split shows, lower strength and direct tensile strength will show still ward. Because in split, at least there is some compression portion, non uniform stress distribution in M O R that is modulus of rupture and split testing impedes, the propagation of crack that is delay failure. Therefore, this is the case we have discussed, this crushed aggregate exhibit better modulus of rupture than rounded aggregate and because of bond of moisture condition also, moist bond. So, bond is very important in this one be split.

So, crushed aggregate with rough surface actually some or the other here. This shows better modulus of you know undulation will be there, in case of crushed aggregate rounded aggregate this surfaces they might show split, might differ moisture condition also influences. Now, it influences sorry it influences in a different manner moisture condition influences in different manner, how does it influence? Higher moisture content shows I think, I have shown diagram earlier higher moisture content actually shows higher tensile strength, unlike compressive strength why because it minimizes the shrinkage, while dry specimen shrinkage comes into shrinkage.

So, this is because of shrinkage you know, shrinkage this is in this case it is because of shrinkage, shrinkage comes into picture. So, in case of dry specimen there is some shrinkage which will be always be available, and there the tensile strength becomes lower both M O R as well as the direct tensile strength. So, moisture condition aggregate type everything affects this.

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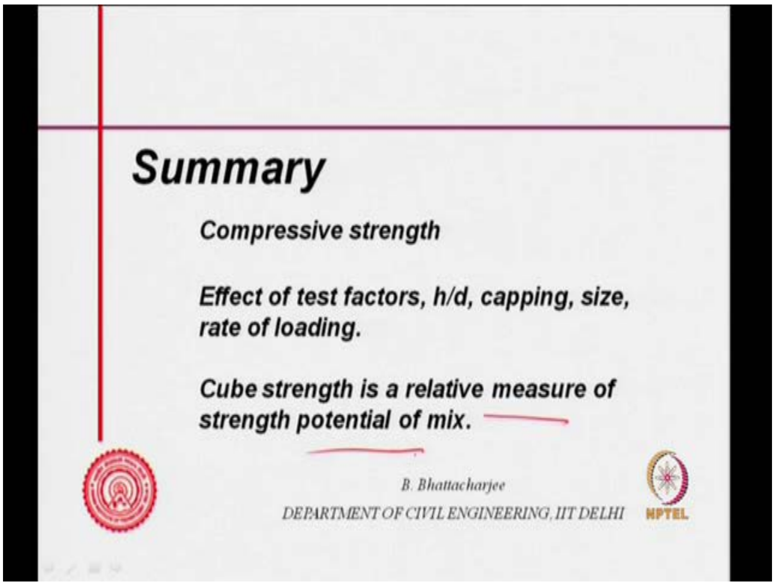

Therefore, what you have seen you have seen compressive strength the affect of test factor set by d h by d capping size rate of loading and we have seen. Finally, I would like to say that the relative measure of strength of potential mix that is, what it is and tensile strength? This also varies with the type of measurement modulus of rupture, gives you higher value code of course, uses different which we have, which will be talking about in the next class. Sometime you know how the, I think we have talked about this actually the code gives you 0.7 under root of C K, you know these are based for relative for use in design, so there are some conservative value, but test conditions how it affects that is what we have seen. So, I think we can with this we can close our discussion on this third lecture for the modulus module, you know module 6. Thank you, very much and we will be looking at modulus of velocity and other mechanical properties of concrete, in the fourth lecture of the 6 module.

Thanks.