Fire Protection, Services and Maintenance Management of Building

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Lecture – 49
Non Destructive Testing

Continuing with little bit from what we did last time, number of test. Now, we if I just recollect a few things this is important number one location as I said because properties of concrete varies systematically with height.

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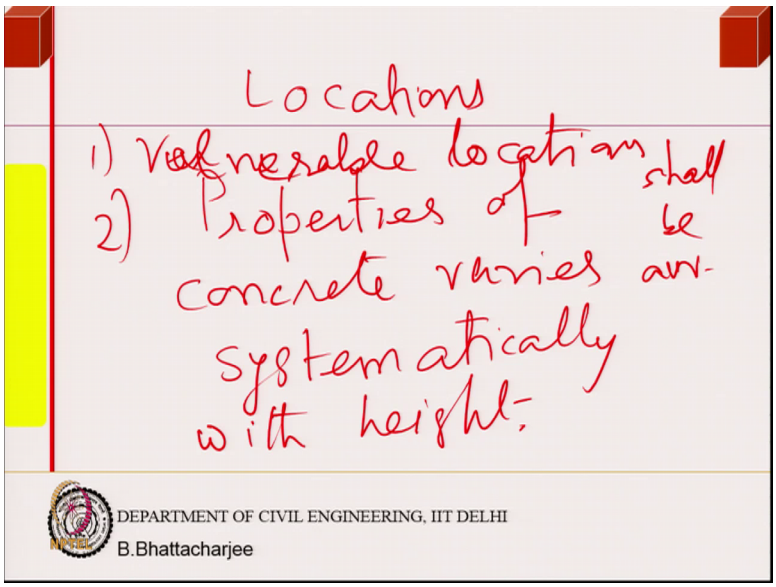

So, this aspect we must keep in mind while selecting locations right. And also do not select locations particularly for damage, where damage can occur for a test vulnerable location should be avoided. So, this is number 2 1 vulnerable you know vulnerable locations shall be avoided. So, these are 2 aspect; this is 2 aspect right.

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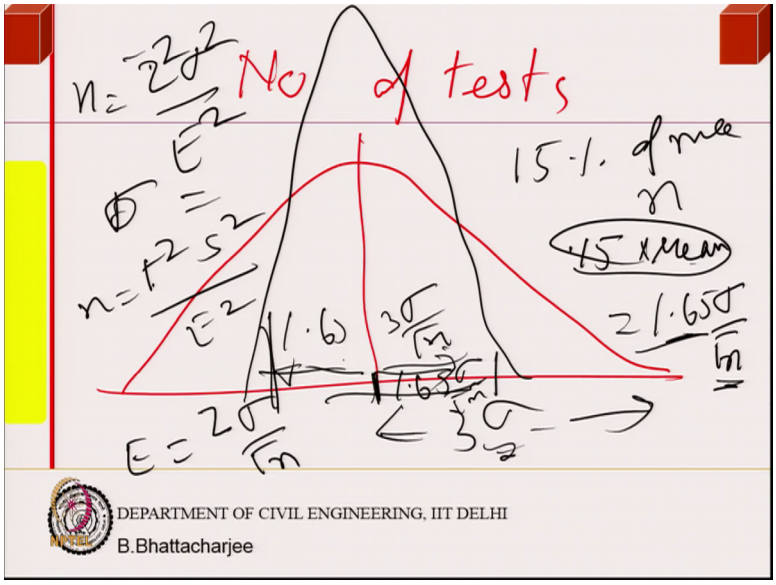

While number of tests what we said is.

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Normal, we assume that most of over results will vary whatever test you do because they will depend upon too many factors.

So, population of the result whether it is let us say strength result or hardness result or anything of that kind they very normal distribution normally you know well shaped curve right. So, you have a mean and all that. Now, when you do you test a couple of a number of them you make you know you test number of them right, N number of tests let us say you carry on and find out there means such means there distribution is also normal, but spread is less.

If this at the standard deviation sigma you know 3 sigma is this let us say standard deviation is sigma, this will be 3 sigma under root N that is what we will see. So, if you do more number of test this spread will be less; that means, you all you will be closer to the true mean.

So, 95 percent of the time let us say I want my error. So, this we know that this variation is 1.95 percent of the time it will be this area would be 1.65 sigma right by under root n. So, if I want that my errors should be within plus minus, you know some value let us say 15 percent of the mean, 15 percent of mean then this distance should be 0.15 multiplied by the mean, mean or mu or whatever you call it that must be equals to 1.65 sigma under

root N right 15 percent to the error we are talking about some sigma divided by mean I mean divided by sigma is nothing but coefficient of variation coefficient of variation. So, N you can find out if you know the error let us say, if this is error if this is your error which could be expressed as percentage of mean or otherwise then E should be equals to this value for 95 percentile I will I am calling it z I mean 1.65.

Otherwise in general supposing say 99 percent then it would be you know near about 399.9 percent, then it will be 3. So, 98 percent 2 or whatever it is. So, supposing you know this value I generalize it as z, divided by sigma under root N therefore, N can be calculated from this as N is equals to you know N is equals to z square sigma square divided by E square E square. So, N can be calculated from this one. So, number depending upon what is the E, we want number we can calculate for any test.

Now, supposing sigma was not known to me, I measured a few and estimated the standard deviation in terms of what we call s, s is the deviation for small samples small number of samples. If I find out the try to measure the standard deviation, then I call it which is a measure of standard deviation s. In that case if this my sigma will be relatively you know reliability of sigma reliability of s to represent sigma depend upon number of samples I have used to find out s. Whatever it is then this follows what is known as students t distribution. In that case z gets replaced by t, t will correspond to the number of cells you know number of samples you use in finding out s.

So, it would be t square divided by sigma square by I mean s square. So, N will be t square s square s is the estimated standard deviation divided by E square. Goes without showing saying that t is higher than larger than z for corresponding depending upon the number of samples, you use for you know t is larger greater than z compared to corresponding for a given value of N and it will depend upon number of samples you have attempted or used in finding out s. So, this concept I just wanted to repeat a little. Then we go back to now we can go back to our discussion on test and investigation. We will go we will discuss on test and investigation right. So, we will discuss on test and investigation.

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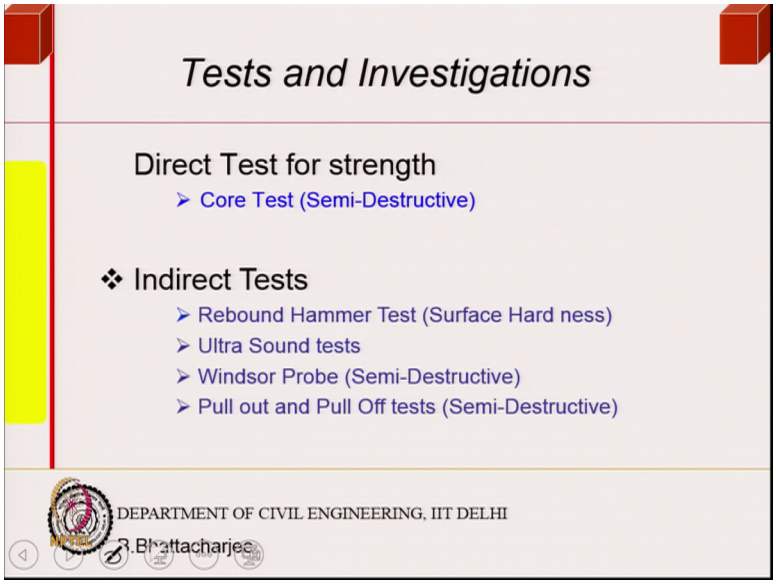

So, far we discussed mostly about planning and visual survey. Now first test could be simply that you have seen a crack put a glass strip as I mentioned earlier in case of those segments. And see whether the strip is breaking down or not. If it is cracking then it is the tell-tale is tell-tale glass is cracking; that means, the crack is expanding and it is a live crack.

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So, this example wise this was done you know this was done in this was done in that segment that I was talking about. So, this is a blue coloured crack you can see not the double red blue colour crack. And there is a glass piece you can see that being put in strip

fix over the crack this is by epoxy. And I have shown you last time the scale through which I can measure the crack dimensions.

Now, this is fixed and then this is handled fully.

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This glass strips were you know it is it is actually handled fully throughout right. So, it was then lifted up shifted placed.

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So, flash first fixing then lifting it up doing a complete handling of it because this will be lifted put into the yard stacking yard these are precast segments stacking yard then it will be put to the truck. So, in that process not only that you left it just like that is the crack expanding or any expansion occurring during the handling process that was seen. If it is in situ structure where it placed the you know if the crack is expanding under the current load existing load, then it will simply cause it to crack. So, that is what one wants to identify.

And by identifying then you know you can find out whether this has cracked or not in this particular case it did not crack. So, though why since it didn't crack one was you know one could expect that the crack are it is not further expanding there are all what we call dormant crack or you know dealt crack dealt crack. So, the blue colour marks are the crack marks etcetera.

The other than there are various kinds of tests involved. If I am doing strength test direct test for strength that is your core test, you drill a core out of concrete and that is semi destructive that is semi destructive. It is not non-destructive it is semi destructive then there are several indirect tests. Some indirect indices some indirect measurement results of some indirect measurement indices you can actually relate to strength or get some indication of the strength or quality of concrete.

So, one of them is a surface hardness test. We call it rebound hammer test we will discuss about that. Then there is another one is passing ultrasound ultrasound you know. So, velocity finding out velocity ultrasound test then there are this was done a quite earlier you was what we call an Windsor probe test, which is also semi destructive. Then pull out and pull off test these are also semi destructive. So, these are some of those test which you can use for determining strength.

We will discuss about other test methods. First we are looking at strength and quality of concrete.

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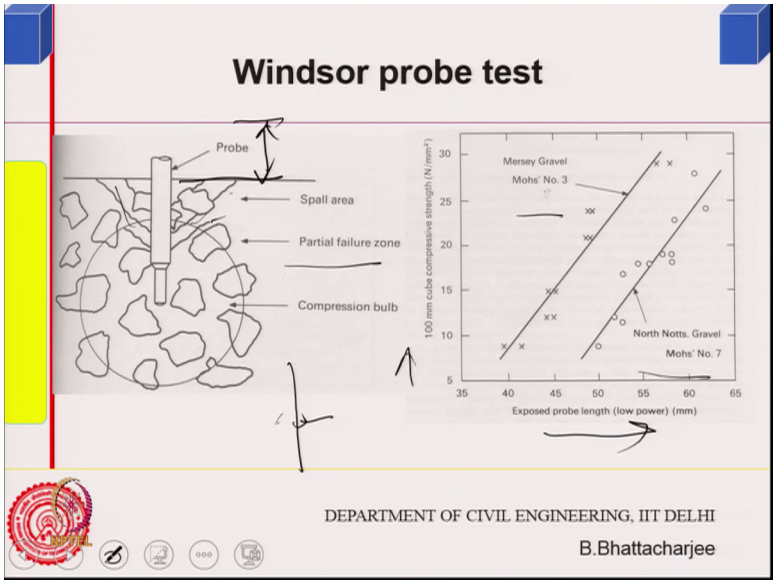

Now, let us look at relatively less popular test that is called Windsor probe test. In this you have the gun and you place that gun on the concrete surface and shoot. So, a bullet right a probe will go inside you will penetrate into the concrete. So, as it is penetrate in the concrete, you know this is the probe which penetrates into the concrete, it causes this sort of damages or crack right. And this the compression bulb because it will compress as you if you know a gun shot from here let us on to the concrete it will cause local compression.

So, the compression bulb is here and if it is a very strong concrete if it is compressive strength is high what will happen it will not penetrate much. And if it is weak concrete it will penetrate more. So, the you know this is of course, a spoiling of concrete can occur then partial failure zone and so on. Now this length total length minus the penetrated length or unpenetrated length is a measure of the strength of concrete or can be correlated to the strength of the concrete, more this length higher the compressive strength.

So, here it is this is the exposed probe length verses cube compressive strength. People have tried to correlate base show some sort of correlation with you know some kind of aggregates with other kind of aggregates, you might find out you know say some gravel and some other gravel. So, depending upon type of aggregate you will find the penetration is different.

Well this is not very popular test, but people have used this earlier.

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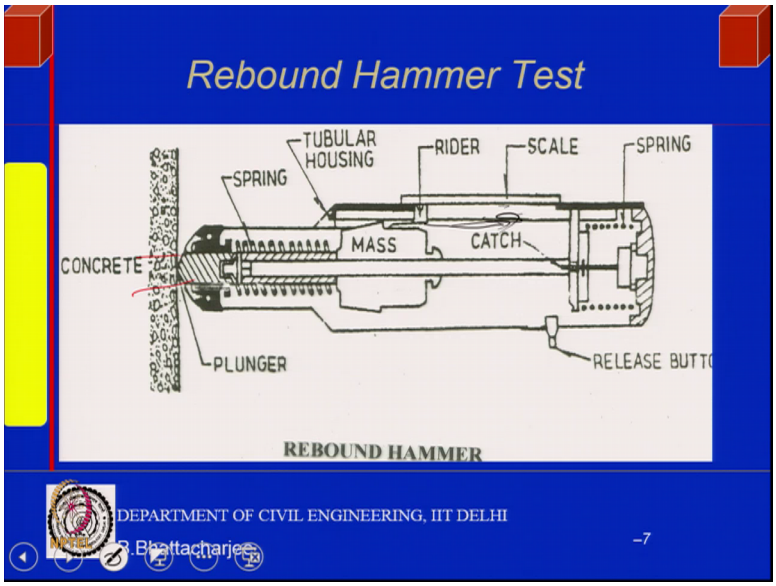

Now, this is quite popular test. Rebound hammer test. Because it is cheap instrument cost is also relatively less and time required is also relatively small for doing the test. So, it is a cheap test. The normal type of hammer which is quite often used looks something like this. This is your concrete surface. There is a plunger there is a spring and there is a mass, there is a mass right. Now this is this you know this is this is in the in the housing of course, is there now this mass is connected with a rider this mass connected with a rider. So, what happens is if the mass goes backward the rider will go backward and there is a scale here there is a scale here right.

These days it can be digital straight away in between it was thermal chart paper where it will get recorded. And before to that it was simply some reading which will you have to read because rider will get stuck wherever it goes. So, what is done is you have another spring here. So, you press this, you press this across there is an you know you can press this normally on that on to the surface. As you press the spring has compressed the more mass goes down there and a point comes this automatically it recoils you know it just hits and recoils back. So, amount of recoil or the amount this rider or this is this has come here, that is measured that is amount of recoil.

Because the moment to press it a point comes when the mass gets released it is usually locked initially locked when you press it press those plunger against the concrete surface, you know the spring gets released the mass gets released and it hits with a particular

impact energy of the order of around 2.7 kilo Newton metre or something of that order you know 2.7 such kilo Newton metre and then this impact causes this to recoil back and you know as it recoils back this rider moves along with it and you can read into the scale. So, this is how it is right. So, this is the release button first initially it is locked then you release and then press it then. So, it is it is a kind of an impact given to the concrete surface and you know like a hammer and it comes back.

So, this recoil is amount of recoil is an measure of the surface hardness of the concrete. Now this dimensions of this one is about 1.2 milli you know centimetre 12 millimetre or so.

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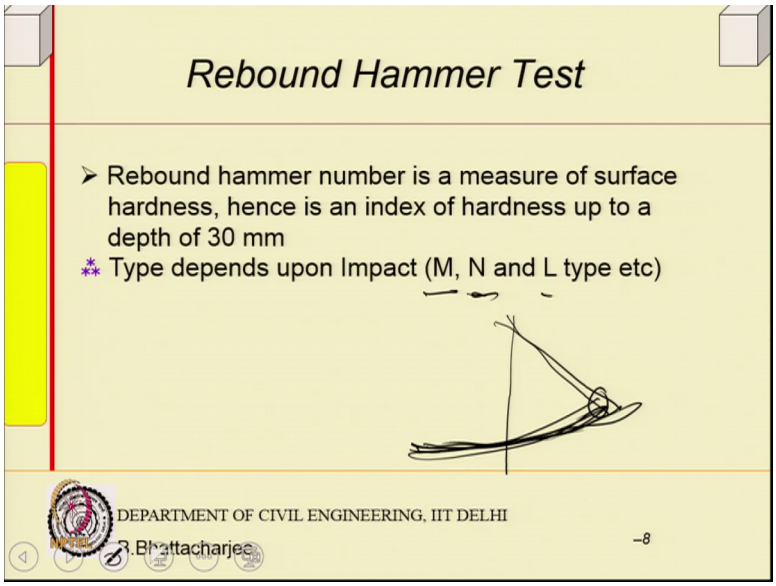

So, pretty small. So, pretty small actually. So, this rebound number is a measure of measure of surface hardness. Because you are putting an impact and it is coming back. So, measure of surface hardness. And the impact goes up to the normal these are called normal type of hammer. It goes only up to 30 millimetre from the surface of the concrete, goes up to 30 millimetre from the surface of the concrete right. So, nothing inside you do not get any information from inside. It is only the surface of the concrete. Now there are 3 types m N and L type. The one I showed was N type one, I showed was N type that is normal used for structural concrete light beam column etcetera.

M is used for mass concrete whose impact energy would be roughly around 10 times of this one used in large you know like dams and similar sort of places. And L is for light

missionary. And so on it is a pendulum type what you have is you have actually a mass something like this which will come and hit and then come on a arc it is guided arc right. So, it is a pendulum type. So, there is a pendulum mass which will come and hit the concrete you know machinery surface and then it recoils back along the pendulum arc you know there on the arc and we measure. So, that is called L type not very commonly used, but one can use them one can use them ok.

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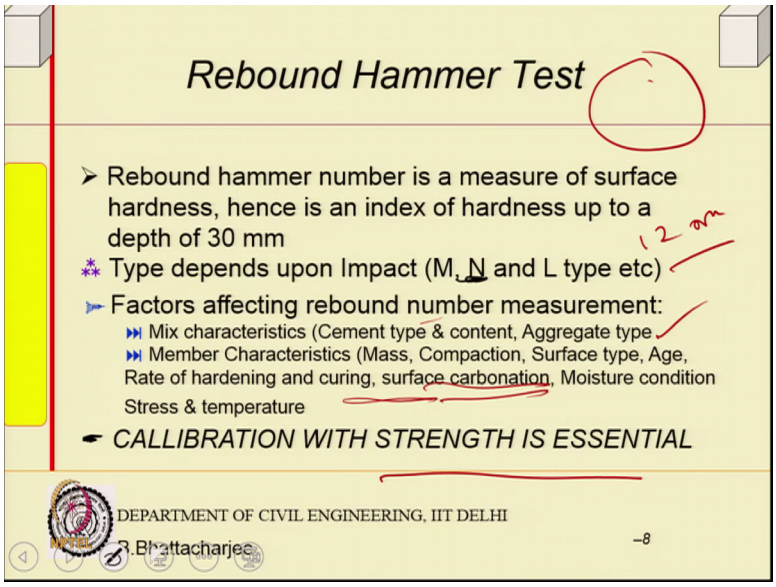

And then these are the 3 types. Now, factors those affects this rebound number values are; obviously, cement type aggregate type that is very important. Supposing I put very hard aggregate I get more rebound number and you see I told you that even normal type you have got 12 millimetre you know 12 millimetre is a something like 12 millimeter you know 1.2 centimetre 12 millimetre is a plunger dimension. Now 12 mm plunger dimension means it can directly it almost 10 aggregate. Because if you have 20 mm aggregate or something of that so; obviously, your hardness read hardness would be higher.

And if it is fixed or motor, it would be relatively lower.

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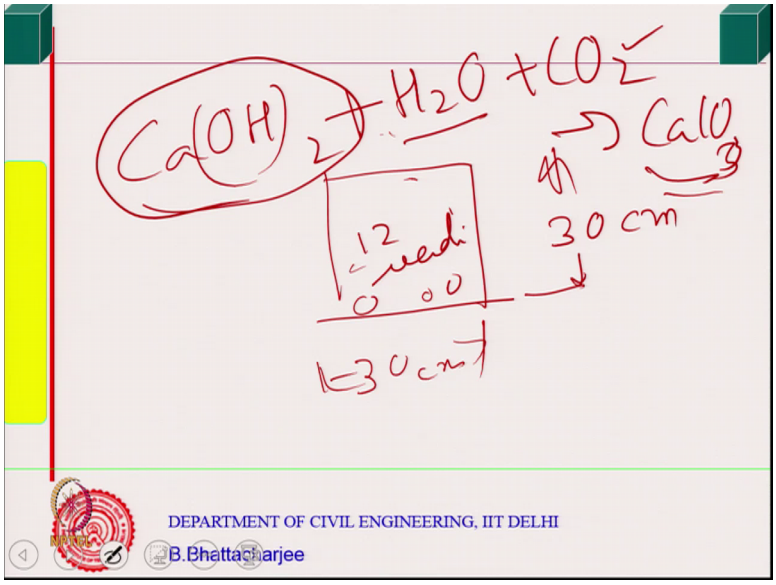

So, therefore, you going to take in a square metre area, in a square foot area I mean square you know 30 centimetre by 30 centimetre, 30 centimetre by 30 centimetre you take around 12 readings at different places. And you average it up. Because the variation somewhere you will get aggregate somewhere you will get surface must be cleaned polished first. So, a surface preparation is also required. Surface must be cleaned and polished and then you take 12 building in one square foot area average it off that gives the average rebound number index about average rebound number index.

So, this will depend upon aggregate type cement type and also content; obviously, then some time it will depend upon the compaction. Highly compacted one will give you better and if it is massive you know relative mass also has for example, light one might absorb lot more impact vibrate and therefore, rebound maybe relatively less. So, this issues are there. One important is a; obviously, with age; obviously, hardening will be more curing most important it was called surface carbonation.

Carbonation now this of course, we did not cover, but you see the calcium hydroxide in presence of water and carbon dioxide will form calcium carbonate. Right now this is present from the cement hydration. And if there is a conducive moisture condition atmospheric carbon dioxide may form calcium carbonate

So, surface concrete maybe what we call carbonated; that means, you will have calcium carbonate in same instead of calcium hydroxide. Or you know some alkalis whatever they are there. Now calcium carbonate is a hard mass, calcium carbonate is a hard mass.

So, your rebound number will increase because it is hard mass where internal strength may still remain the same.

So, rebound number tends to increase if the concrete is carbonated. So, surface carbonation is the other thing and moisture condition is other one if it is moist it will show less hardness value less rebound value. So, also a sometimes stress. Now stress is you seen that stress you know up to about 7 MPA.

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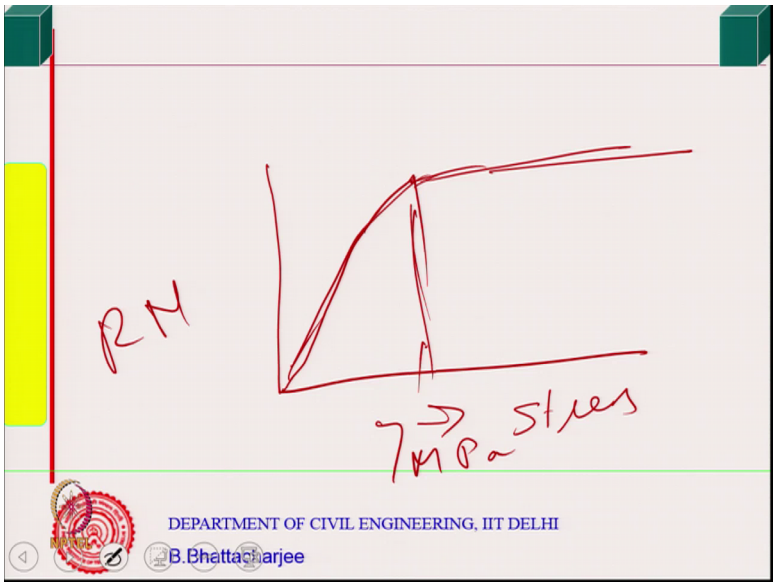

You know if you try to find out on cubes, cubes you know loaded cubes put it under compression plate of machine platen.

When you find that this is that stress level up to about 7 MPA or so, it the rebound number put increase. And beyond that it may practically becomes constant. So, at lower stress level, you might find the rebound number is less. Because you know it is if the highly stress section as you can understand that if it is criss stressed more compact sort of scenario. So, rebound number so, but it occurs only at the less stress level 7 MPA is very small.

So, it is something of this kind. So, the stress level is also important and stress temperature has minor affect. So, all these factors affect the rebound number index or rebound hammer value rebound umber index. So, therefore, it will vary from site to site place to place concrete to concrete. And therefore, it is necessary if you want to get

strength indication then you must have a calibration to the specific condition in specific concrete.

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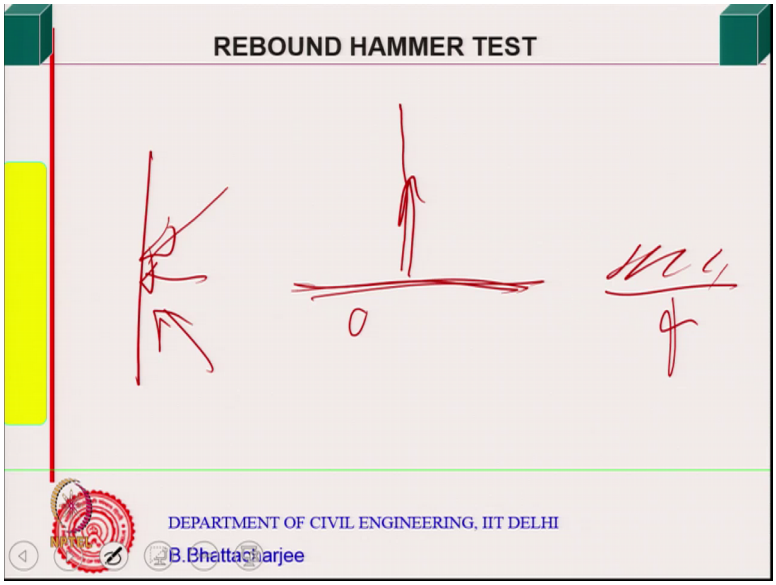

Usually manufacturer supply a calibration chart. Depending upon you know depending upon whether you have taken the rebound value on a flat surface; that means, you know if this is your surface concrete surface let us say. So, recoil will be less because it is acting against gravity. So, if you are taking rebound number on a floor rebound, it will be less. If you are taking on vertical surface, then it would be higher rebound number. And if it has horizontal surface it will be different and if it is inclined like this or inclined like this again it will be different.

So, manufacturers do provide calibration chart at different angles right, but such calibration charts cannot be used for predicting strength because they are concrete specific, where they have done the calibration you want to do for yourself you better calibrate yourself.

So, a calibration with you know for strength you want to estimate, but you want to get an idea or relative comparison of concrete you know in terms of it is quality or surface hardness you can do that you can you can you can use this. So, strength needs calibration strength needs calibration. And some of the codes have actually given you way to calibrate also. For example, European code current N you know current European code I might mention the name sometime it gives you the way how to how we can calibrate, but

that procedure they provide some basic curve you know there is curve there is a curve they suggested, that is the basic curve and then you do a correction on those curve. Unfortunately, the basic curve itself may not be applicable in Indian scenario. So, you have to generate your own it for any site.

So, you know if you want to do calibration. So, what you do you cannot use this to predict strength on it is own. You got to have some sort of compressive strength measurement either through core or through if the cubes are available using cube right. So, that is the thing, but you can get quality of concrete.

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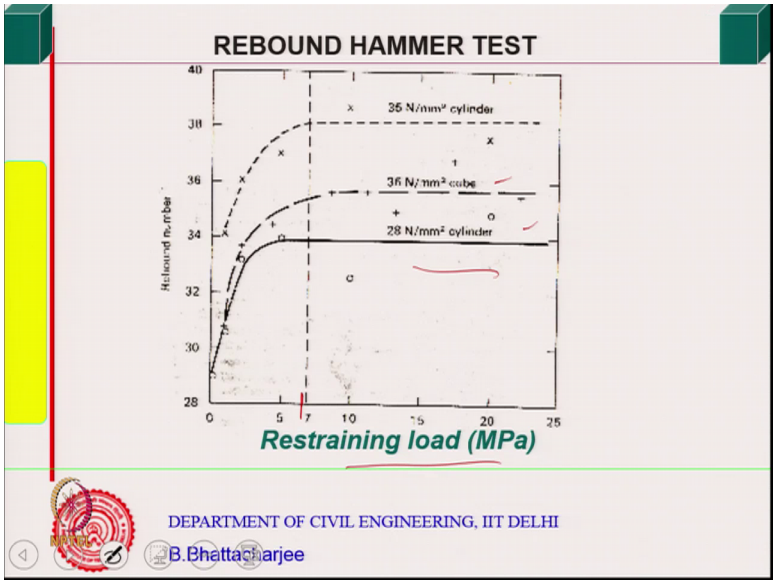

So, this is what I was talking about the you know I was talking about the stress level you know restraining load in MPA. So, supposing I have put in stress then rebound number varies up to beyond 7 MPA you see for cylinder cube or etcetera; practically no variation. So, if you are calibrating then you must put the cube not free on the ground or on some surface. You must put it under the compression testing machine put an lord of this order 7 MPA or so, stress and then take the rebound number value that will be independent of the stress right.

So, that is how it is. Right what is done is you see you want to do the calibration either you take in situ rebound number N you know.

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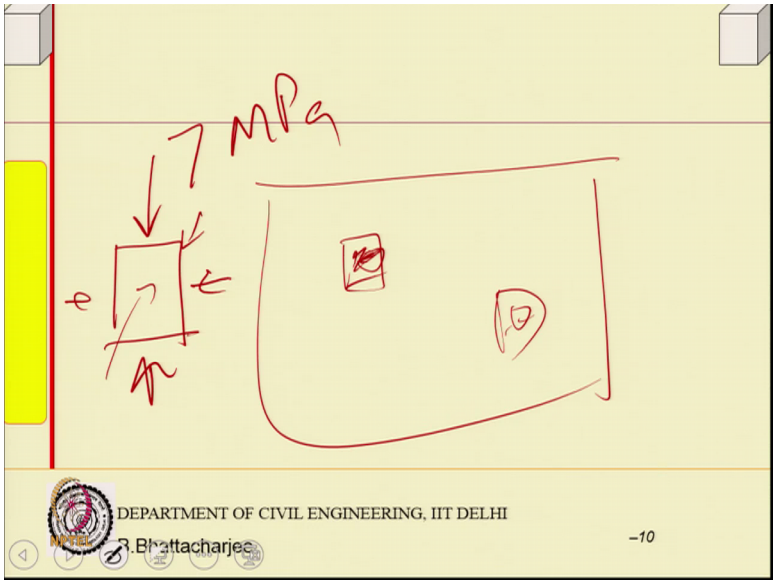

For example, I want to do some calibration. So, what I do is I first measured rebound number value here. And some other places some number of places we will come to that sometime later on and then take a core from this area itself. Take a core another core from this area itself. Then I can correlate the core strength is the rebound number value, but supposing I have cubes available which can occur if it is a situation where the concrete is not very old, the cubes are still there some cubes are left right or material is left I can make cube out of them wait for the age to come 20 days whatever the days is age right when I want to make the test. So, do curing as it has been done inside and I want to establish a correlation.

So, what we will do is, in that case I will put the cube under 7 MPA load and take rebound hammer value from this side, this side, this side and this side. So, then I get the horizontal rebound number values right. Horizontal rebound number values now vertically if you want to get it vertical correlation for the vertical then you might use the relationship between horizontal rebound number and vertical rebound number from the manufactures guideline right. Because relationship between horizontal the corrections required for directional change of the rebound hammer that one can obtain.

So, this is one test which is very commonly used which is very, very commonly used actually right. And very commonly used test for in situ first in situ quality of concrete or understanding surface hardness of concrete because it is relatively cheap. Machine is not very costly hardly any mechanical equipment with a digital you know attachment which is there today. And it can also go to it can record continuously today. So, it can actually

store the data also and maybe do all kind of plotting and things like that contours and such things are possible today.

the other test is very popular test is ultra sound velocity test. You know velocity of sound is proportional to or rather velocity of sound is given by this equation.

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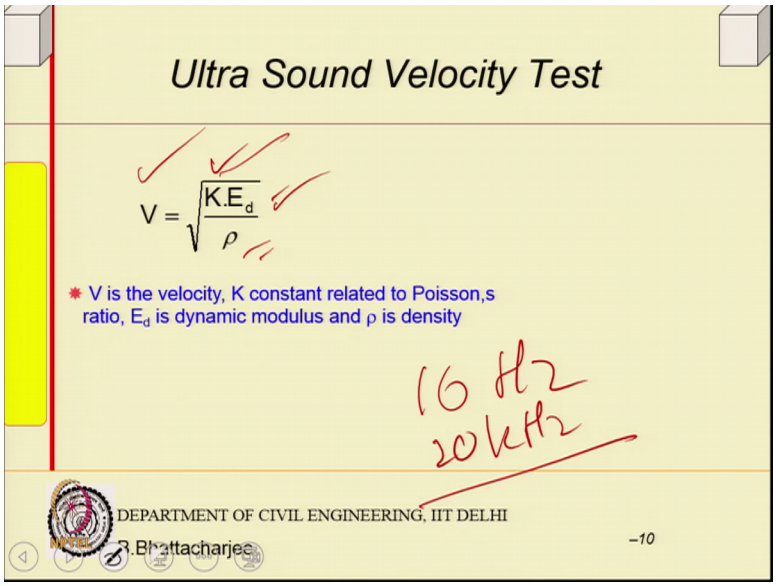

You can you an derive this. You can derive this because mechanical wave velocity of mechanical wave not sound I mean ultrasound or whatever it is velocity of mechanical wave, after all we know that longitudinal wave is nothing but compression and tension of the you know it is compression rarefaction of the material or medium. So, if it is passing through the concrete it must be compressing the concrete and must be it must be expanding and compressing and expanding and compressing.

Therefore, the elastic modulus of the medium is involved. You know elastic modulus because it governs the velocity right, this rate at which will vary also the density, so, also the density right. So, one can actually derive this velocity relationship from wave theories. So, it is given as K lambs equation or whatever it is. K is related to Poisson's ratio etcetera and E d is the dynamic modulus rho is the density. So, velocity of sound in mechanical or mechanical I mean velocity of mechanical waves in medium is a function of elastic modulus and density. So, therefore, there is some correlation between the velocity and you know quality of concrete it is compactness solidness soundness etcetera.

We you can also understand supposing if it is porous, then there is air. And velocity of sound in air is much less than that in solid. So, you know in steel it is much higher 5.6 or of that order kilometre per second. While in air it will be 340 meter per second 344 over to whatever it is order is of that order. So, you see velocity of sound in air is much less than solid in concrete it is of the order of around 4.5 kilometre good concrete solid concrete would be would be of the order of around 4.5 kilometre per second or. So, if you have lot of words in the concrete your ultrasonic I mean pulse velocity of mechanical wave will be lower.

Now, why ultrasound there 2 3 reason one of course, the noise part of it, but that is not very important. Other thing is there should not be other wave phenomenon disturbing your measurements right. Audible range is 16 hertz to say 20 kilohertz. You know or 22 something or 16 of this order. So, anything up to 20 kilohertz or 20,000 cycles that is audible range. And any higher frequency would be ultrasound. Any lower frequency will be infrasound. So, ultrasound means very high relatively high frequency small wavelength and wavelength is not comparable to either aggregate size or the specimen size. So, at least one wavelength one wavelength will be contained within the aggregate.

Now, if you use let us say audible range, your dimension of the specimen or even aggregate size might be an aggregate. Because it is a heterogenic concrete is heterogeneous material, if you look at the millimetre or centimetre level. So, particular millimetre level it is heterogeneous. So, you do not want any other kind of phenomena like diffraction standing wave formation etcetera occurring or any kind of you know resonance because of the dimensions. So, wavelength should be sufficiently small. And that is why you use ultrasound that is why you use ultrasound. So,