Building Materials and Construction
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Module - 3
Lecture - 4
Concrete: Production
(Pumping, Placing, Compaction)

Last class we looked into concrete, transporting and mixing together with radium mix concrete also other modes of transportation. Continuing with the concrete production, we shall now look into pumping, placing and compaction.

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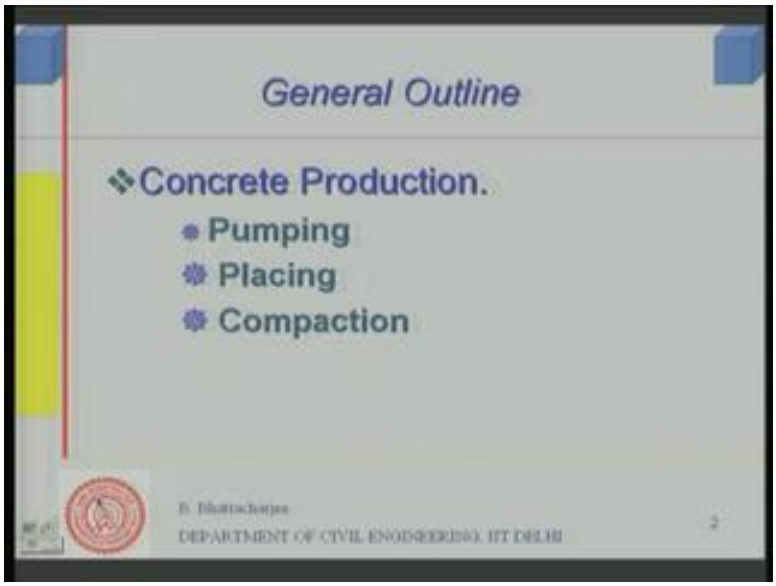

General outline of this discussion would be first of all we will look into pumping, which is really a versatile mode of transporting and placing concrete, then we will look into placing and compaction.

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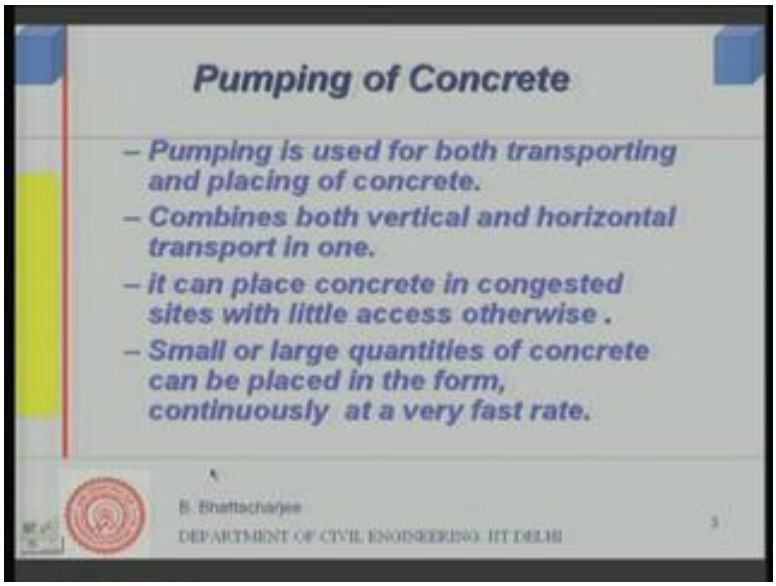

Let us see first what is pumping of concrete? Pumping is used for both transporting and placing of concrete. Well this combines both vertical and horizontal transport in 1. So, it's quite volatile in that sense it can place concrete in a very congested site with little access otherwise. And small or large quantities of concrete can be placed in the form, directly continuously at a very fast rate.

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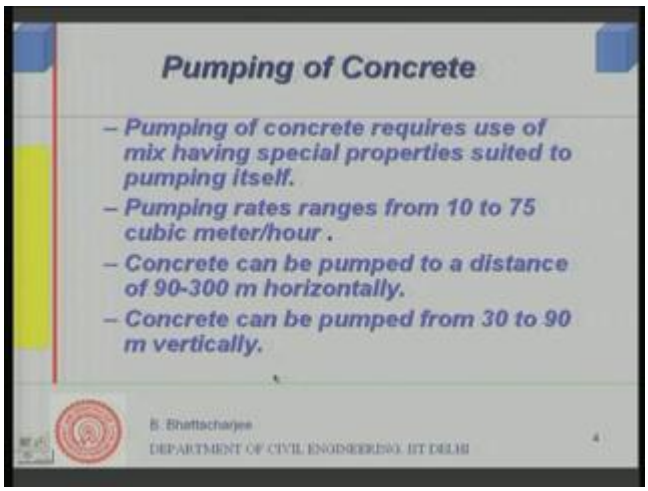

Now, let us see what is the basically is there any difference of the mix required for pumping. Well that is there is the mix that we can transport through pumps, require some special properties ranges of pumping rate can be 10 to 75 cubic meter per hour and concrete can be pumped through height of 90 to 300 meter horizontally.

Well vertically 30 to 90 meters, but remember both can be done simultaneously that is both 300 meter and 90 meter in vertical height, 300 horizontal 2 cannot be done together.

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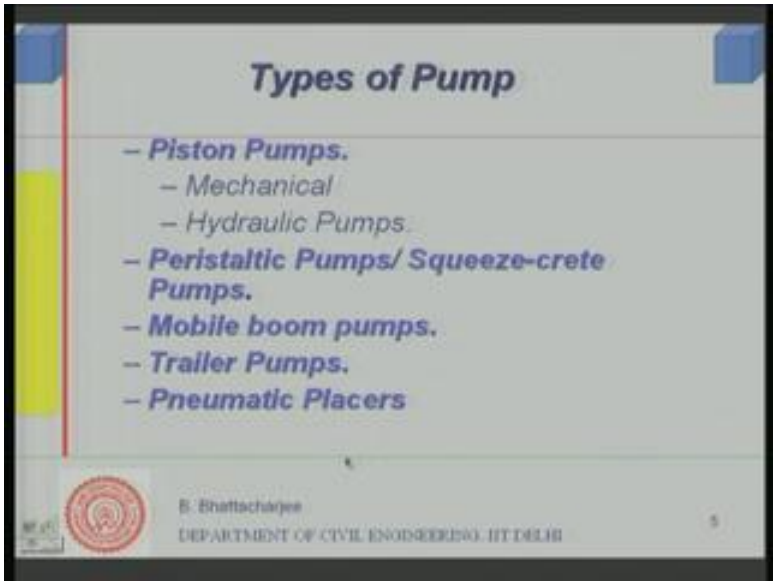

There are varieties of pumps, so if we look at types of pumps: the first ones are the Piston Pumps: Mechanical and Hydraulic pumps, your second variety is called Peristaltic Pumps or Squeeze Crete Pumps. Well same, either this piston pumps they can again be Mobile boom pumps, can be Trailer Mounted Pumps and there can be other type of pneumatic placers of concrete.

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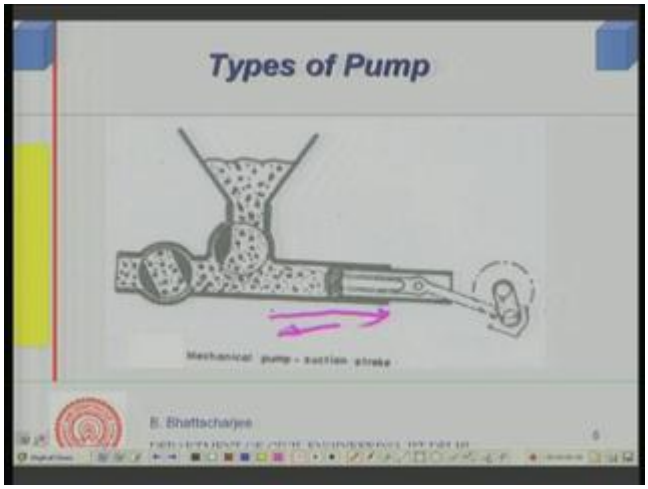

Continuing with the type of pumps this is what a piston pumps look like, see it's is a reciprocating pump as can be seen and currently this 1 is in its suctions probe where by concrete is through the suction hopper, concrete is concrete enters into the pump. This piston moves along this direction and you see along the suction direction this moves like this. And this valve now it is at open position, whereas this valve now is at closed position.

So, during the delivery stroke the piston moves along this direction and this bulb get closed and this bulb is open. So, this concrete as you can say it becomes horizontally a line to the delivery pipe. And concrete is delivered outward, that is how a piston pumps works.

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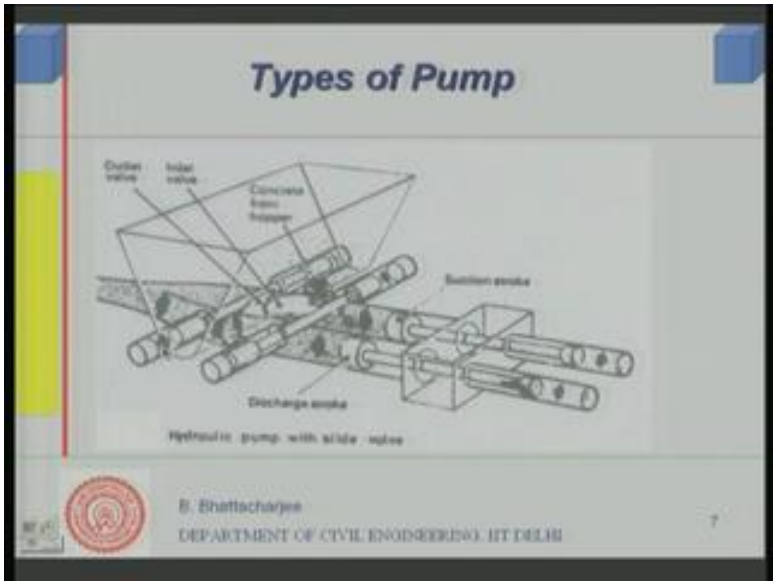

We continue with the type of pumps, usually since there is a suction in delivery, the pressure on to the concrete increases and then decreases; increases and decreases. So, it is a sort of varying not constant now, to reduce this effect of suction and relaxation of suction high pressure and lesser pressure 2 twin pumps can be joint together, while 1of the pump is in suction strake the other can be in the delivery stroke.

And this can be hydraulically driven as well. So, as you can see this hydraulically driven with you know same piston pumps, but the pistons are now driven hydraulically. So, this is in the suctions stroke and the other 1 is in its delivery stroke.

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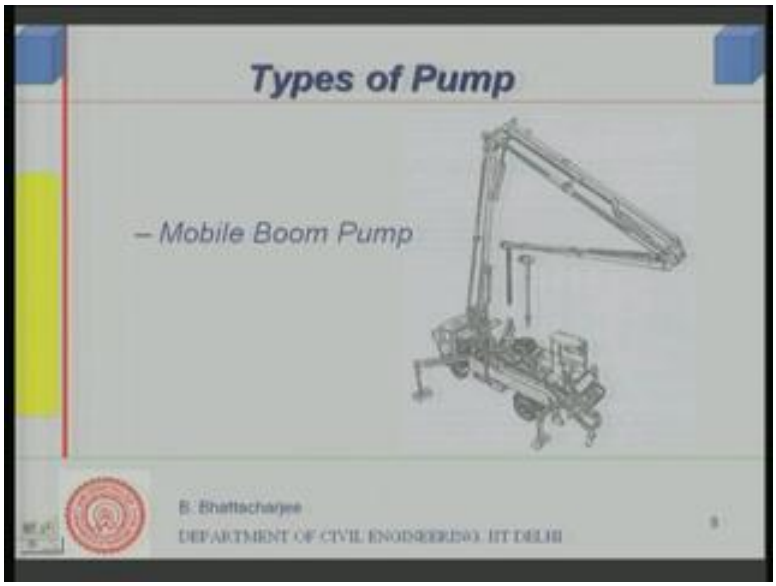

And same any one of these types of pumps can be actually mounted on a truck, so it is a mobile boom pump.

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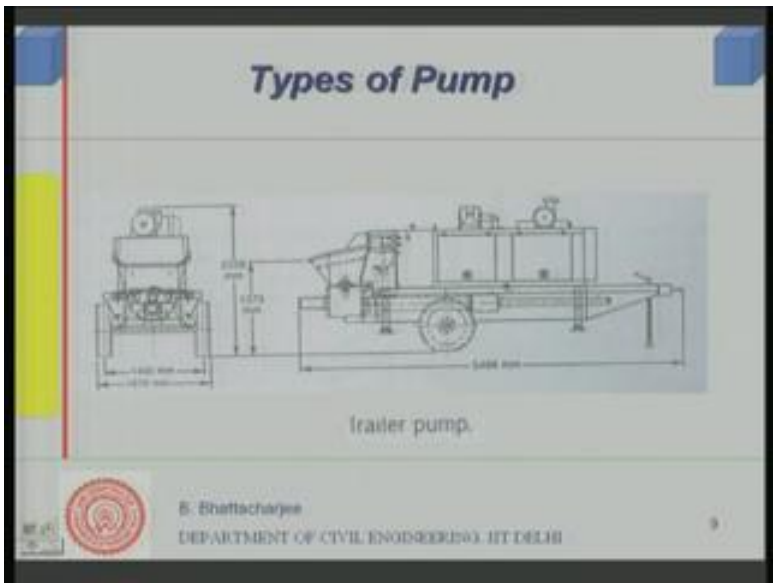

This is a trailer mounted pump as you can see, the pump is mounted on the trailer and is very common. And usually used for large capacity pumps and that is what is mostly used currently in the country.

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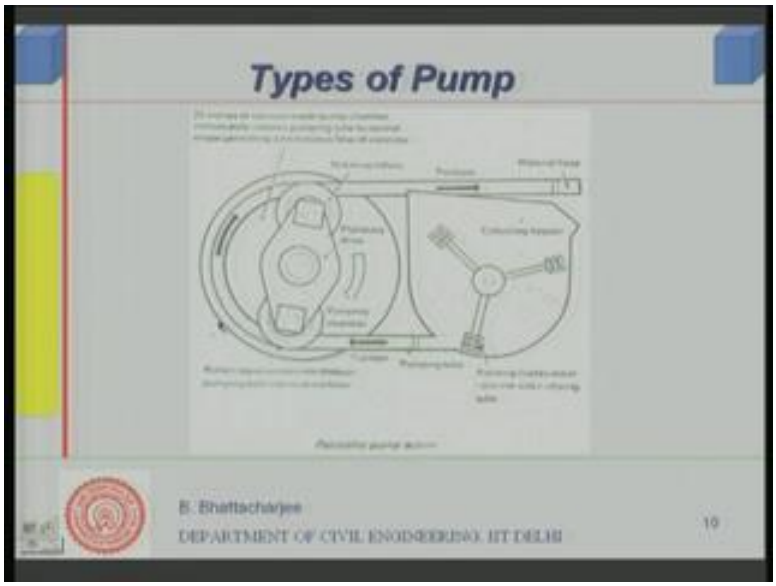

This is another kind of pump called Peristitic pumps now these pumps, in case of this pumps you see you have a flexible hoarse and there is a hopper it collects the concrete this 1 is a rotating blades to help delivery of the concrete to the flexible hoarse. This is the planetary system planetary drive with its central axis here; this are other rotary actually rotary drives and this rotates this board roller rotates about this axis, this roller rotates about this axis.

And this 2 together whole thing rotates like this, this squeezes the pump pipe here the flexible hoarse here. Drives the concrete as it goes around and here the concrete is delivered under pressure this is called squeeze treat pump. And now it is used, but not so much unlike the piston pump.

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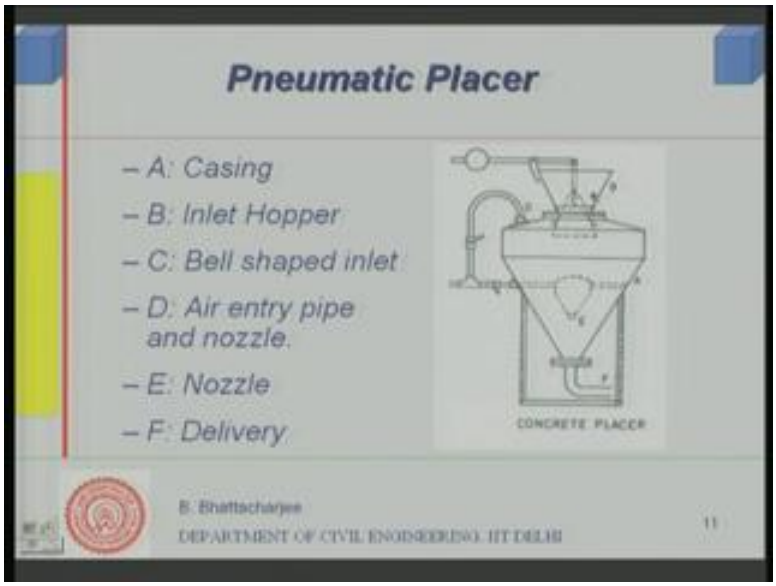

The pneumatic placers is used for a grouts usually as you can see it has got a casing this is the casing, this is the inlet hopper, this is a bell shaped inlet and this is air entry pipe with a nozzle, this is also the nozzle and this is the delivery. The concrete is actually driven by compressed air pneumatically.

So concrete enters here, the pneumatic air enters here, air entry D through this and then finally, you know air under pressure through a compressor. And then it is delivered through this usually used for grouts or relatively dry sort of mixtures, so these are the types of pumps.

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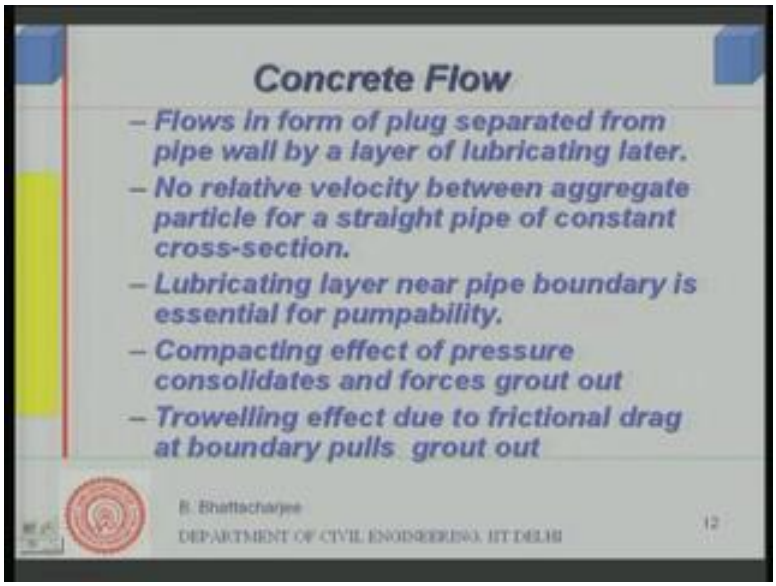

Now, how does a concrete flow in a normal pump I mean normal you know delivery pipe of a pump, its flows in the form of flood separated by pipe wall by a layer of lubricating layer. As you can see and no relative velocity between aggregate particle for a straight pipe of constant cross section exist. Lubrication lubricating layer near pipe boundary is essential for pump ability. You see the concrete pumping concrete is generally a material which has got lot of solids it's not like liquid or like any other fluid.

So, that it can flow easily on its own now, the material that can flow in concrete is basically water. So, we make a plastic mixture or mix out of the solid materials, solid ingredients and the water. Now, this water should the very fine materials forms the slurry and this slurry is you know forms the lubricating layer at the boundary of the pipe. And through this lubricating layer concrete is actually moved, under pressure in the case of pumping.

There are some compacting effects on the concrete also, because you apply a pressure. And then this is also released as it moves, because as I said the pressure is not a constant pressure it increases during the delivery stroke and then reduces a little bit. And then therefore, it gets compressed a little bit and this pressure also force, forces little bit of grout to come out and get accumulated at the pipe boundary.

There is something called a trowelling effect, if you trowel a concrete surface you will see that the water on that slightly tries to come up. So, this trowelling effect also takes

place due to frictional drag at the boundary. So, at the boundary a lubricating layer is formed that is what is been said in totality.

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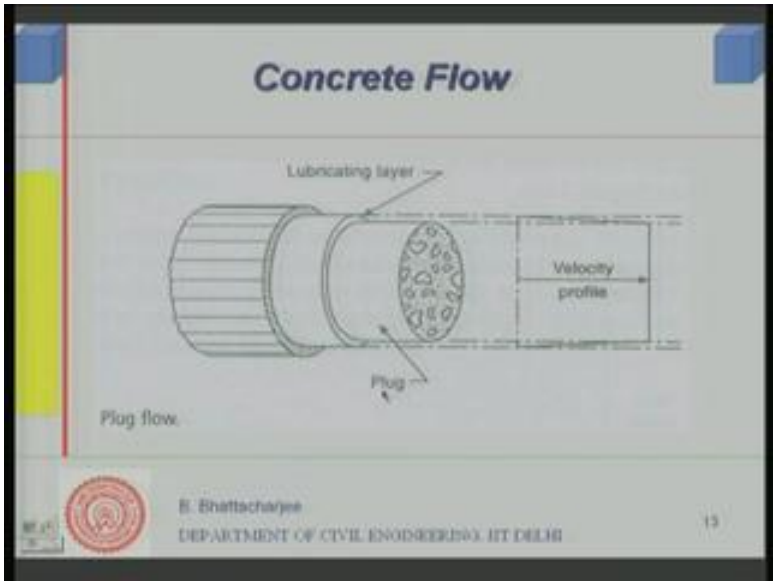

Now, the flow would look like these plug flows as you call you see you have a fine lubricating layer at the boundary. Fine lubricating layer this is the plug you know complete plug, which is solid and this lubricating thin layer the velocity gradient exist here and for this whole plug the velocity is constant. So, velocity profile if you look at it is constant throughout and here there is a variation of velocity 0 at the boundary and there is an implicit.

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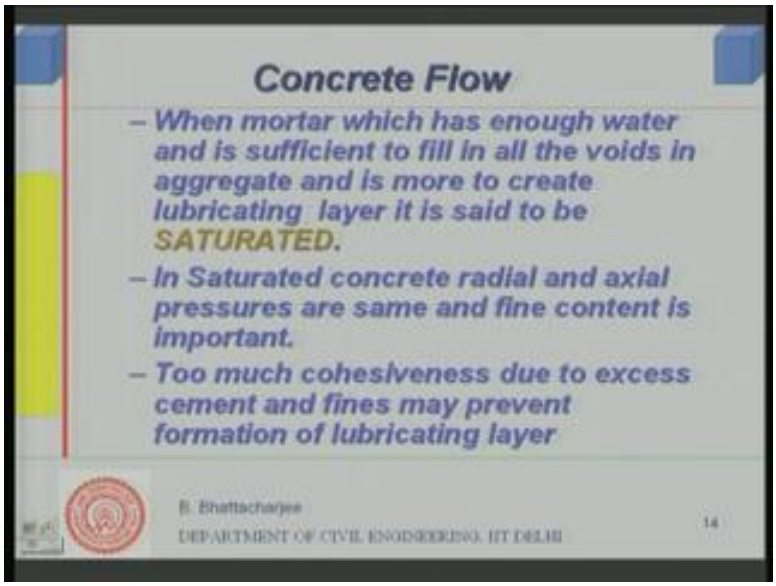

So, this is what we call it plug flow now, this is facilitated when concrete is what is called Saturated. What is state of saturation? When mortar in concrete has got sufficient water and that can feel all the voids in the mortar system. And the mortar itself fills all the aggregates and slightly more may be and the system is such that, it can create you know sufficient cement paste in the mortar system.

Again and sufficient water in the cement paste itself such that, lubricating layer can be formed concrete decides to be saturated. In saturated concrete radial and axial pressure both are same and this is fine content is very important. Because, it must form sufficient amount of mortar if you have excess of fine then there is little bit of problem. Because, too much of cohesiveness due to this excess of fines or cements you know fines include cements also, because we are talking about the particles here. And this can actually prevent promotion of lubricating layer.

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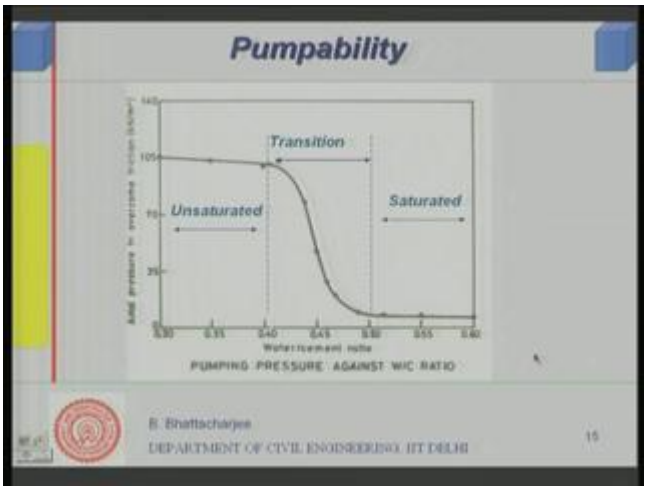

So, pump ability is governed by what? Lubricating layer must be brought the saturated concrete is easy to pump. And early experiment done in 1950s have shown that water to cement or rather you can say the fines ratio. The fines may include today, including fly ash and other materials which I mention which has cement ratio fine in nature you know total powder fine very fine powder.

So, water to cement or water to powder ratio we can call in today's terminology, where rate increases beyond a point; that means, you have sufficient amount of fines such that the fine holds on to the water, water cannot flow on its own. It is actually sort of trapped by the solid system the very fine particle in system.

So, you have sufficient amount of fines such that water cannot move through the interstitial pores of the fines and it is held together. So, this is said that water to cement ratio or water to fine you know water to very fine powder ratio when this is high, there is sufficient amount of water it can be saturated.

So, this zone 1 you can say see that this zone is a unsaturated zone and this zone is a saturated zone transition from 1 unsaturated to saturated and this is the saturated zone, where you have sufficient amount of water and overall there must be sufficient amount of fines in the system the next diagram will make it clear.

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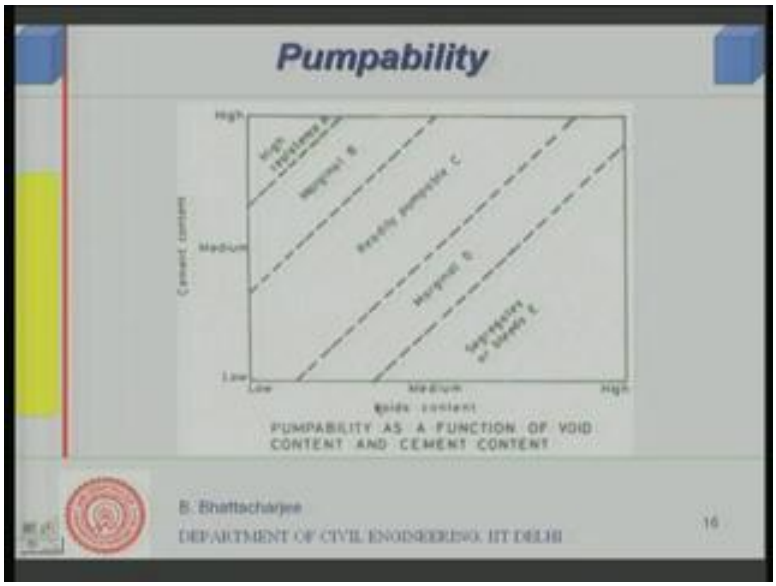

A little bit this you can see that when the total void content in the system versus cement content to the plot, void content it means that in void content the aggregate system overall and the cement content if you see. If you have high voids there will be segregation, because water will be just move away leaving the solids. So, the tendency to segregate or bleed when your high voids in the medium you have less amount of fines.

On the other hand, if you have too much of fine there will be high resistance to flow because too much of cohesiveness is there. In between this is marginal, this is marginal, but most easily pump able readily pump able situation is this. So, when you have sufficient amount of fines such that, voids are waste, but at the same time fines are not too much to create high resistance to flow pump ability is possible.

So, quantity of fines are very important fines here we need cement if you added fly ash of course, then also possibly very fine. And or the fine aggregate below say 150 micron those are important right so that is what makes concrete pumpable.

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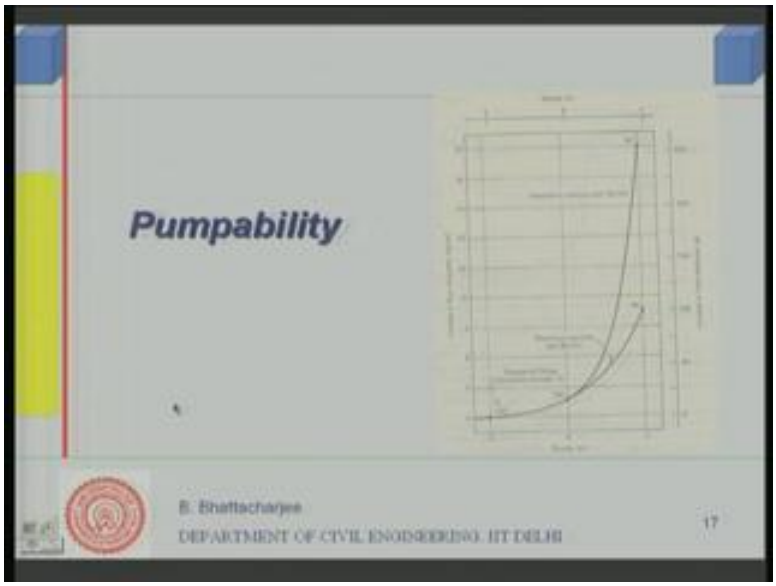

Well, pump ability of course, we measure as usual see later on in 1 of our discussion that, slump is am measure of flow ability of concrete or workability of concrete as the terminology goes. Pumpability is also a function of workability, it can be crudely related to workability that is slump here. So, very high slump concrete is pumpable now as you can see the slump actually increases along this direction.

Slump increases on this direction it is 3 centimeter to 13 centimeter means 130 millimeter and the flow resistance reduces. So, as I increase the slump flow resistance reduces; that means it becomes easily pumpable. So, roughly speaking usually speaking we can say a slump of 120, 130, 150 these are all pumpable mixtures. That is crude way of looking at it, but of course the mechanics is not really the 100 percent understand understood till date. So, we use a very high slump for pumpability. Right what happens if we pump the concrete is there any effect on concrete?

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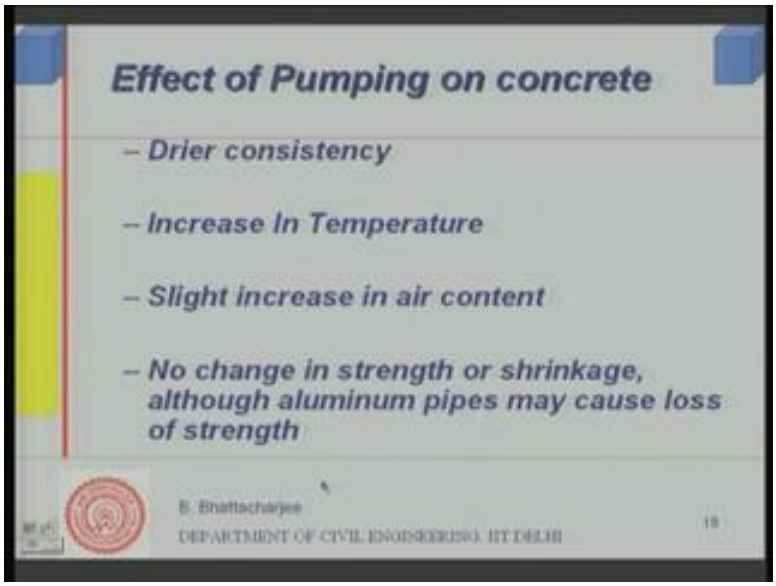

Well, practically there is no negative effect; it becomes makes it a little bit drier after all you are applying pressure to the concrete. Then increase the temperature slightly, air content in the concrete may increase well again and as far as strength shrinkage etcetera are concerned. There is no negative effect; no reduction in strength, no reduction, no increase in the shrinkage takes place.

Well, aluminum pipes otherwise also is problematic as far as concrete is concerned. Because, aluminum can react with some component of the cement, so this can reduce cost reduction.

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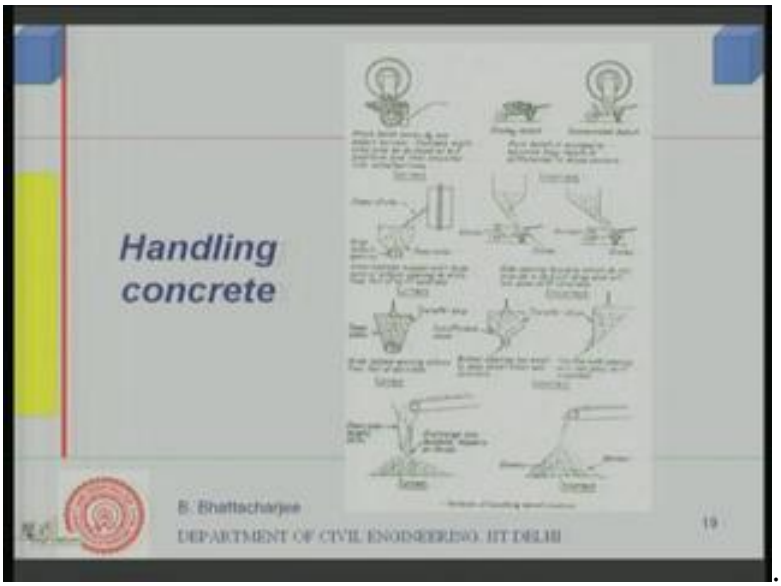

Some do's and do's so that is all about pumping some do's and don'ts as far as concrete handling is concerned. We shall look into some do's and don'ts and as far as concrete handling is concerned. Now, this is you see when you are discharging your concrete the concrete should be discharged in single go right.

Single go whole mix, whole discharge from the single mix should be discharged in a whole wheel barrow and not part by part what happens, when you mix your concrete and you are discharging through the delivery shoot of the mixture. Initially the stones have a tendency to fall on to the wheel barrow and then later on it will be less stone effect.

So, as you can see here the stony batch is there less stony material. So, should be actually transported in 1 goal loaded into the wheel barrow in 1 load Alright. Similarly, should not be like this delivery should not be like this, if it is like this what will happen is stones will have a tendency to accumulated it here. And the switch mortar would have a tendency or a cement more enough with fine materials flowable materials.

The stones will try to accumulate here, rest of the material will try to accumulate here; similarly is the case when this very angular irregularity. On the other hand, if it is a bottom opening discharge or it is a smooth shoot you will find there are you know is to the right from the bottom then there is problem does not occur.

Because, then everything goes together, but if you have large inclination then large coarse aggregate have the tendency to go further away, whereas the slurry of water will flow this way.

So, bottom open bucket should preferably be used this is the correct mode similarly, this is the correct mode right. The tapered bottom opening bucket alright not like this, because this will be again tendency to aggregate large tone aggregates to come here. And fine aggregates to or in a move or if it is narrow too narrow like this, it is too narrow like this or too narrow like this, what will happen is only the fine material or slurry material the mortar will come down, but the stones will remain there they will get stuck there.

So, initially your mortar will come and then next the stones would come. So, in this process what will happen? The uniformity of a concrete is closed, this is to be taken care of while handling concrete. Similarly, if it is through an if it is through a conquer bell you see the series of shoots are used, hoppers and shoots are used, in order to see that concrete is remains uniform after discharge.

Whereas, if you just drop it what will happen the large aggregate will come here mortar will only reach their stone will reach there. So, these are some tips 1 should use while actually handling concrete right. Now, next look to the next phase of production of concrete. So, we have seen so far that we have actually batched the concrete, mixed the concrete and then transported it by various kinds. So, means that is possibly we have talked about.

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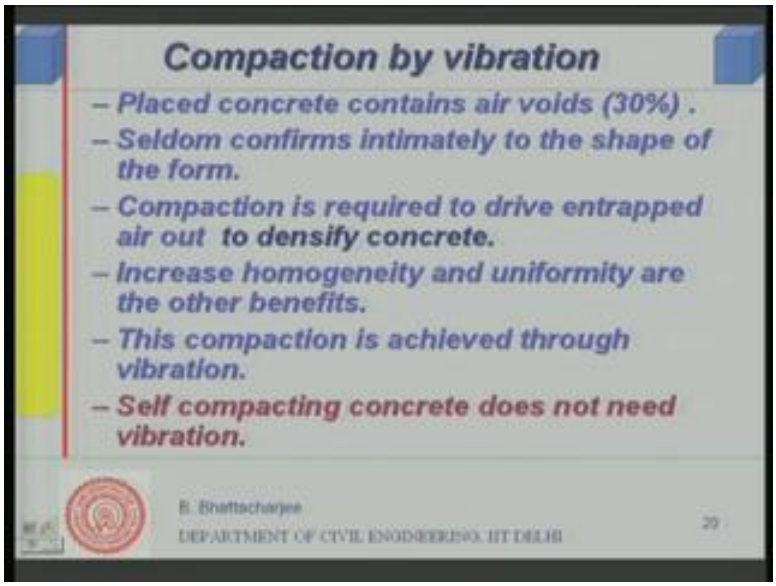

Now, let us look into next phase of our production process that is called compaction. And this compaction we will do usually by vibration, but not in all cases, the special cases will come. This is required, because in placed concrete you place through whatever means normal concrete will contain will contain large amount of voids as much as 30 percent. And of course, you do not place exactly into the shape unless highly flow able component that is a different issue altogether.

Otherwise, you have to move the concrete a little bit to get into to the right kind of shape and that is also, done by vibration or compaction process. So compaction is therefore, required to drive the air out of concrete in other words to densify right, and also it causes movement in the concrete a little bit to exactly match with the shape of them. Alright it ensures improvement in homogeneity also uniformity of the concrete. Now, this compaction is normally achieved through vibration.

Now, a special case which I think I might have mentioned earlier sometime, something called self compacting concrete and it does not need vibration. The name itself suggests, this self compacting in the initial performance of the concrete can be defined performance of concrete to check performance of the component in early stage.

A self compacting concrete has a got a very high performance in the early stage so much. So that, it does not require any compaction such a concrete of course, would not require vibration basic idea is to do away with vibration with this particular concrete. So, we are

not talking of that concrete the moment we are talking of the normal concrete, which requires vibration.

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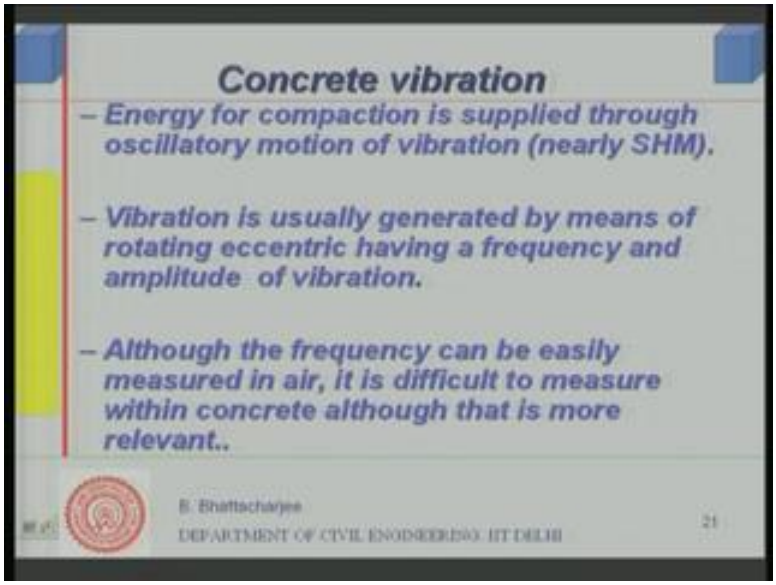

Well this energy of vibration or this energy for driving out the air or for the purpose of compaction is we supplied through oscillatory motion of the vibration right, which is nearly simple harmonic equation. This is generated by rotating eccentric having a frequency and amplitude of vibration. So, generally we are rotating a eccentric as we shall see and the frequency can easily measured in here; we can measure the frequency here, but it's difficult to measure the frequency in within concrete although its actually more relevant. So, it is more relevant to measure within concrete, but that is difficult to measure.

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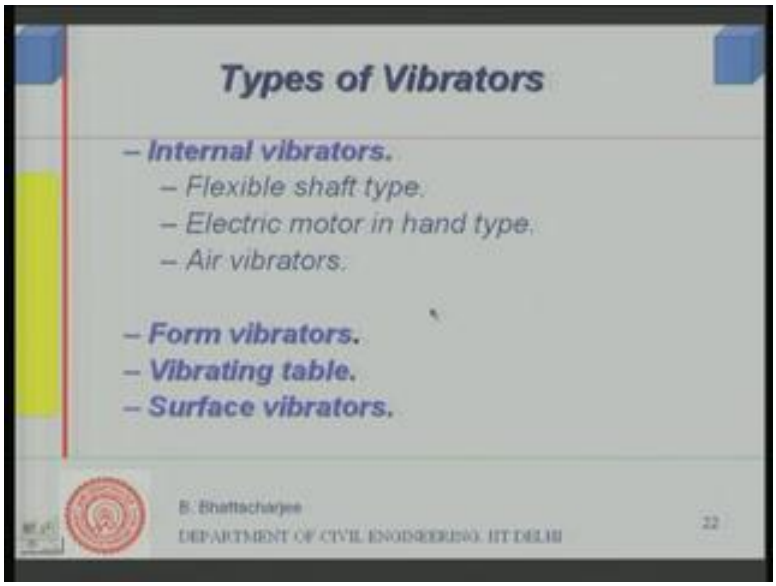

Let us see what are the types of vibrators there is something called Internal vibrators the most popular 1s and many of you might have seen it, if you seen a construction side usually they are 2 types: Flexible shaft types which are the most common type and electric mortar in hand type. Then, there are Air vibrators that are again internal vibrator air vibrators. Form vibrators those vibrates the form itself, then vibrating table, surface vibrators.

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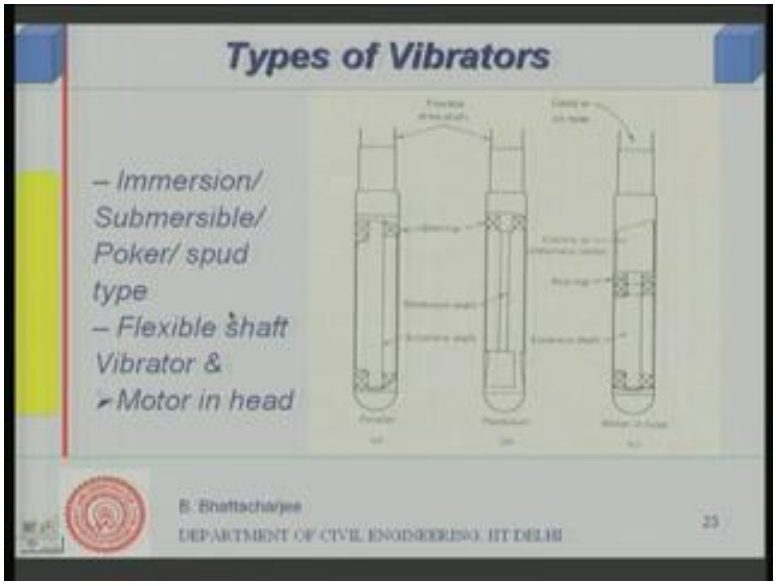

So, let us see 1 by 1, first we will look into internal vibrators continue with the type of vibratos; these are called immersion, submersible, poker or spud type vibrator. They are either called immersion, submersible, poker, spud type this is first 1 is the flexible shaft vibrator and the other is a mortar in head. Now, you can see this diagram this is the flexible drive type and this is mortar in head itself this is a right.

So, this has got a flexible force right, that is a flexible shaft usually this is a string and this is the mass, rotating mass eccentric which looks like see the shape is like this you have got a excess mass here. So, it is a eccentric shaft and these are the bearings, so the spring that is a flexible shaft which is usually a string which rotates causes rotation of this 1.

Since this is eccentric this generates a kind of oscillatory motion during its rotation similarly, you can have something like a pendulum shaft. So, you have a shaft gain the flexible shaft you know is here the spring that rotates from the mortar, a prime mover, a electric mortar, which usually or a diesel mortar which causes rotation of this shaft. And this finally, cause rotation of this pendulum shaft and this has got this eccentric oscillatory.

So, this 1s both of these are flexible shaft; the other is an electrical cables comes here and this is a mortar here, eccentric shaft is here; this is a bearing and this a electric or numerator mortar here, which causes rotation of this 1. And due to this eccentric rotation of this eccentric it imparts a kind of oscillatory motion through surface of the vibrator, surface of the poker vibrator, to the concrete in the surrounding.

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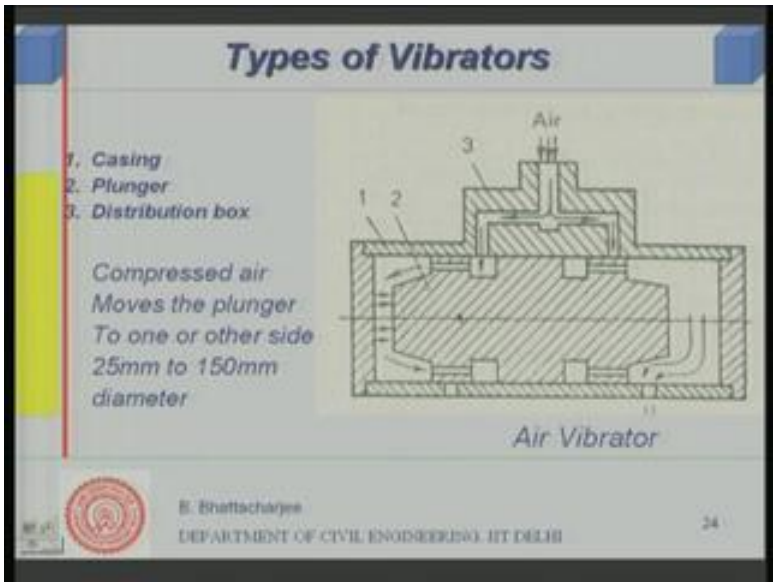

This is the air vibrator, in this case see air comes through this a 1 is the casing as you can see, 2 is the plunger, so this is the plunger which moves this way; 3 is the distribution blocks through which air compressed air can move like its applying pressure on this side and the excess pressure that has gone out earlier would come out through this. The compressed air causes the plunger to move through from 1 side to other, you know 25 millimeter to about 150 millimeter diameter this 1 is and it moves to and fro. You know moves the plunger from 1 side to the other and imparting oscillatory motion, to the concrete in the surrounding. So, this diagram shows the air vibrator not so common, but the previous 1 is more common particularly the flexible shaft type.

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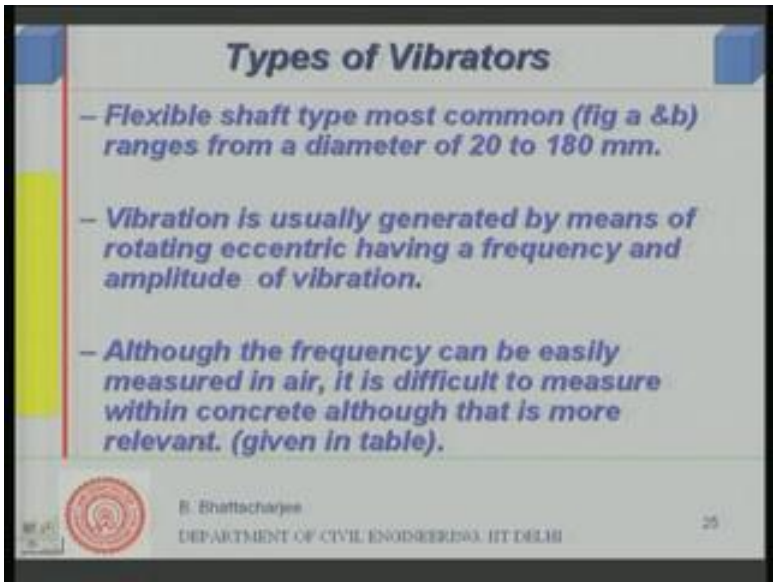

Here, this is the most common and its diameter ranges from 20 to 180 millimeter, usually generated by means of rotating eccentric having a frequency and amplitude of vibration that you have mentioned. And the frequency can be this we have already said right and more about this we will have in a table.

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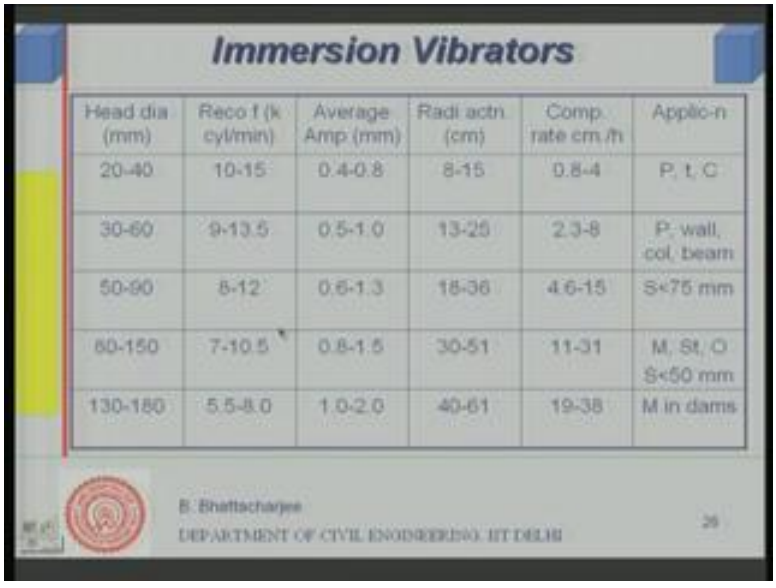

So, this immersion vibrator usually if you see if the Head diameter is between 20 to 40, recommended frequency is 10 to 15 cycle per minute, Average amplitude is of the order 0.4 to 0.8 millimeter radius of action is about 8 to 15 centimeter. So, you know it can

operate it can vibrate the concrete within a radius of between this range. And compressive the compaction rate is about 0.8 to 0.4 centimeter per hour.

So, this is applied in case of plastic concrete, thin sections actually this will be applied in section where there is very thin section lot of reinforcement is there. So, that is where you will apply this particular form 1. Right 30 to 60 millimeter this recommended frequency is like this average amplitude is of this kind radius of action is so much and compaction rate is given by this wall, column beam.

And if you see the last n in your larger side these are usually used for mass concrete in dams, because there are no reinforcement where you have congested reinforcement you would possible go for this sort of thing very thin wave let us say, wave of a box section you know box section a vertical member, vertical wall very thin 150 millimeter or about 200 millimeter in thickness.

And it can reinforcement gauges on both sides and also let us, say precious cable is passing through this and it was very difficult to pass through this, using a poker vibrator of large diameter. You can use this vibrator of a smaller diameter of course, you have other means of vibrating them also, but if you are using this immersion vibrator this is a kind of suggested range given.

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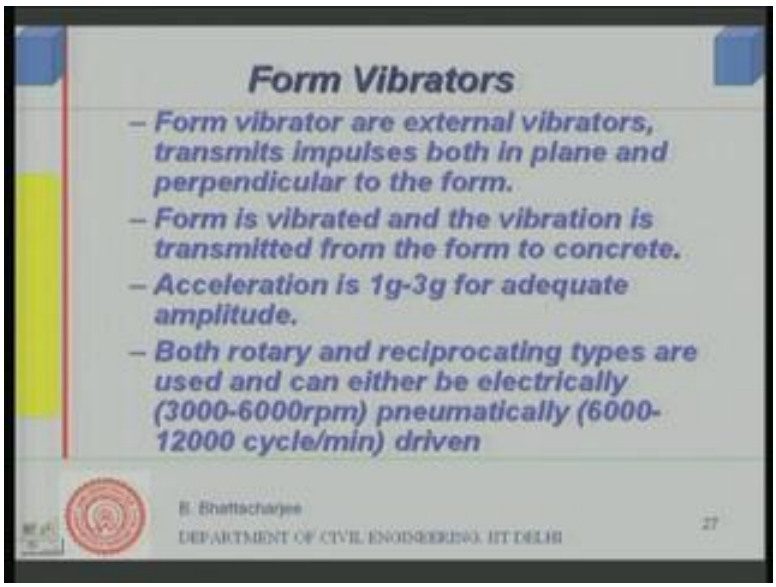

The other variety is the form vibrator, these are used these are actually external vibrators and these transmit pulses both in plane and perpendicular to the form also. In other words, you place it on to the form itself and it vibrates the form and when it vibrates the form, in turn vibration of the form is transmitted to the concrete and causes concrete to vibrate. Naturally some amount of energy is lost in the process, because your vibrating in the form also right.

So, some amount of energy is lost, but where do you can't actually vibrate with the poker vibrator, the needle vibrator form vibrator is the only solution. Because, if you have too large amount of reinforcement then it will be difficult, to vibrate with any vibrator, so form vibrator could be another approach.

Well its acceleration is 1g to 3g for adequate amplitude. Both rotary and reciprocating types are used and can they can either be electrically driven or pneumatically driven right, you can see that 3000 to 6000 rpm, 6000 to 1200 cycles per minute or rpm you can say is a you know pneumatically ones uses larger cycles per minute, right.

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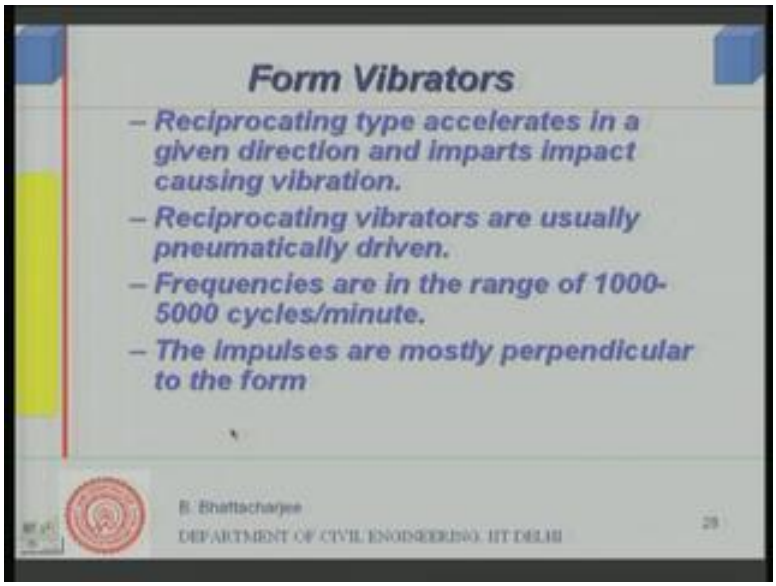

Reciprocating type accelerates in a given direction and imparts causing vibration. So, basically imparts an impact and as I said, it is both plane in plane that is along the plane of the shattering and also transfers direction of vibration is important on to the concrete. So, it vibrates you know transfers both impact energy transmitted horizontally also vertically along the plane of the form wall and also to the concrete directly.

Reciprocating vibrators are usually pneumatically driven, I mentioned earlier frequencies are in the range of 1000 to 5000 cycles per minute this are mostly perpendicular to the form; the impulses are mostly perpendicular to the form.

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Vibrating table, so form vibrator we have discussed internal vibrator or needle vibrator; the other type of vibrator is a vibrating table. Vibrating tables are usually used for pre cast elements like you might have seen if you have gone to a laboratory, where concrete cube are tasked for testing purposes there this is a vibrator on a table. So, table vibrators are damn used only for pre cast elements, because large slab pre cast slabs we will discuss what is pre cast later on.

So, pre cast slabs or pre cast members they can be vibrated on vibrating table not very large, but small 1. So, the frequency is usually less than 6000 vibration per minute and amplitude is greater than 0.12 millimeter. So, this is table platform is vibrated and you put your mould, so the concrete there and just vibrate it. The other kinds of vibrators are: surface vibrators which exerts their vibrators you know, exerts their effects at top surface of the concrete.

So, this is only useful for slab cannot be used for any other kind of element, concrete element. So, this 1 includes vibrating screed, pan type vibrator, vibrating roller screed, vibrating plate and vibratory roller for pavement concrete. So, these are kind of vibrators surface vibrators right.

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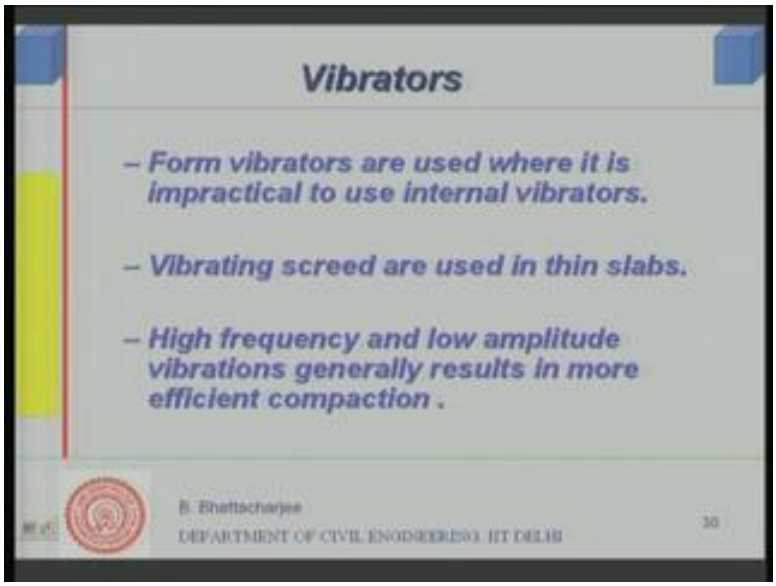

Form vibrators are used where it is impractical to use internal vibrators I have already mentioned this. Screeds are used in thin slabs so, because you can put it on to the surface and vibrate it may be floors know flooring. High frequency and low amplitude vibration generally results in more efficient compaction, so high frequency low amplitude that is the idea. Now, let us see what happens when you subject fresh concrete you know to vibration.

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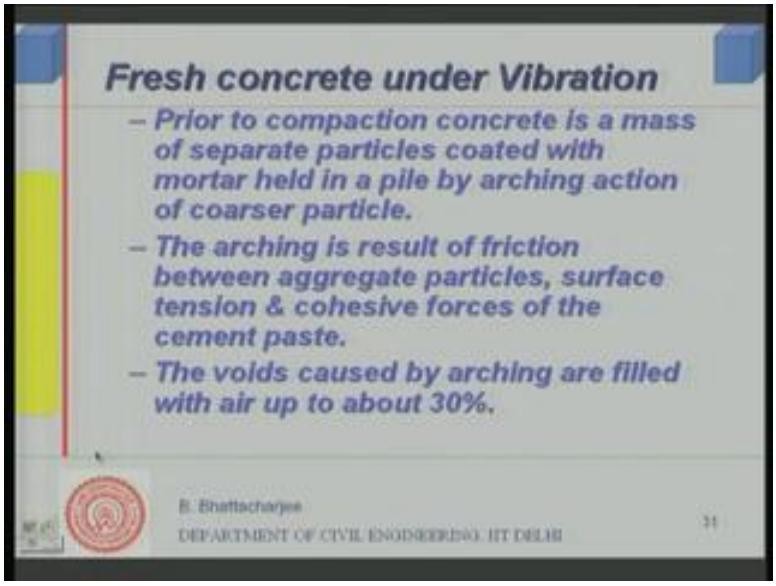

Before compaction it is a mass of particle essentially you know if you have essentially particle at system, something like this heap of particle of various sizes just there you know supported 1 after 1 over another. Sort of an arching action it supports you know it's like soil, which you can have heap of soil, so it's like that concrete masses. So, this has particle separated and coated with mortar held in a pipe and that is called arching action of the coarser particle.

The coarse particle will hold on to the final particle and so on right. This arching is a result of friction between aggregate particles surface tension and cohesive forces of the cement paste. In case of soil of course, it will not be there that to if it's particularly coarse particle alone say coarse stones that will simply be the friction. But in this case, the cohesion of the cement paste also comes into the picture.

Because, it can borne in its plastic state also it can hold it by cohesion then surface tension, since there is some liquid the water is involved. So, the surface tension all this forces interface between liquid and solid is there, so all this forces actually holds this mass into position. Now, this mass will have some interstitial voids in that as I showed you little bit earlier, this voids by due to this arching are filled up with air as much as 30 percent.

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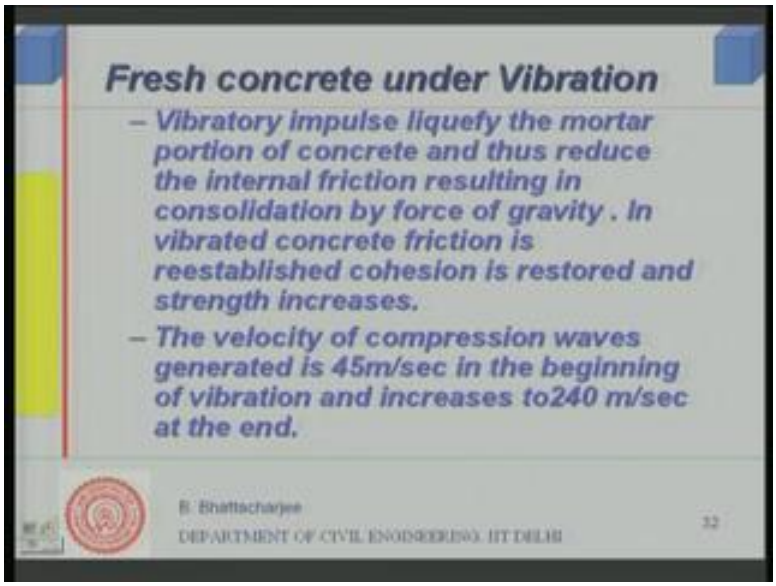

When you supply vibratory impulse you know this liquefy the mortar portion of the concrete and reduces the internal friction; basically what is happening is you know, you

are supplying impulse and the mortar now on the move and can results in reduces down the internal friction. And therefore, it does what is called liquefaction of this mortar and thereby further you know causes consolidation of the force of by due to the force of gravity.

So, when you are actually physically you can understand, when you are vibrating like this the internal friction between this particle system would actually will overcome this internal friction. And when the particle try to settle down on its own way So, by gravity. So, that is what it is been said right. There when you settle down the cohesion between the particle is reestablished, the bond between the cement coated material you know between various types of cements coated materials together.

So, that actually is reestablished and then they become a solid material and strength into this. The velocity of compression waves generated is something like 45meter per second in the beginning of vibration and increases to 240 meter per second at the end this is because you have voids. So, velocity initially is less as the voids get reduces the velocity increases 240 meter per second you barely going to towards that velocity of mechanical waves.

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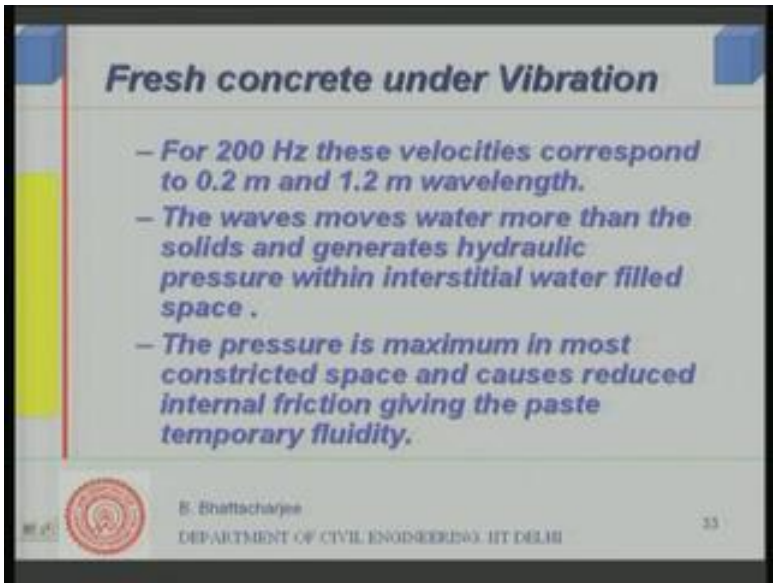

For 200 hertz this velocity corresponds to 2 meter and 1.2 meter wavelength. Because, velocity is know and you know v equal to f lambda, so if you know the frequency 200 hertz corresponding wavelength we can find out. These waves actually causes movement

of water more than the solid particles and if your water is stepped into the pore or the interstitial pores of the system.

So, this will causes lot of movement of the water, so there will be excess pressure within this pores which results in breakage of this you know hydraulic pressure within this interstitial space and causes its breakage. The pressure wherein is a maximum constricted pore and causes it causes breakage of that interstitial pores system itself and reduces down the friction.

So, it gives concrete a temporary fluidity you know I mean the paste in the concrete a temporary fluidity. And there is a mechanism how this compaction results from vibration.

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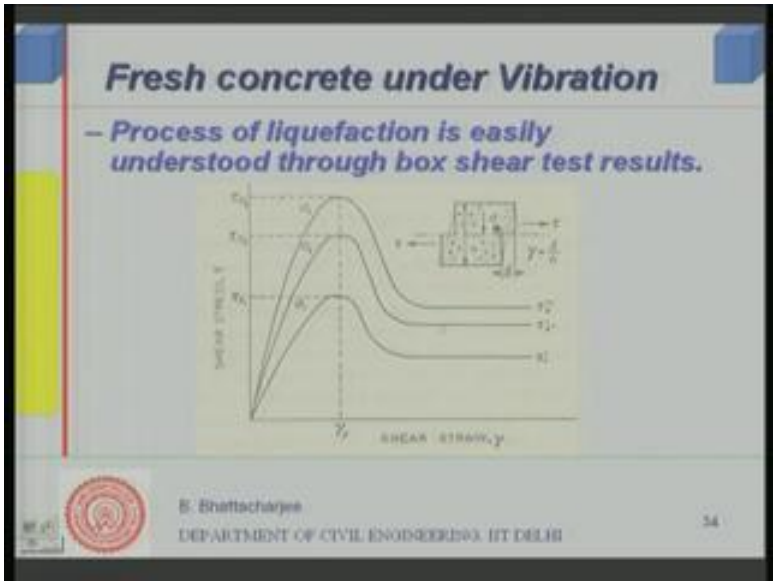

This is easily understood, 1 can do what is known as box shear test and early work done in box shear test. You know here what is done is you have a concrete here and you have a concrete here. These are all fresh concrete sort of fresh just after mixing all that it does not solidify. So, you have apply pressure here I mean force here and force here, the shear force here; within 2 boxes this is a box mould it is usually done for soil.

So, very those who have done a course in soil would understand this box shear test is often done for soil. And then this is another box, so you pull them off this 2 separate boxes actually, this is 1 box and top box and concrete. If you and then you pull them off;

but apply a pressure vertical pressure. So, as you increase the vertical pressure the sigma 1 sigma 2 and sigma 3 the shear force it can with stand is higher and a shear strain increases.

So, you know the increase in shear strain something like this, this sort of behavior is observed. So, increasing sigma tow maximum tow it can with stand increases you can understand you never putting pressure like this. If you are trying to pull them it would be difficult to pull it you know higher the pressure more difficult it would be pulled. So, that is why this in shear string increases or maximum shears.

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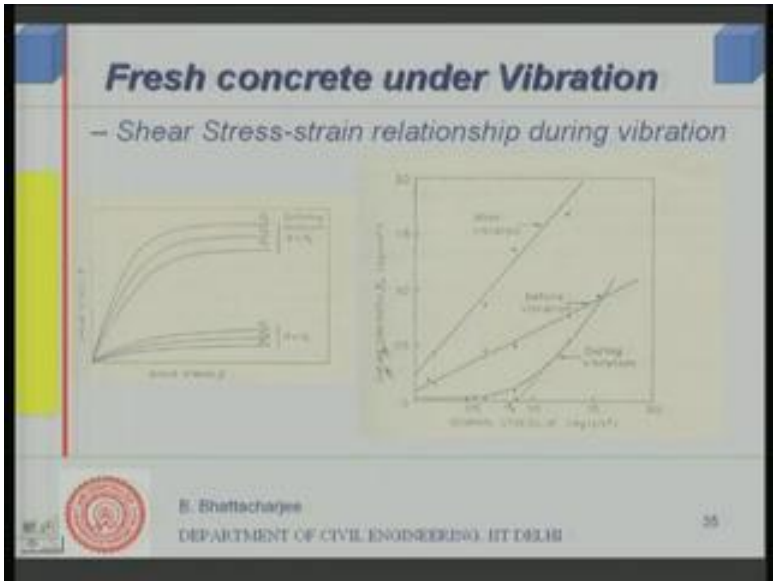

Right, but what happens if I am vibrating? It is been observed when you are vibrating, when the vibratory force is more than the normal force this sigma 1 sigma 2 and sigma 3 the tow values reduces down significantly, where the tow values you have much higher before vibration. And value of vibrating if the vibrating force is more than the normal pressure, then this increases you know this shear strength reduces significantly.

So, this diagram also again shows the same thing if I plot the normal stress versus shear strength as I said as I increase the normal strength; normal stress you know that pressure I applied from top this will be the behavior prior to any vibration. As I increase the normal stress the shear strength or the maximum shear it can withstand will increase that is what we have seen in the earlier diagram.

But during vibration what happens is this is the path followed. So, normally if the normal stress as the shear strength is very low so long as a normal stress is not greater than the vibrating force or equivalent vibrating stress. So, so long as the equivalent vibrating stress is lower than the normal stress you know you find that the shear strength is very low. But once this normal stress increases beyond the vibrating force, this path involved.

So, by applying vibration actually shear strength is reduce significantly there by it can collapse it can move, it can collapse that is of course, the viscosity dynamic viscosity also changes.1 can look into those issues, but we are not into that details, but the point that I am trying to make is simply that when you apply vibration its strength reduces. So, therefore, it's there is a liquefaction which takes place. And yet can move very easily and get into the new shape and get compacted in the process.

So, after vibration if you try to do the shear box shear test again, you find that the as the normal stress you increase the strength shears strength increases significantly. Because, now it is all compact there cohesion has been reestablished and this is how it behaves. So, this is what is the you know principle of compaction through vibration.

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Compaction takes place in 2 stages: in the first stage vertical settlement of coarse aggregate takes place, in a manner similar to packing of granular material and shape of the aggregate plays a major role, air voids up to 5 percent remains after this stage. So,

what happens is actually the granular material will collapse they will you know on their own way move and take the new positions, so this is the first stage right.

So, it is like all granular material at that moment they are not bonded strongly, because all the some cohesive force are there. Because, you do before the material has become solid it is still in plastic state compaction is all done till it is in plastic state. So, basically the particulate system they are not bonded. So, when you apply vibration they would move out and try to settle on to new position and then of course, the cohesion would proceed.

So, by this process actually 5 percent void is reduced to up to about 5 percent that is the first stage. In the second stage concrete behaves like dense liquid now, there are some five percent voids are there and it behaves like a dense liquid right and air voids are removed from the surface by forcing mortar to appear at the surface. So, what will happen?

Now, you have solids have gone and settled and still 5 percent voids are there it is almost like dense liquid. So, as you vibrate the mortar would tend to come out mortar through the interstitial space between the coarse aggregate and as it appears at the top the air also come out. So air also gets out it moves out, so that is the second stage of the vibration.

In fact, one of the ways of you know assuming whether concrete has really attend vibration to find out the slurry; the mortar slurry or the slurry has come out right at the top there is a liquid sort of the layer at the top that ensures the vibration has come complete.

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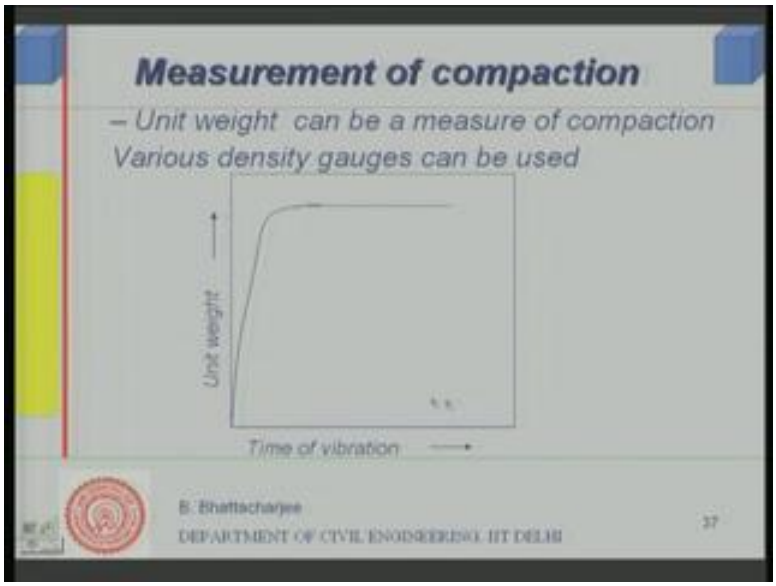

One ways to measure through unit weight right various density gauges can be used for this purpose, see if you look at unit weight time of vibration along this direction, unit weight along this direction. As you increase as you vibrate for certain period of time the density increases, but beyond a point of course there is no increase. So, there is no point over vibrating the system it does not give you any benefit. Because, long term vibration essentially wouldn't make the concrete anymore compact. So, it is not worth while doing long time vibration there is a minimum time and that should be done.

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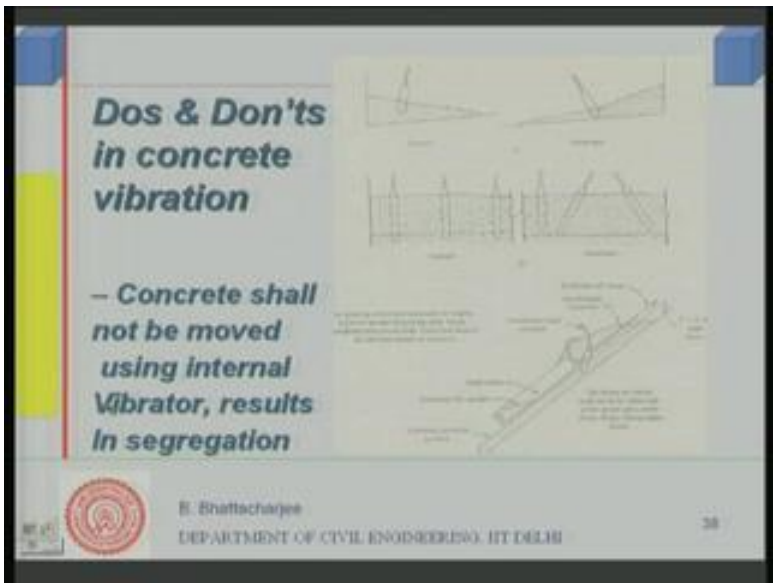

Some Dos and Don'ts in case of concrete vibration, you see this is correct way of doing this is not correct way inclined way to lift concrete up is not desirable by vibration. This is not the right way to do vertically this is what is right. And it is lifted up as soon as the slurry has come down to the top right.

So, this is what it is if concreting at the you know concreting in an inclined, so this is immersion type of vibrator you know it is preferable to vibrate having place from bottom and vibrate it in this manner as shown right. Concrete shall not be moved using internal vibrator, this can result in segregation that is if you try to move too much the coarser particle and the rest of the mortar they may not together.

So, that results in segregation so therefore, you should place it as close as possible to the place where you expect the concrete to remain finally, but slight movement is not avoidable. Because, as I mentioned earlier the concrete seldom attains the shape you want it to attain, because it would be in a form of a heap of a solid and then you vibrate it to attain the right kind of shape desirable shape.

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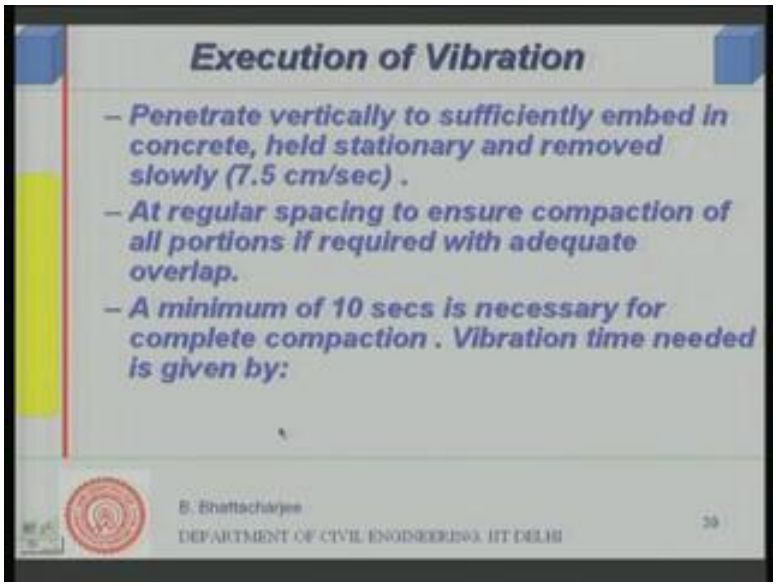

Well this is while executing vibration the needles vibrators are penetrated vertically to sufficiently embed into the concrete, then held stationary and then removes slowly at a speed of about 7.5 centimeter per second. So, that would be the best way of vibration you have to ensure a regular spacing that compaction of all portion. If required there can be adequate overlap you know I can show you diagrammatically something like this.

If this is your needle position and this is the radius of operation then next needle position should be something like this. Such that there's mild overlap small overlap this is as the radius. For example, if you do it like this with radius like this, this portion will remain un-vibrated. So, to ensure complete vibration it should be something like this; it should be preferably something like this.

So, that there is a overlap; sufficient amount of overlap right such that no portion in a section remains un-vibrated. So, should be at regular spacing to ensure compaction of all portion and with overlap. There is no problem if there is a little bit of overlap, but no portion should be left un-vibrated that is important 10 seconds is necessary minimum there are form is available.

Several formula is available I think I have not got those formula is basically, because there are no point having empirically formulas, but later which gives you a large number of formulas most of them are empirical .There are ways of measuring this appropriate time required for vibration also, empirical formula is a available and minimum 1 for a for the first level of idea 1 must remember that minimum of about 10 seconds are necessary for vibration.

And vibration should be stopped when the slurry has come up to the top, slowly it is to be lifted up recommended velocity being mentioned 7.5 centimeter per second at that rate perhaps lift it up. And when you lift up the slurry should come right, at the top ensuring that actually the last portion of the air has also been removed from the concrete.

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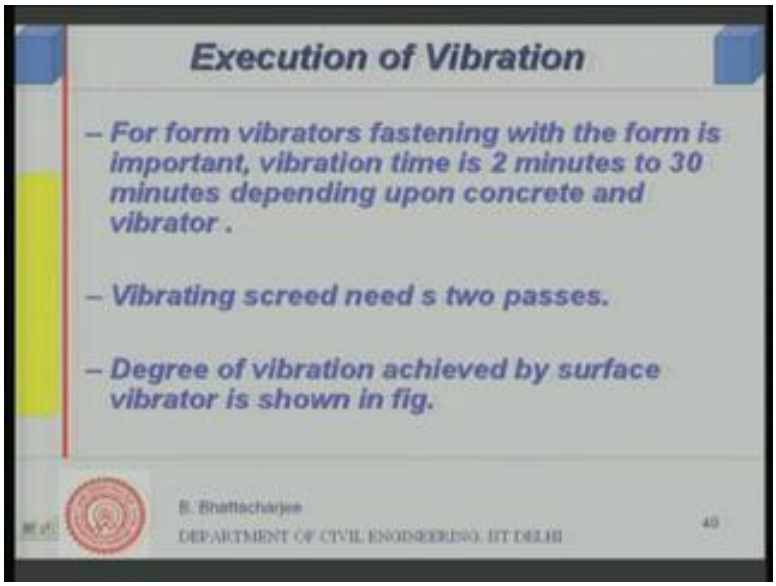

For form vibrators fastening with the form is very very important vibration time is about 2 minutes to about 30 minutes depending upon concrete and the vibrator. So, here you require longer vibration longer period of vibration depending upon of course, the situation, but it should be firmly held in position. Because, if it is not firm then there will be some energy loss at the junction also.

So, it has to be firmly fixed to the form void itself a vibrating screed which is used for floors essentially you know surface vibrator, to remove the air from there usually needs about 2 passes. So, you have 2 passes and then it vibrates from the top to remove the air voids at least 2 passes are needed.

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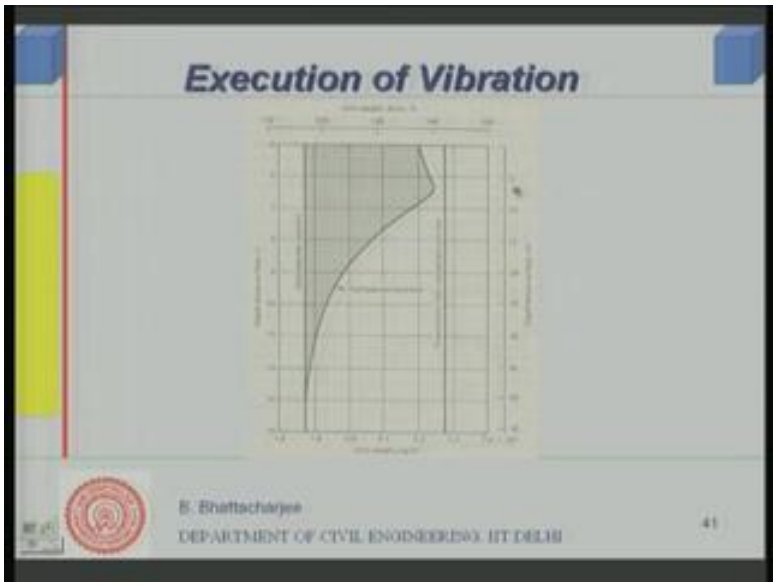

Well this diagram shows the degree of vibration that is achieved by the surface vibrator now as you can see this is the top. So, density of the concrete is maximum somewhere here. this is unit weight 140 pound you know cubic meter etcetera etcetera also given in kg per meter cube to unit weight in terms of kg per meter cube 2.2 or something like that whatever it is into 10 to power 3.

So, 2000 200 or 300 nearly about that compaction you achieve as a depth of this much and as you go down below practically the unit weight reduces and very small unit weight. So, it is a surface vibrators are effective only up to certain depth, not to the fullest extent right, so it shows how the surface vibrators are. So, in a deep section there is no point, because surface vibrators should not be effective.

But in a thin section s thin section it is quite effective as you can see right, so like this is 2 inch this is 4 inch. So, about 100 millimeter corresponding to this is 100 millimeter this is 150 millimeter. So, if you were very large thick section surface vibrators are not useful, but they are good when you are thin sections and you can use needle vibrator. In case of a large mass concrete we have seen, that I can use 180 millimeters diameter needle vibrator. So, in thin section lot of reinforcement may be this will be useful right.

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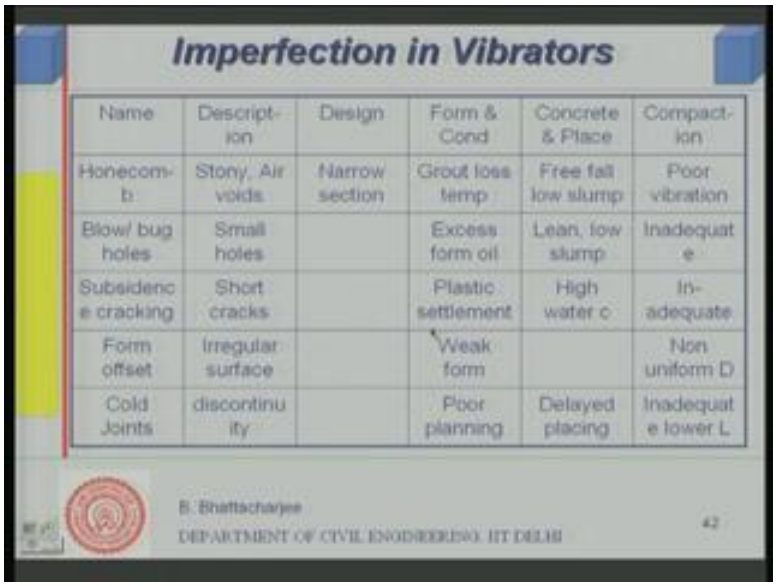

This table shows the imperfections possible in vibrations, if you do not do proper vibration it can result in what is known as honey combing; you know concrete looks like honey comb. So, there are lot of gaps in the concrete system looks like stony and large air voids. So, stone should be visible and lot of air voids, can possibly take place in narrow section it also depends upon form condition right.

So, there could be if there is some grout loss then the stones will remain and therefore, honey comb is impossible. So, if you have a free fall more than 2 meter or you know there is a large free fall loss and concrete. So, the stones remains the mortar is not there this can result in honey combing, as far as compaction is concerned who are compaction can result in honey combing this is usually the result of poor vibration in narrow areas where concrete cannot reach vibrator cannot reach you might see this.

There is something called bug holes or blow holes, which are quite common in case of surfaces you see what happens is air get air or water gets trapped at the molt surface. And most of the concretes many of concrete you would see would actually have some sort of bug holes small holes at the surface of the concrete. So, those are called bug holes right and if you have used a excess shuttering oil this can result in formation of this bug hole.

In a low slump, low cement or lean concrete this can happen and this can also result from inadequate vibration not for poor, but inadequate vibration. So, if you vibrate it fully

somehow this get driven out. But there are other means of actually getting rid of this getting, a better aesthetically pleasant surface of concrete without bug holes other means also, but generally if you want to reduce it adequate vibration ensures that the fine particles slurry etcetera move in the resulting in reduction in bug holes.

A poor inadequate compaction can result in this, in addition to of course, you know excess oil and so on. Subsidence and cracking short formation can take place this are called sometimes this plastic settlement can take place. Well let me, just show you what this could be for example, it could be something like this you know this could be your concrete surface and let us say you have an enforcement here; this is the reinforcement.

Now, concrete settle with time because the water will come out and the solids will have subsidence of the solid will take place, solid tends to go down you know water is the least specific gravity amongst all the materials that you put in concrete. Water has got specific gravity of 1 whereas, cement has got a specific gravity of 3.15 aggregates will be two point six etcetera etcetera you know.

So, water is the least specific gravity specific gravity medium. It will have a tendency to come up as it comes up the solid actually settles down cements will have a tendency to go down, more aggregates will have tendency to go down below. So, as a result concrete subsidence takes place now, when this is taking place this concrete will go down straight, this concrete will go down straight.

But what about this concrete here it will get stuck here. So, as it get stuck it can result in formation of crack short crack at the surface you know short crack like this, it might look like crack might look like this, is your reinforcement or large aggregate. This is your concrete top surface, this sort of crack formation technique now this is called plastic settlement. This can happen when you have high water, content high water content and also from inadequate compaction.

If the compaction is preferred the subsidence would have taken place right in the beginning itself water would have come out. So, this will you know other causes are also there, but inadequate compaction can also help in formation of this sort of cracks which are not desirable. So, adequate compaction is necessary, well form of set you can have irregular surface that is the form work you know not proper it is got a some sort of offset weak form during vibration it has moved out.

The form work its mould would have come out of something like that. So, non uniform actually it will result in non uniform vibration naturally, cold joint this happens when you have old concrete and new concrete you are trying to make. Or the concrete you have just placed and then you are placing the new concrete, you have not the vibrator has not gone into the whole concrete.

So, it will form 2 separate layers as a kind of discontinuity. This could be from poor planning, because 1 concrete you have made you have waited too long it has sat and then you place the next concrete. So, can result in poor planning delayed placing that is what is. And inadequate embedment of the needle vibrator to the previous layer can result in the same sort of cold joint formations. So, this you know many other things causes some of these defects.

But compaction be also an additional factor to result in things like honey combing or for the metal bug hole, subsidence or plastic cracking, etcetera plastic settlement or cold joint formation. So, importance of compaction is actually shown by this right.

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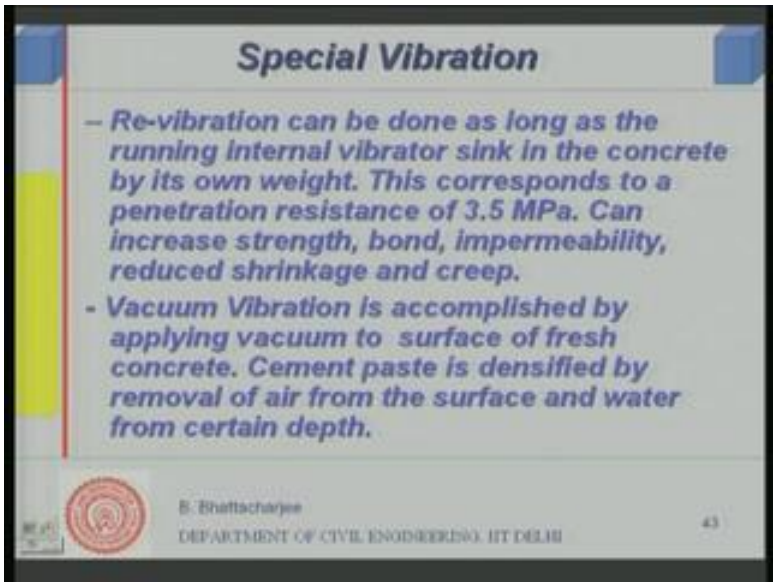

So, let us go back and see something about special vibration some time I might do re-vibrations, but so long my needle can penetrate into the concrete re-vibration is there is no problem my needle must sink into the concrete right. So, this corresponds to a penetration resistance of 3.5 MPa now, penetration resistance is a test for measurement of concrete setting.

If the resistance is high; that means it has already solidified from plastic to the solid state it has gone so long it is less than 3.5 MPa penetration resistance; that means, the needle vibrator can penetrate easily you can still vibrate it right. It can increase the strength, bond, increase the bond strength, it can improve impermeability and shrinkage and creep it will reduce.

Vacuum vibration is special kind of vibration accomplished by a applying vacuum to surface fresh concrete. Cement paste is densified by removal of air from the surface and the water from certain depth this is some special vibration. So, I think we come to the nearly we have come to the end of it.

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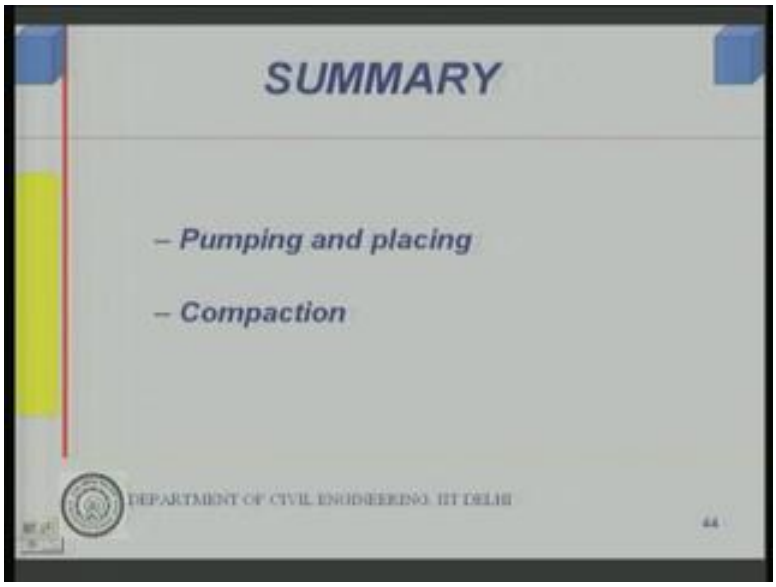

What we have done we have seen pumping and some issues related to placing. We have seen that pumping is really versatile, it can transport the concrete horizontally as well as vertically. You can transport the pump itself therefore, it can go to any place in other otherwise congested site you can place the concrete very easily. So, it can transport and place transport both horizontally as well as vertically.

But you have to actually modify your concrete a little bit with appropriate amount of fines and possibly right kind of slump at the moment that is that would be sufficient for our understanding. Placing we have seen placing should be done in such a manner, that there is no segregation and then we have looked into compaction which means, densifying the concrete, driving out their voids, the mechanism of compaction.

Finally, what would happen if you are not done proper compaction I think that is the end of this lecture.

Thank you very much thank you for hearing.