Concrete Engineering and Technology
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Lecture - 31
Grouting and importance of formwork in concrete construction

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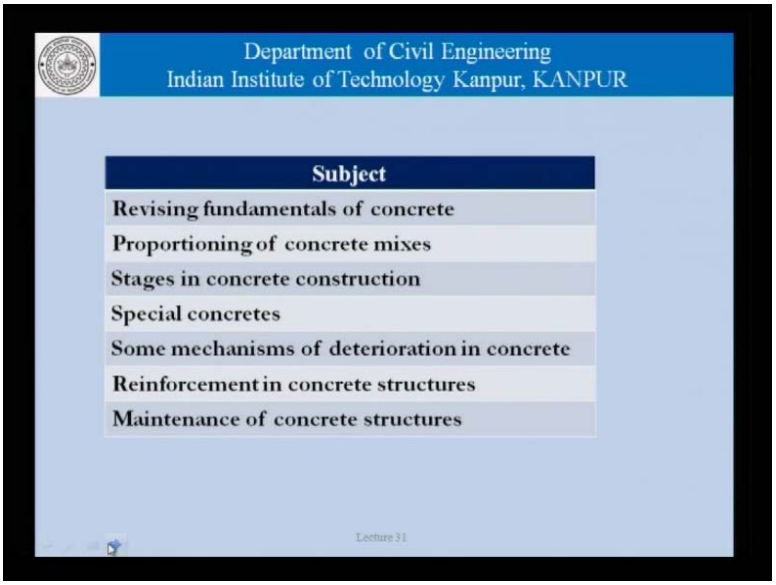

[FL] and welcome to this lecture in this module of concrete engineering and technology where, we are talking of divorce subjects ranging from fundamentals of concrete, proportioning of concrete mixes, stages in concrete constructions, special concretes, mechanisms a deterioration, reinforcement in concrete structures in maintenance. The idea basically beam to have a bird's eye view of the different aspects of concrete and concrete construction including maintenance that a modern day concrete engineer is expected to be familiar with.

In addition to the topics that we have covered here there are some topics which are of special interest, the concrete engineers and do not really fall under the embed of traditional concrete engineering. But, have been said that some understanding of these topics is absolutely integral and vital to ensure quality concrete construction.

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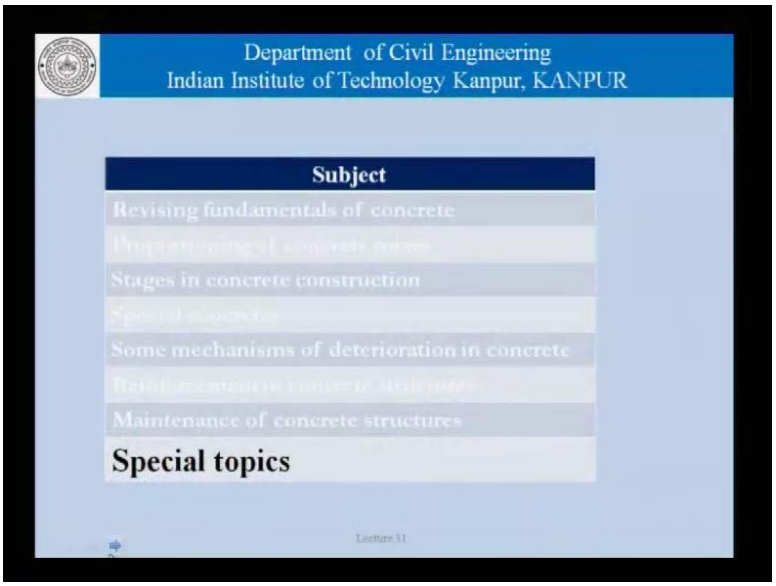

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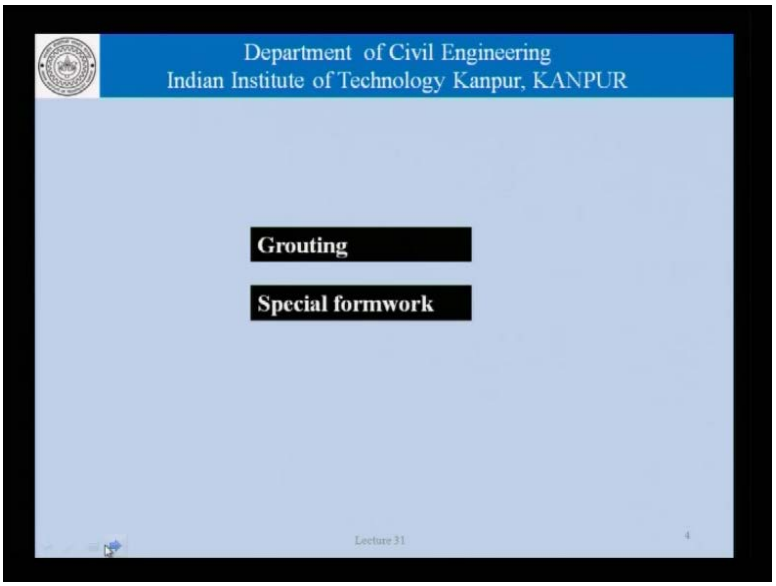

And today we will focus on 2 such subjects. One of them being grouting. The second will be special formworks. So, we know but, formwork is we will be talking about some special issues related to formworks; developments in the formwork engineering if you want to call it that have taken place in the last couple of years.

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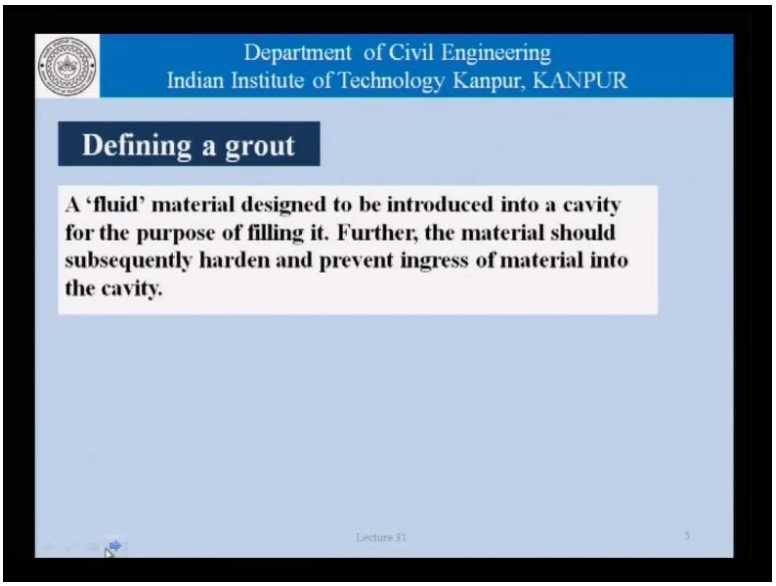

So, now starting the discussion with grouting. What is a grout? It is defined or it can be defined as a fluid material designed to be introduced into a cavity for the purpose of filling it. Further, the material should subsequently harden and prevent ingress of deleterious material into the cavity.

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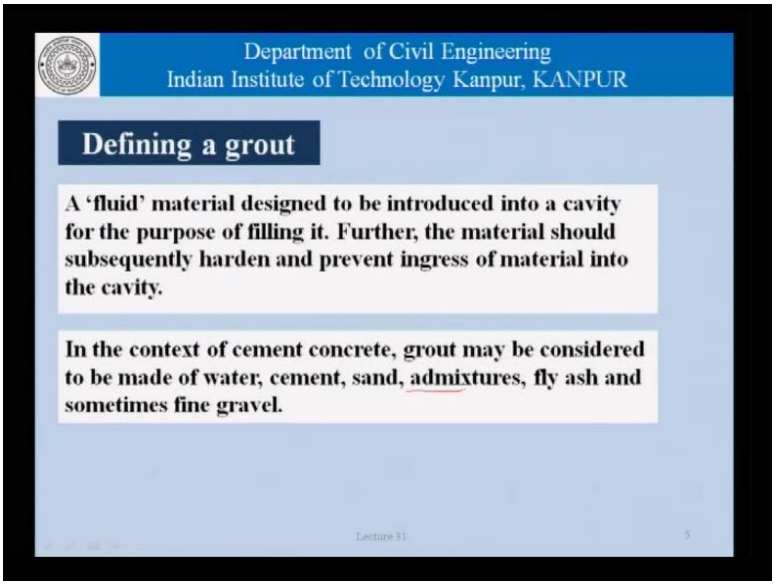

So, in a manner of speaking when the dentist fills the cavity with some material it is also grouting, accept that in most cases he does not apply any pressure or the pressure applied is limited to pressure applied by the hand that in are a kind of work that is in the kind of

civil engineering that we talking about. It would be basically application of mortar, that is what we do when we apply mortar to a surface of quick work or concrete and so on. However, when it is grouting typically there is special associated with it, we fill the cavity with the fluid material under pressure and that material hardens in the cavity.

In the context of cement concrete, grout may be considered to be made of water, cement, sand, admixtures, fly ash and sometimes fine gravel. Now, fly ash in mineral admixture. It can be used, it may not be used. When we said admixtures here, we are typically referring to chemical admixtures which could be water reducing agents, accelerates at time and so on. And at times other than the sand which is having a certain (( )) size we could use slightly bigger particles than that and still use it in grouting.

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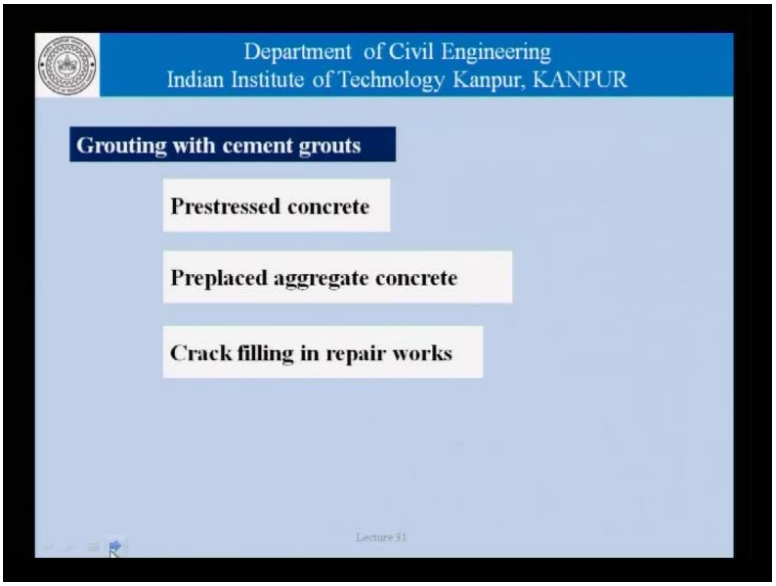

Now, coming to the applications of cement grout as for as civil engineering is concerned. One of them is in pre stress concrete, the other reason preplaced aggregate concrete and the third is crack preliminary repair works besides several where applications which are not traditionally which are not really in the embed of concrete engineering. Coming to pre-stress concrete, we had talked about at sometimes that there are 2 kinds of pre-stressed in concretes.

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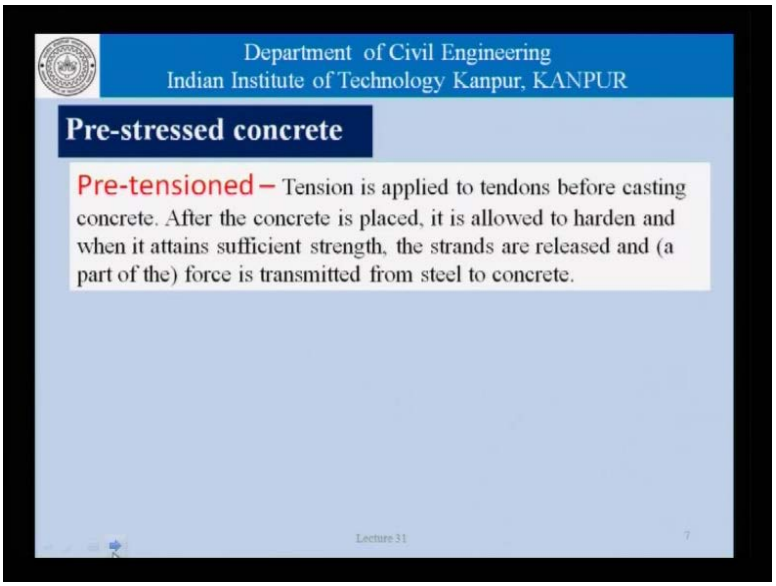

One is pre-tensioned where, tension is applied tendons focused in a concrete and after the concrete is placed it is allowed to harden and when it attains sufficient strength, the stands are released that is, the tension in the stands is then transferred from the steel to the concrete or at least a part of it is transferred the concrete and by that token the tension in this steel tendons reduces is to some extent. Coming to post tension systems

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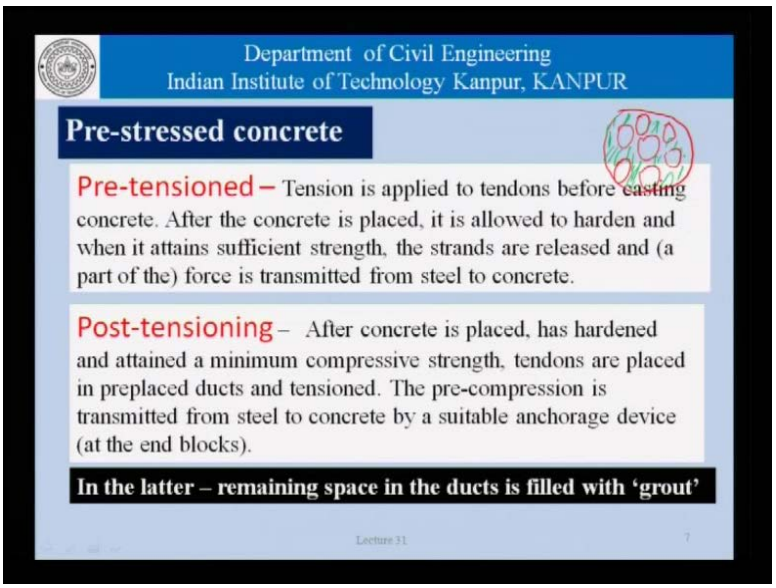

In this case after the concrete placed it has harden tendons has obtained how many minimum compress strength, tendons are placed in preplaced ducts and tensioned. So,

basically the ducts are already in place at the time when the concrete is casted. The pre-compression is transmitted from the steel to concrete by a suitable anchorage device at the end blocks. So, this is the principle of post tensioned concrete.

And in the later case which is post tension system, the remaining space in the duct is filled with grouted times. So, basically what is happening is that, if we have a duct we have a certain amount of space which gets occupied by the tendons and the remaining space here, this space is what we seek to fill with grout.

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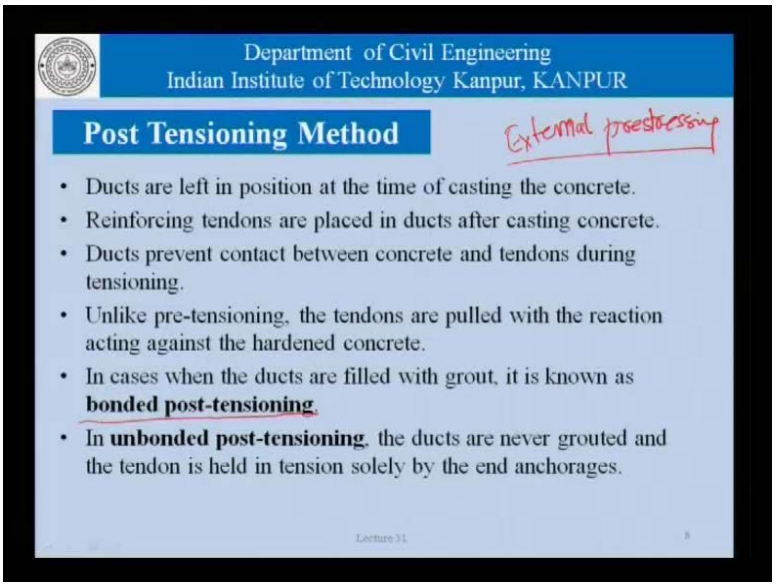

As far as the post tensioning method is concerned: the ducts are left in position at the time of passing the concrete, reinforcing tendons are placed in the duct after the concrete has been cast, the ducts prevent contact between the concrete and the tendons during tensioning, unlike pre-tensioning the tendons are pulled with reaction against the harden concrete and that is why we need a certain amount of strength in the concrete before the tensioning can be done.

In cases when the ducts are filled with grout the whole system is known as bonded post tensioning and that is what we talked about in the previous sketch that we made. In the case of unbounded post tensioning the ducts are not grouted and the tendons have then tension solely by the and anchorages. And in this contacts I would like you to look up the systems that have been used in external pre-stressing. So, external pre-stressing is a completely different thought process compared to normal pre-stressing in terms of

pretension and post tension that we talked about just now. In these sense that these tendons are placed outside the member which is been pre-compressed. We will talked about a little bit when we talk about some discussion on external pre-stressing would take place, when we talk about repair systems is one of the method that is often used as a rehabilitation tool.

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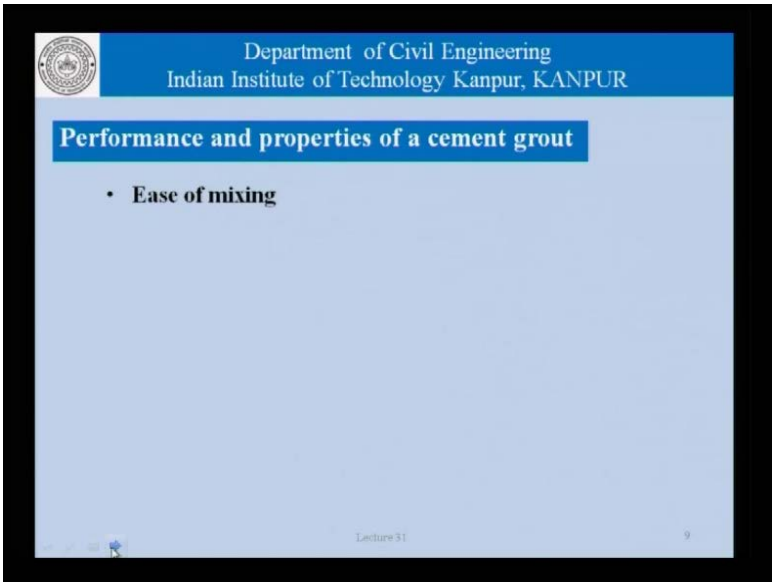

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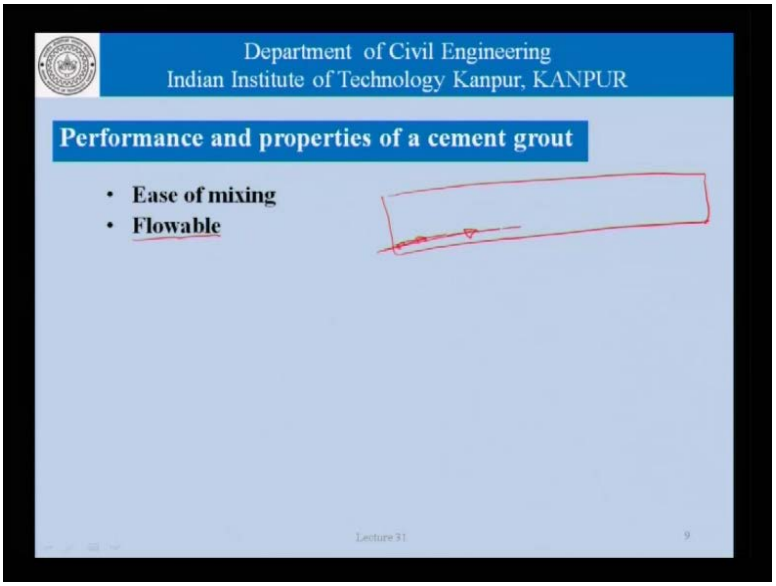

Now, coming to the performance and properties of a cement grout. After all when are grouting, a duct trying to fill this space in the duct which is left after the tendons have

been placed we need to have a certain performance, we need to have grout which fulfills certain criteria. One of then obviously is the is of mixing the materials should be such there it can be easily mixed. Secondly, it should be flowable. Unless the grout is flowable, it will difficult to push the grout into the duct.

And please remember that these ducts are often several meters longs. So, if we have a concrete guarder which is let say 20 meters long, what we would expect is that the grouting operation should starts here, the grout would accepted to flow to a reasonable distance may not be the entire 20 meters because we could be trying to grout though multiple locations but, still they would be a substantial distance involved for the grout to be able to flow and that is why we need to have flowable grout. At the same time if the grout is not having a flowing consistency it would be difficult to even use normal pumps in the construction process.

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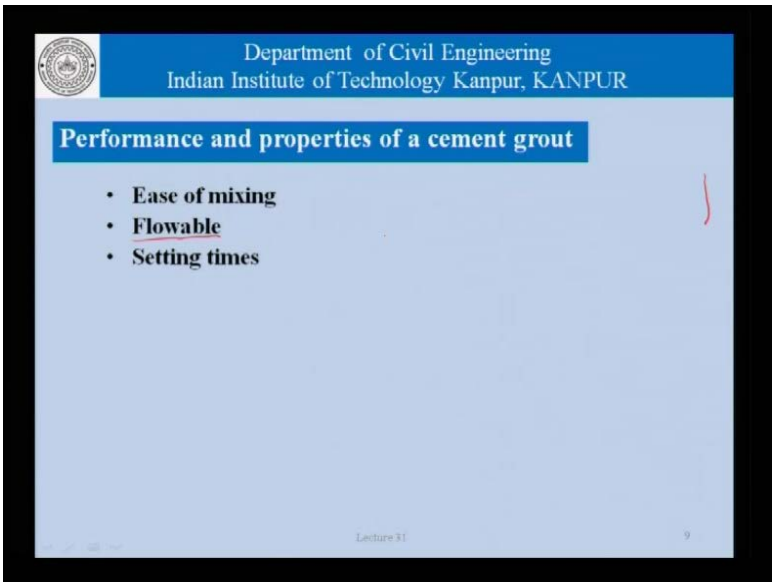

Another property for the grout which would be of interest was is the setting time. Like all concrete construction, the grout once it is re-stress final location we would like the system to set and therefore, the setting time is of great importance as far as grouts are concerned.

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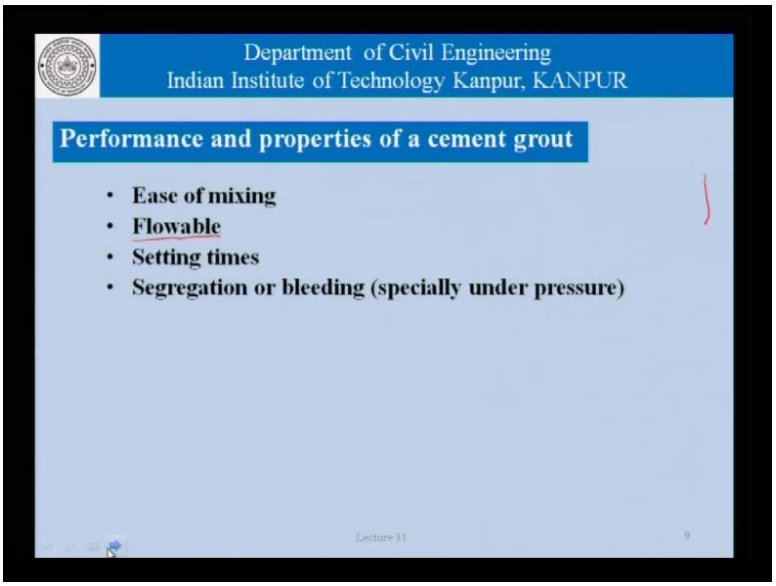

Segregation or bleeding specially under pressure. Grout like any cementitious composite that we have talking about tends to bleed. That is, water tends to separate out from the constituent materials and this tendency for segregation is sometimes enhanced when the material is beam moved under pressure. So, to have to be able study or we should have a bench mark on what is an acceptable level of bleeding.

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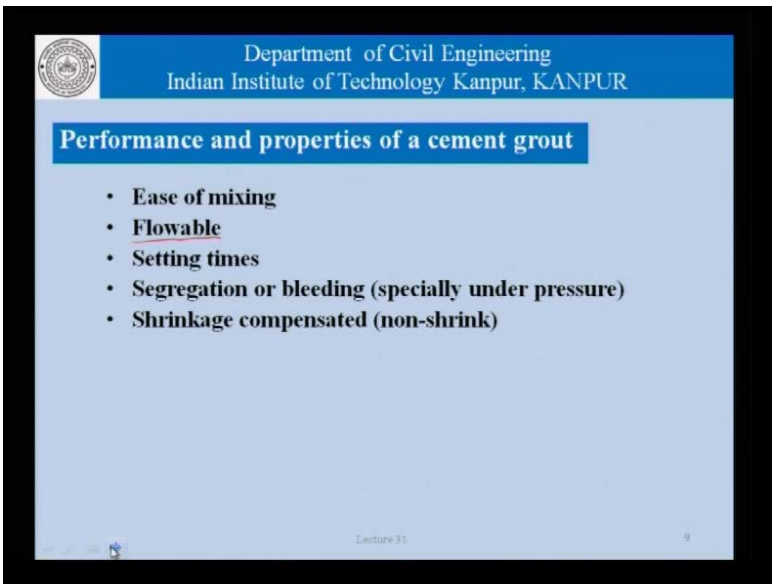

Shrinkage compensated - Again, grouts because they do not have cores segregate. Proportionally speaking the volume of cement is much higher and therefore, there is a

tendency for the grout to shrink unless special measures are taken to admixtures so on. To make and design shrinkage compression grouts that is non-shrink out do not have which do not shrinkage.

So, therefore we do not test which will determine the shrinkage that grout under goes and have specification is which will say that only a certain amount of shrinkage is acceptable.

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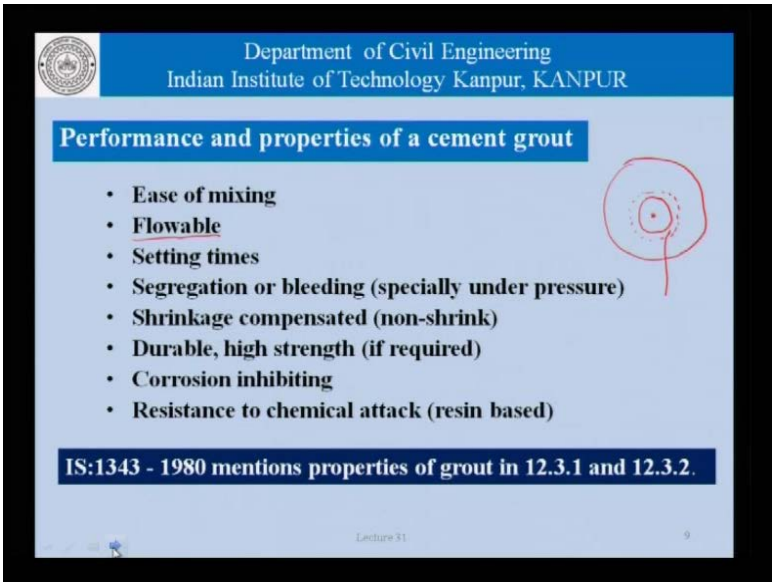

Durability and strength are obviously requirements in any cement based construction and grouting in post tension concrete, ducts is no acceptation we need or we made specified that for the grout that we will use it is the certain strength at a certain point time whether it is 28 days of 7 days or 3 days or whatever the time being.

Corrosion inhibition: Remember that the function of grout is that it should surround the tendon and one of the purpose of having the cementitious grout is to protect this tendon against corrosion. Therefore, effort is sometimes made to use a corrosion inhibitor. Night rites are example of non-corrosion inhibitor and they are used sometimes in the grout in order to impart operator corrosion resistance to be tendons. Resistance to chemical attack is an important issue especially for dealing with chemical grouts or specially dealing with reason based outs rather than cementitious grouts. As far as specification are concerned for example, in India highest on 1343 mentions some of the properties that are required as far as grouting in pre-stress concrete construction are concerned in sections 12.3.1 and 12.3.2.

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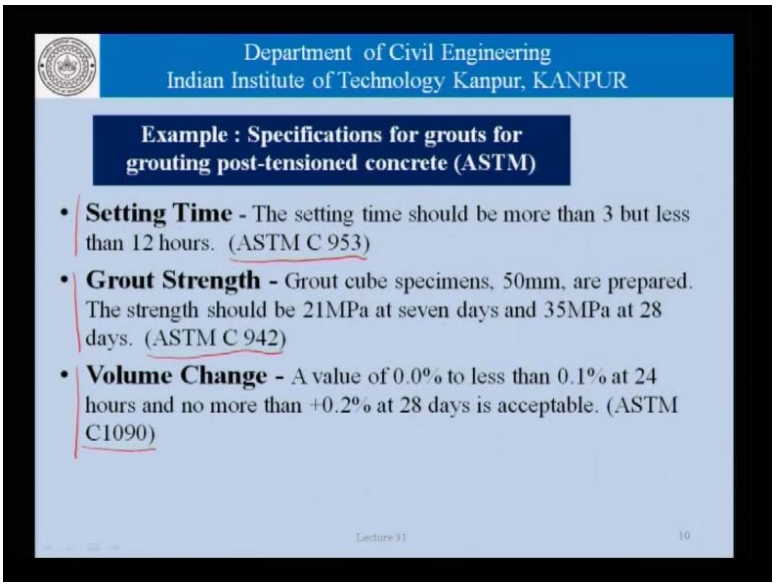

As far as ASTM standards are concerned, some examples or some performance parameters are that the setting time should be more than 3 hours but, less than 12 hours. Strength of the grout tested with 15 mm, specimens at 7 days is required to be at least 21 MPa and a 28 days is 35 MPa. Similarly, the volume changes: there are specifications on how much is acceptable volume change at 28 days. It should be remember that when it comes to setting time or grout strength or volume change this test have to be specially design and I would request you these refer and read these standards in order to be able to understand and appreciate the tests completely.

It is important to note how the setting time of grout is determined and how it is different from that of the setting time of cement. With this connection we will also recall that we have talked about the setting time of concrete and that again was a very special method, not really same as testing the setting time as cement but, in principle the same that is based on penetration resistance and same is the story with strength and volume changes for as grouts are concerned.

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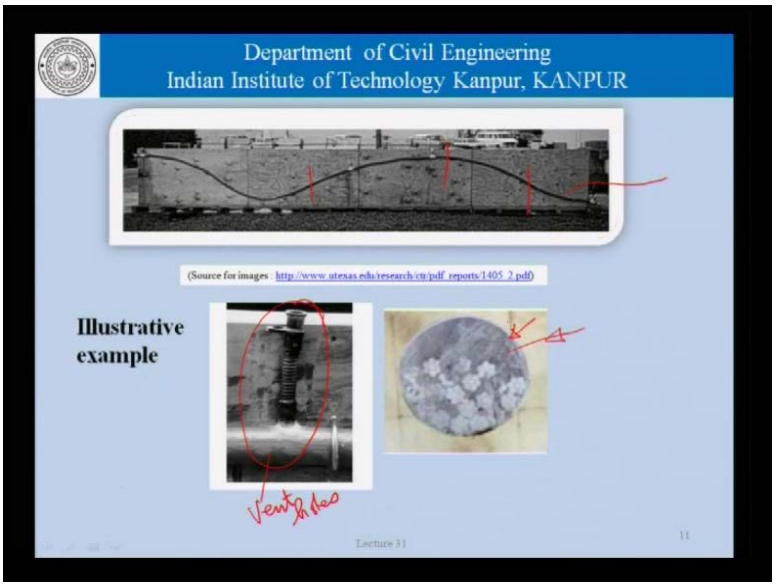

Now, this here is an illustrating example taken from one of the references. So, the pre-stress tendons are not necessarily straight and they could follow the profile which sometimes looks like this. And these here are vent holes which help us remove the air from the duct while the grout has been moved in and then of course, we can try to take pictures of cross sections at different places and try to see whether or not the duct has been fully filled with grout.

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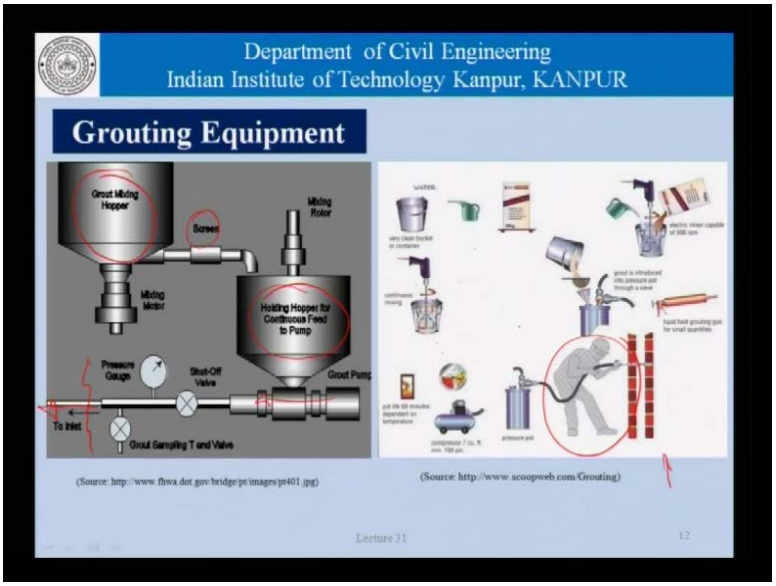

This here is an illustrating example of water which is a kind of equipment that is used. We have a mixing hopper here where the material is being mixed. Through a screen the material listed into a hopper and then, to a pump and finally, to the inlet where the grout is transferred from the mechanical system here to be concrete duct. This here is another example where we can see that there is a person involved at the end of it carrying out the grouting operation and the quality of grouting done is very much related to this skilled of the percent involved.

So, there is no denial that work men shape is one of the very important determinants as far as quality of grout is concerned.

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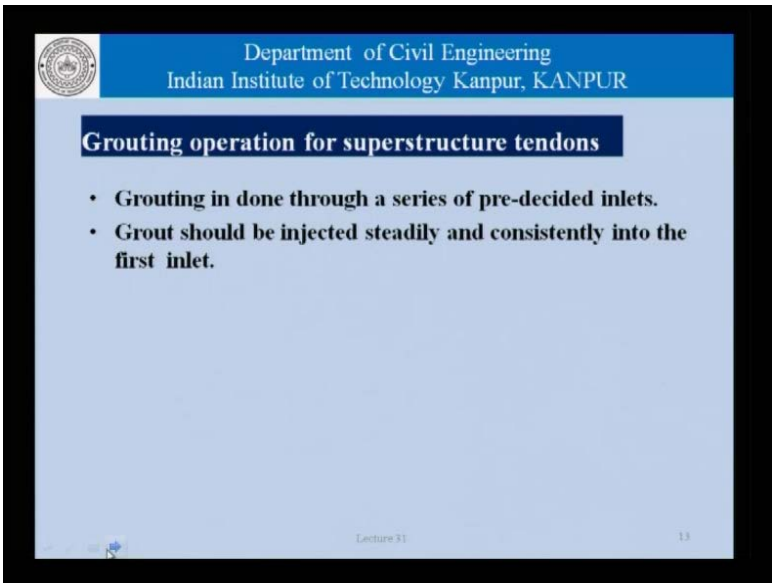

As far as the operation for superstructure tendons is concerned, grouting is done through series of pre decided inlet. Grout should be injected steadily and consistently into the first inlet. So, we cannot have intermediate supply of grouting, we cannot just grout a little bit stop then, start grouting again that unnecessarily needs to air pockets in the grouting systems and that is very highly understandable. So, we must ensure that the grouting is carried out steadily and consistently once the operation has started.

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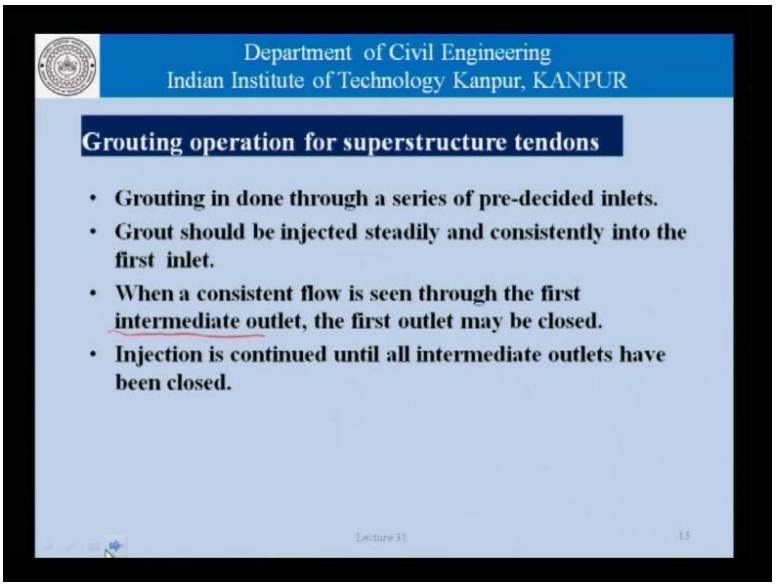

When a consistent flow is seen through the first intermediate outlet. So, there are series of outlets and we are trying to pump the grout into the first outlet and as the grout immerges in the second outlet of the first into which is outlet the first outlet can be closed and then we used the second point as the inlet to push the grout further and this processes carried on till all the grouting completed. As we say here injection is continued until all intermediate outlets have been closed.

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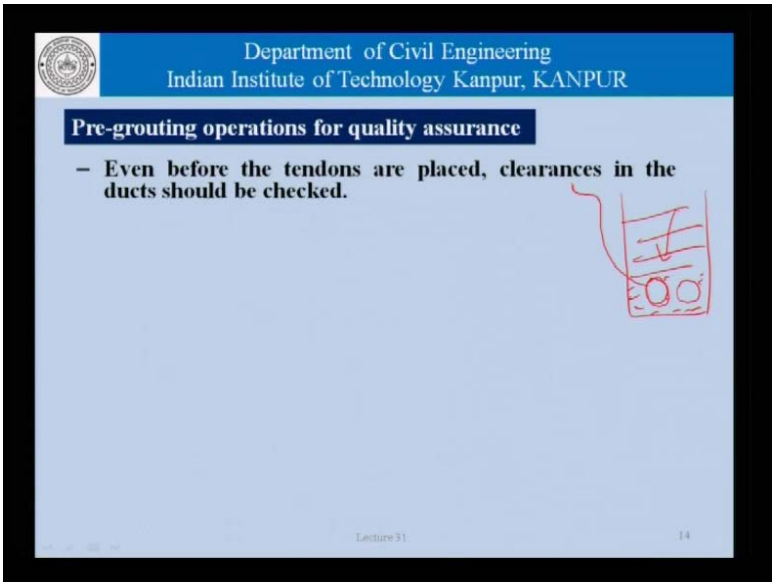

As far as pre-grouting operations for quality assurance of the whole program is concerned even before the tendons are placed. So, what happens is that if we have a concrete beam and we have this duct where we want to place that pre-stressing tendons later on. At the time of casting the concrete here, vibrating it in all that can process these ducts may get deformed and if these ducts deformed during the concreting process it will become difficult for the tendons to be placed. And this is the kind of check which is being done here that is even before the tendons are placed clearance in the ducts should be checked. It should be ensured that the tendons can be easily placed in the duct.

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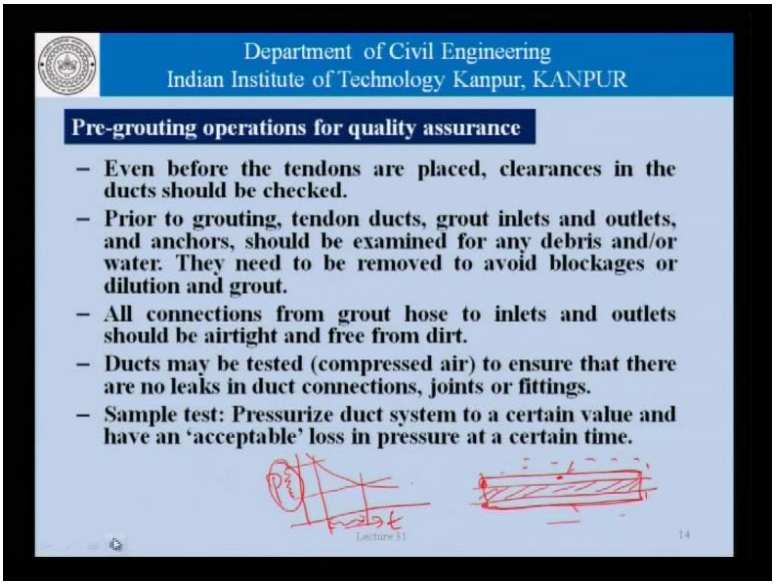

Prior to the grouting, tendon ducts, grout inlets and outlets and anchors whatever they are should be examine for any debris and or water. They need to be removed to avoid blockages and or dilution of the grout.

All connection from the grout hose to the inlets and outlets should be airtight and free dirt. Ducts should be tested using compressed air to ensure that there are no leaks in duct connections or joints. Now, how do we do that? One way of doing that is pressurize the duct system to a certain level and then have an acceptable loss in pressure at a certain time. So, what will happen is that, if we have a duct system here we surrounded by concrete and so on, it obviously has some tendons in it and this void has to be filled. They will be some obvious leaks in the ducts but, these leaks in the ducts and so on cannot exceed a certain value and in order to determine whether there is any problem in

that connection. If we pressurize this air here, if we pressurize the system here, what we will get over time is that the pressure will drop. Now, this drop if it is too much, if this drop is connection stable then of course, we need to carry out repair work on the duct system before we do the ground. Therefore, what we need to do is to say that we will carry out the test for a certain period of time and the pressure drop during that time should not exceed a certain pre-determined or an acceptable level.

So this is how we can ensure an airtight duct system. It is not air tight in this scientific sense of the word but, it is airtight in engineering sense of the word.

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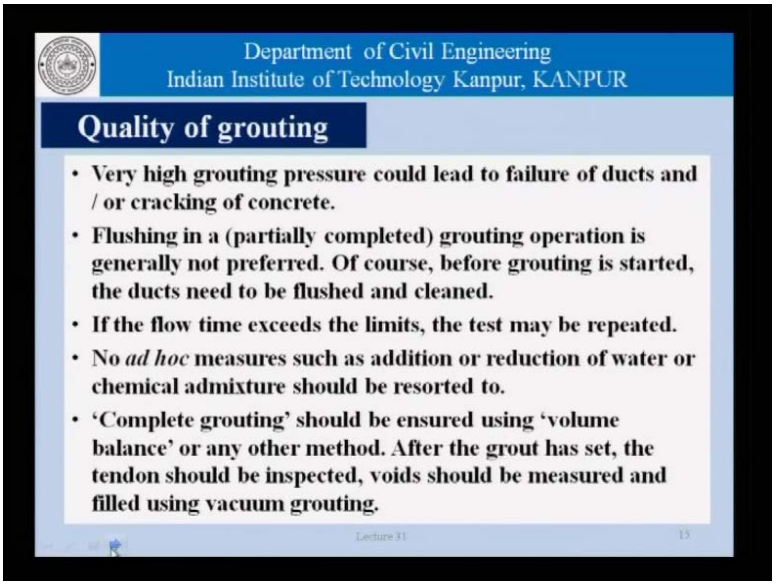

As far as the quality of grouting is concerned very high grouting pressures could leads to failures of ducts and in cracking concrete. Flushing in a partially completed grouting operation is generally not preferred. We cannot stop the grouting operation and then, try to flush it out and then, commence again because of the obvious reason that the flushing may not ensure all the removable of grout and that would become a problem if you want to go back again and grout a system.

Before the grouting of course, the ducts needs to be flushed and cleaned as we discussed. If of course, the flow time that is the flow ability of the grout which is typically measured using normal finals which could be well finals. And specification as given in terms of the acceptable flow time if the flow time exceeds the limit that is the grout is more viscous then is acceptable that test can be repeated once. But, no ad hoc measures

such as, addition or reduction of water or chemical admixtures should be resorted to even though grouting operation carried out in the field.

The field engineers should not resort to ad hoc measures. A grout design for a certain specification if it is not performing in the field for whatever reason it could be, it could be temperature, it could be compatibility of materials, it could be change in material and so on. A proper study should be carried out and then only that grouting operation should be continuity because ad hoc measures could lead to problems later on in the maintenance of the structure. Complete grouting should be ensured using volume balance or any other method. After the grout set the tendon should be respected word, should be measured and filled using vacuum grouting with whatever other method is available.

So, basically there is very little that we can do once we are grouting a post tension pre-stress concrete tendon. We do not know if all the void, if all this space in the duct which was supposed to be occupied by the grout has been occupied by the grout other than by doing some kind of volume balance or carrying out non destructed tests which could be carried out while the grouting operation is being carried out or after the grouter set and then, we look for pockets of air.

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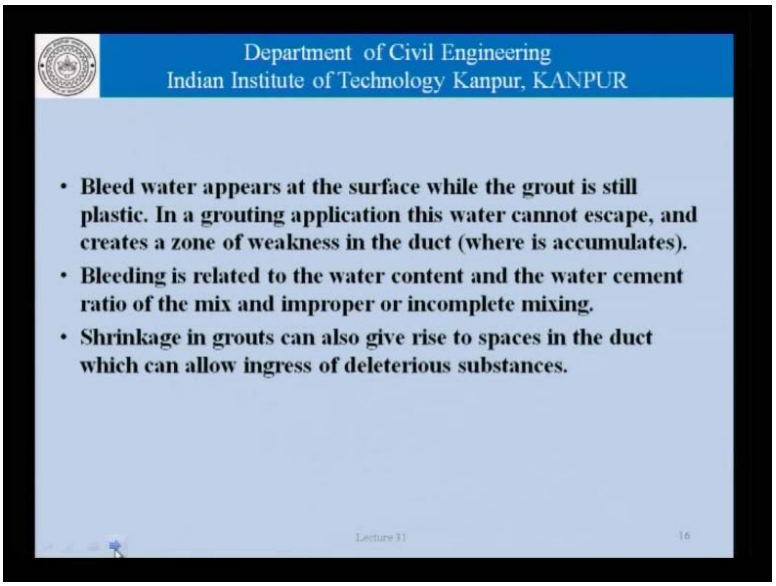

As far as bleeding is concerned, bleed water appears at the surface while the grout is still plastic. And in a grouting application this water cannot escapes and there is no way that

we can take it out, it will therefore create a zone of weakness in the duct wherever it accumulates.

As we have seen in these of concrete, bleeding is a related to the water content and water cement ratio of the mix and of course, improper or incomplete mixing. Similarly, shrinkage in grouts can also give rise to spaces in the duct which can allow ingress of deleterious substances and that is why we need to ensure that grouts need requirements in terms of bleeding and shrinkage in addition to whatever other criteria we may choose.

So far we have discussed the issue of grouting in post tension pre-stress concrete tendons. The principle of grouting is the same but, now let us spend a little bit of time talking about grouting in a pre-placed aggregate concrete system.

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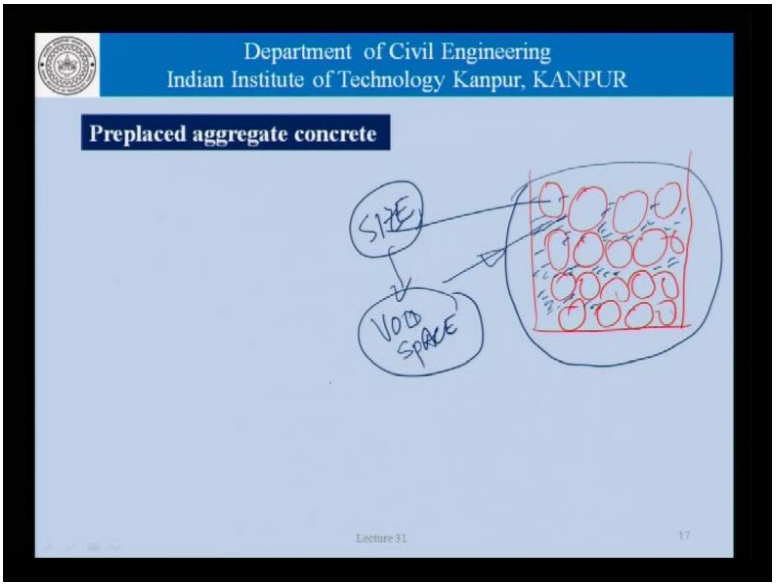

Now, as the name suggest preplaced aggregate concrete refers to a situation where wherever we want the concrete instead of trying to cast the concrete there we placed aggregate first and then, try to fill this space with cement mortar. So, in engineering terms this is what is called preplaced aggregate concrete because at the end of it what we get is a concrete system which comprise course segregate embedded in mortar accept that they were not mixed to begin with only the aggregate first placed first and the mortar was pumped in at the later point of time.

Now, when we are considering the requirements of the grouting material, that is the mortar that we used to fill the system. The principles of grouting good apply that is we would be interested to know, what is the size of the course segregate and the particle size distribution which will determine the characteristics of the void space? If we have very small particles the amount of void space will be different compared to having larger particles. In the case of concrete construction we deal with particle sizes which could be as much as 20 mm or 25 mm or sometime we may be 40 mm. Sand on the other hand is defined as material which is lower than about say 4.5 mm.

So, it is not so easy to decide the characteristics of the grout unless we know what is the kind of void system that we are dealing with which is related to the maximum size and the particle size distribution of the aggregate that we have used.

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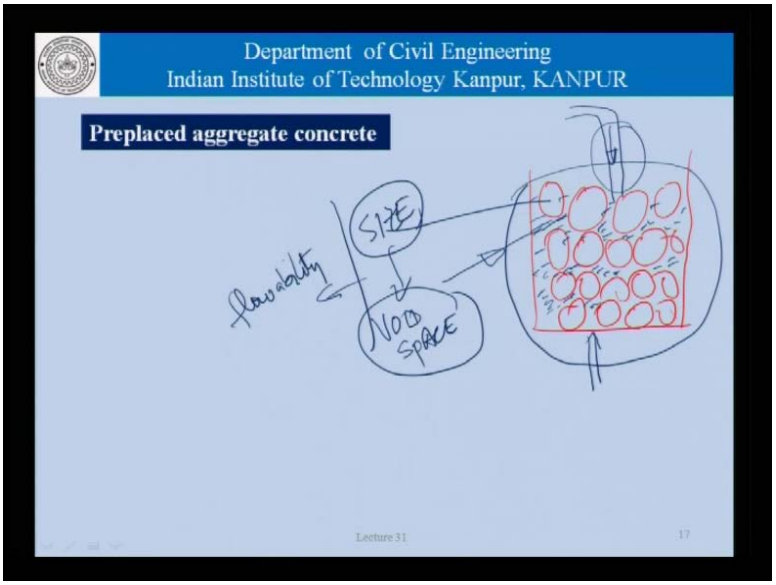

Now, having said that for a given system we need to have a certain flowability of the grout and that is again very similar to the kind of flowability that we were talking about when we talked of grouting in the case of ducts in post tension concrete construction. As far as the construction is concerned in preplaced aggregate concrete where do we start the grouting process, whether we take a pipe and just let the gout flow under gravity filling this spaces here or we try to push the grout under pressure from below. If we are pushing the grouting top there is a possibility that the grout might not reach all the spaces whereas, if you pushing it from the bottom the chances are that we would be able to

accomplish higher filling even though it is more difficult to do. So, there are issues related to quick preplaced aggregate concrete but, in this limited discussion that we have I am just trying to show it as an illustrative example relative to grouting. As far as subject is concerned is lot more to study than of course this.

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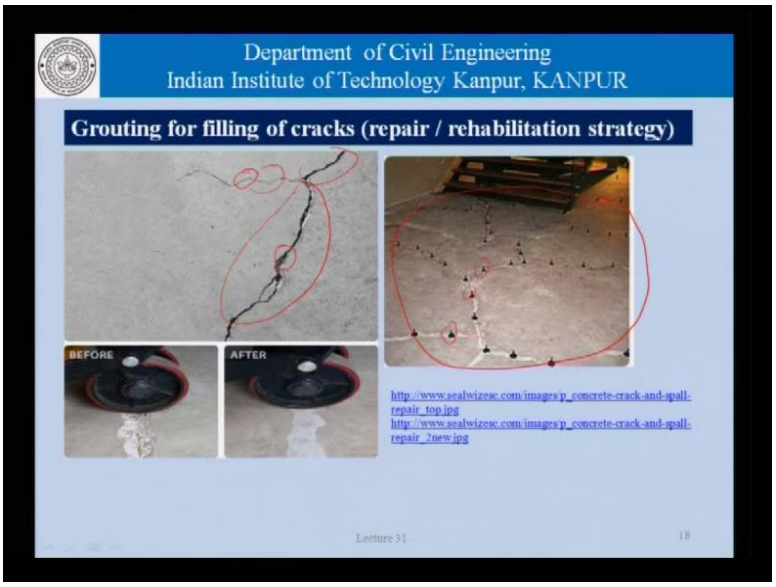

Now, let me just quickly go over the third example of grouting that we are chosen to talk about that is grouting for feeling of cracks in repair rehabilitation strategy. So, if we look at a concrete crack we could typically see something like this. The cracks could be wider, narrower at the surface and so on. What we often do not know is how deep the cracks and therefore, do not have any idea as far as how much volume of the mortar or the grout will be required to fill these cracks. How this filling process works is shown here in this picture. We see that the cracks are sealed; these are nibbles which are left in place and used for the grouting operation. So, once we start filling here, the grout appears starts flowing inside the concrete and then appears in neighboring nibbles and we close those nibbles and start from different places cracking system ensuring that the entire cracks system has been filled with the grout.

So, finally we have a system which looks a little agree because of this kind of patch work along the cracks and that needs to be painted. Obviously, in this cases will be depending on the width of the cracks. We would need to have different specifications for the flowability of the grout that we can deal with. A grout which could flow into a crack

width of this magnitude will not suffice if you are trying to fill cracks of this magnitude. So, these are the kind of balancing acts that an engineer at site means to be play. In order to grout a crack system one has to decide what is the kind of specification, what is the kind of parameter that you would use to control the quality or control the performance of the grout?

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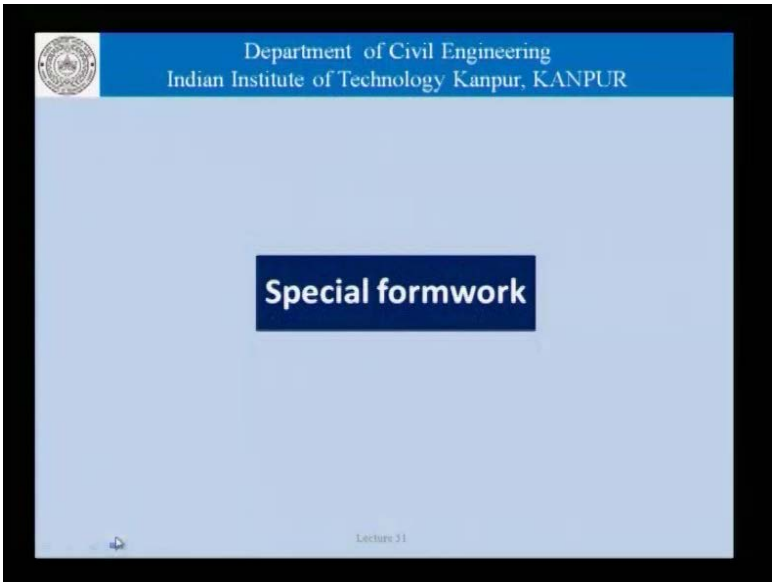

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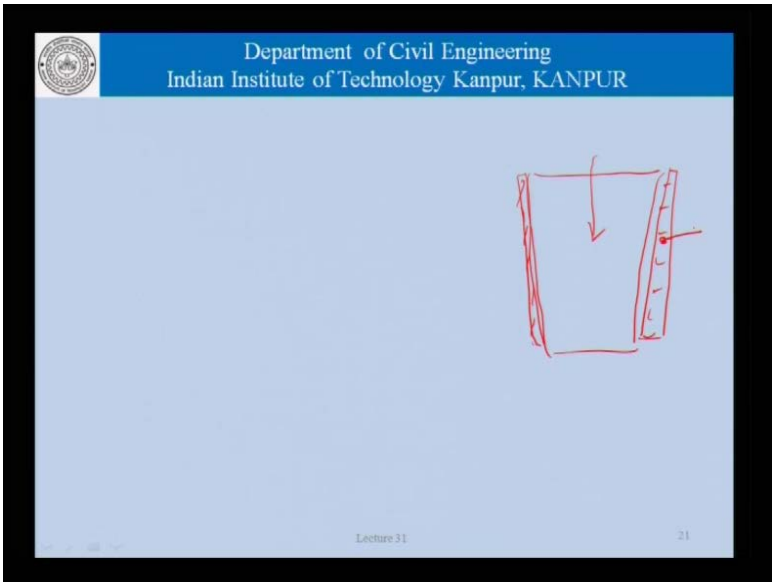

Now, with this discussion we come to an close on the first part of our discussion today which was on grouting. Now, continuing or discussion we talk a little bit about special

formwork. Now, before we talk of special formworks, we must know what is formwork. All look at the form work definition and the function once again.

Formwork really refers to any structure which is put in place before concrete is placed, in ordered that the concrete that is cast inside is given a certain shape. Now, therefore this structure which is the temporary structure that is the form work which is removed after the concrete gains sufficient strength should be such that it is able to withstand the normal loads of construction without impairing the properties of the concrete. Even though it is a temporary system, it is an important system to ensure that the final product of concrete member or the structure that we are taking out has a good quality is important at the form work that we have is of the quality. And therefore, this system also needs to be appropriately designed to ensure that whatever we accept form it in terms of shape, size, tolerance and so on is met.

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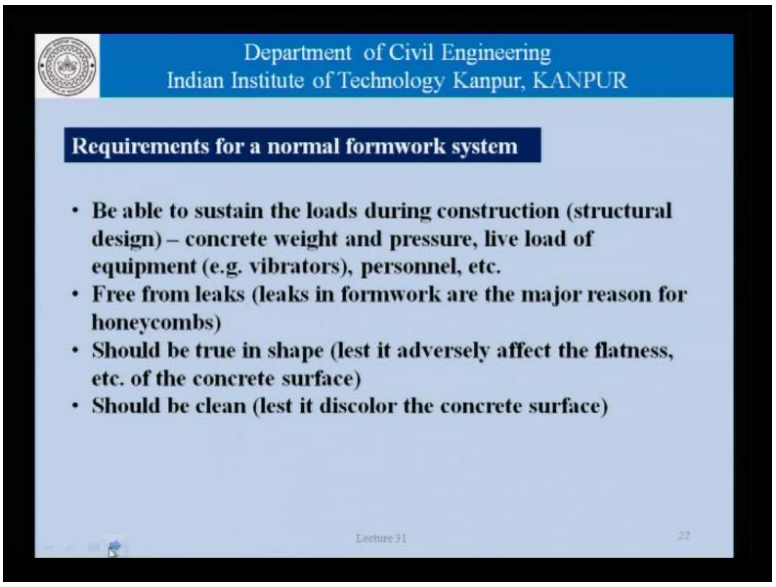

Now, re-iterating these requirements it should be able to sustain the loads during construction and that is more or less similar to that of structural design. The kind of loads that could be are concrete weight and pressure, the live load of equipment that is vibrator and so on, personal that is speed to moving around on the form work or on the concrete during construction, you can think in terms of slab while it is being cast, not only there will be a dead weight of the concrete of the slab but, also there will be some vibrators and other equipments which should be on it, there will be people moving around to

ensure that the concrete is properly cast, vibrated, compacted and so on. And finally, there will be people moving around even after that for curing, inspection and all those kind of purposes while the concrete is still not strong enough. Once it is strong enough it has sufficient strength the formwork in it needs to be removed. How long does it takes is a different matter. It depends on the kind of properties with the concrete, what other kind of strength development so on.

The formwork should be free from leaks. That is, the joints in the plates of the form work whether the they embed of timber or whether they made of plywood or steel, the joint should be free from leaks. They should be properly sealed because leaks in the form work are the major source for honeycombs and honeycombs is something which is highly deleterious and as a direct paring on the durability of the structure. Should be true in shape, unless the form work is true in shape there is no way that we can have a concrete structure which will be true in shape. So, if a wall has to be vertical the slab has to be flat then, it is important that the formwork has the right kind of tolerances that is, those place are not having undulations because if those plates or parallels have undulations the concrete that is cast against them will obviously reflect that. The formwork should between lest it discolor the concrete surface or impart the properties which are not desirable from the settings or any other point of view. Now, this is the generally discussion on any kind of formwork.

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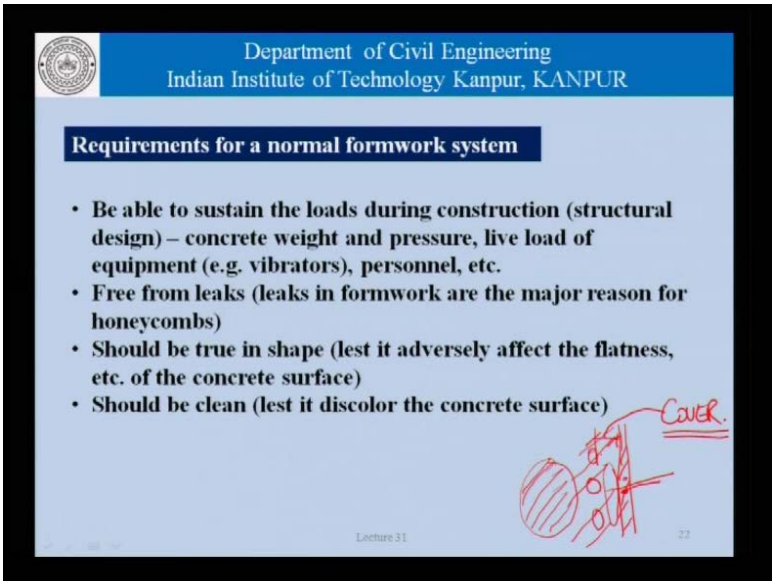

We must also remember that once the concrete is cast against formwork that is if we have this as my formwork panel against which some concrete is been cast and this concrete has reinforcement then, this distance here the concrete here is really the cover concrete. We must remember that depending on whatever happens at the formwork level or in the formwork the properties of the concrete in this portion here are the once that are likely to change closed. Formwork is not likely affects the properties of main body concrete but, it has a direct bearing on the properties of cover concrete. And the properties of cover concrete or a very important issue and then we are talking in terms of durability of concrete structures. Conversely speaking therefore, if we want durable structures we need to have put quality cover concrete and in order to ensure good quality cover concrete we need to have good quality formwork and that is what gives raise to special formworks and the whole lot of discussion relating to that aspect. Some of it which we will briefly discuss from this point onwards.

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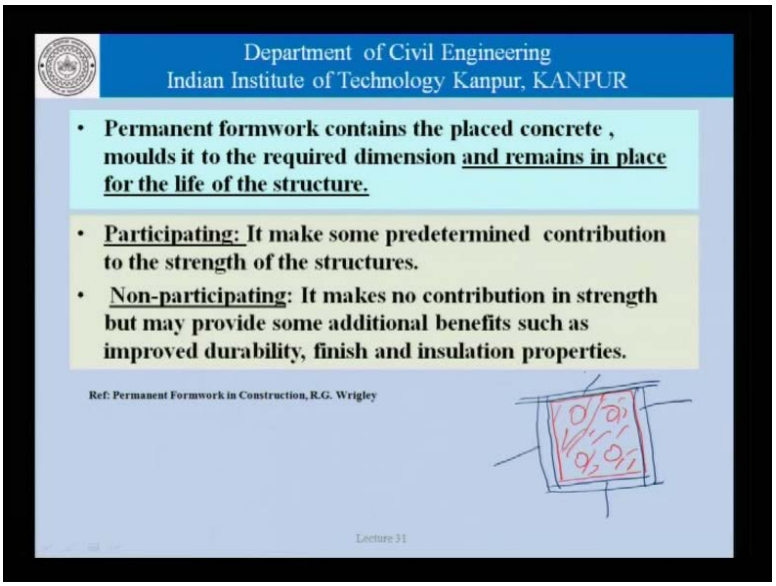

Now, coming to special from works. Let us first talk in terms of what is called permanent formwork. Temporary formwork is the normal formwork which is removed after the concrete has achieved sufficient strength. Permanent formwork on the other hand contains the placed concrete, molds it to the required dimension and remains in place for life of restructure. That is, this formwork is not removed after the concrete has been cast it becomes part of the concrete remember itself.

Now, in this there could be two kinds of permanent formwork, what can be called as an participating formwork and one is participating formwork in which case a predetermined contribution is may it to the strength of the structure. That is, the form work is part of the is structure behavior as far as the concrete number is concerned and of course, then we can have a non-participating formwork where it makes no contribution at the strengths but, provides only additional benefits in terms of durability, finish and insulation and all that can be.

Now, let me explain this is sure little bit again. Consider a column with reinforcement and whatever it is. If this was the normal concrete that we used, what we would do normally to cast this column against panels which could be made of plywood or steel and we remove these plates.

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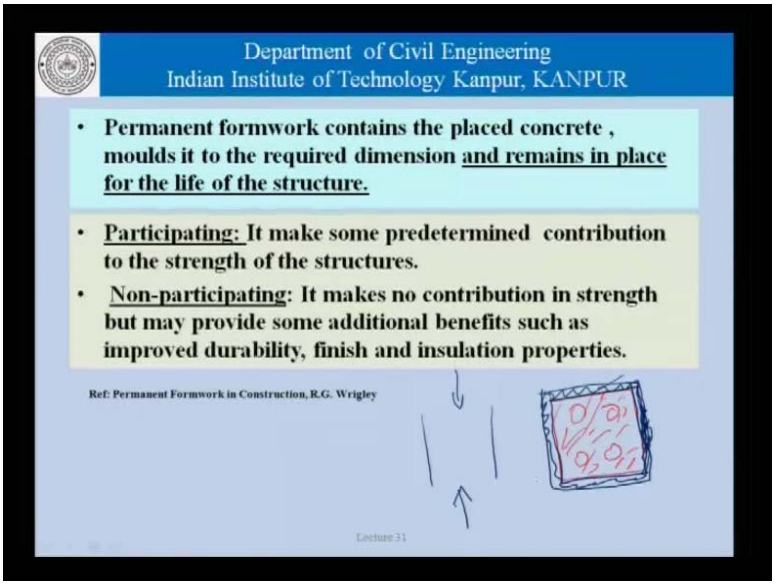

This is the normal construction that we would do. As against that, if the panels were now such that as against that, if these panels were now such that they would remain as a part of the column and not removed then, we can expect two things. One is that this panel is depending on it is thickness, the material, the kind of structural properties and so on. This panels are considered when we talk in terms of the load carrying action or the load bearing action of this column is concerned. The other option of course, the other possibility of course, is that these panels are not considered when we talking in terms of

the load carrying mechanism of the column and the same thing really holds for the beams as well.

So, we have participating permanent formwork and non-participating permanent formwork. That formwork differs from regular formwork, in that sense that it becomes a permanent part of a structure and is not struck of after the concrete has hardened and gain sufficient strength.

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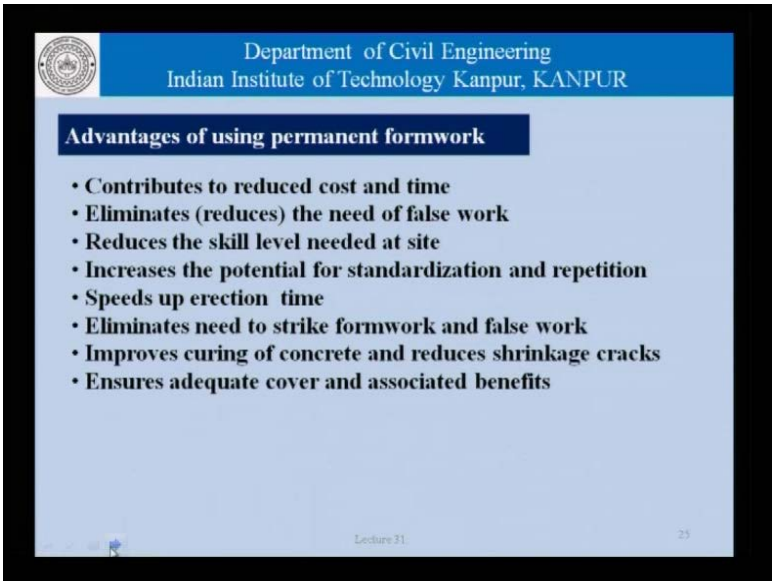

Now, an advantage of using this kind of formwork system is that it could contribute to some kind of reduction in cost and time because we do not have to wait for striking of formwork. The entire processes for as striking of the formwork is simply not there and once the concrete has been cast we can proceed with the other operations. It eliminates the need for doing any kind of false work, reduces the skill level needed at site because formwork is skilled operation erecting the formwork is a skilled operation. Most of these panels that are made are precast or prefabricated panels which are used in the construction and therefore, the skill level required in the direction is different and of a much smaller magnitude compared to erecting normal formworks. Increases the potential for is standardization and reputation. Now, this is something which is very important as for as civil engineering construction is concerned that if we have standardization in sizes then, it becomes lot easier for all engineers to have certain discipline as far as quality control is concerned.

Flexibility in concrete construction is of course, the principle reason why concrete is a popular material but, if we have some kind of standardization as far as sizes and so on concerned it will help in ensuring better quality control. Speeds up direction time, eliminates the need to strike formwork and false work, improve the curing of concrete and reduces the shrinkage cracks. Obviously, the purpose of curing is to ensure that water from the concrete does not escape into the atmosphere and if you have permanent formwork then, what we have ensured is that the passage of water to the atmosphere becomes all that more all that must more difficult. Ensures adequate cover and associated benefits, as we try to draw in the previous pictured. Having permanent form work effectively adds to the covered thickness or depending on how would designer use the cover thickness we can have a reinforcing bar here

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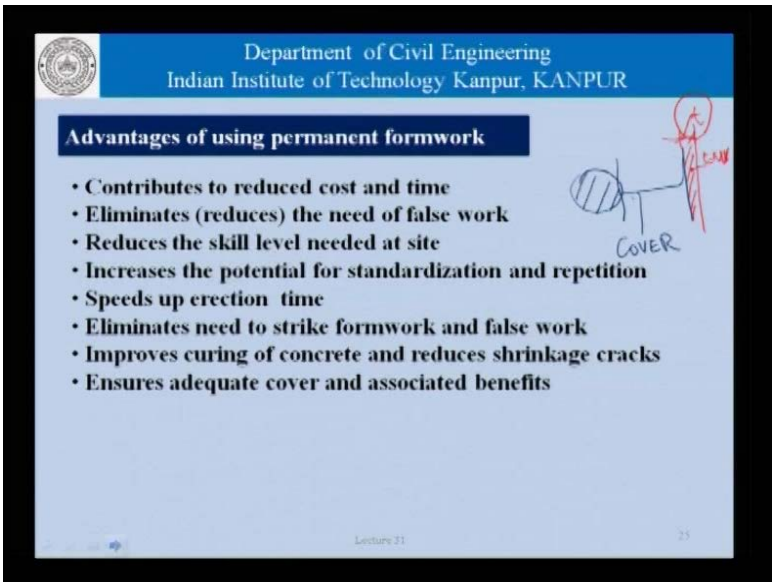

We have normal concrete up to this point and this is our traditional cover concrete and if beyond this point we have a permanent formwork of a certain amount of thickness. Now, whether this thickness here of the permanent formwork is to be counted towards the cover thickness or not is decision which designer has to take. It has to have certain sanction as far as specifications and design methods are concerned. But, none the less it should be bond in mind that we end of it this permanent formwork is also contributed to protect in the reinforcement from the environment outside. Permanent formworks can be used to provide decorative finish surfaces because this per side of the panel is not cost

into. It can be used to provide decorative finish surfaces because they outside of the panel we can have designs, we can have colors or what were we want.

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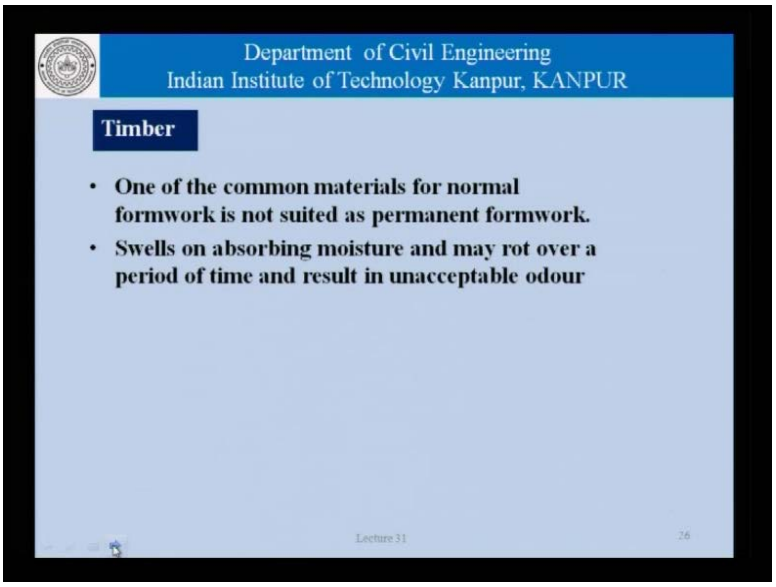

Now, let me talk about timber or plywood which is one of the most common materials used for normal formwork is not really suited for permanent formwork construction because it absorbs water, swells and may rot over a period of time and result in unacceptable odour. So, these are the kind of problems that normal plywood applications would have if we were to allow them to be part of the concrete structure and that is why we not have them which gives us a pointer as to what are the kind of materials that we are looking for when we are talking in terms of permanent formwork.

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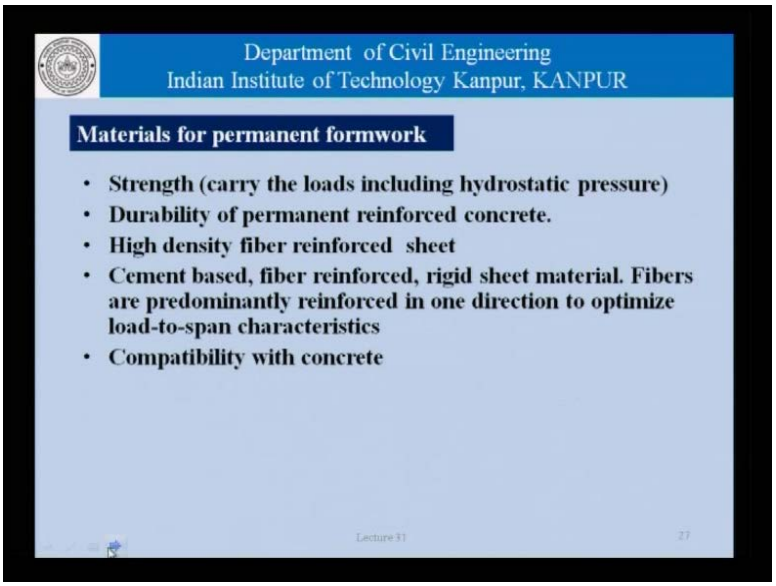

The material should be such that they have sufficient strength to carry the loads including the hydrostatic pressure of concrete that mean act, they must have sufficient durability, they could be therefore, made of high density fiber reinforced sheets. It could be cement based fiber reinforced rigid sheet. Fibers are predominantly reinforced one direction to up to optimize load to span to characteristics in those panels and there should be a compatibility of the formwork panels with the concrete itself.

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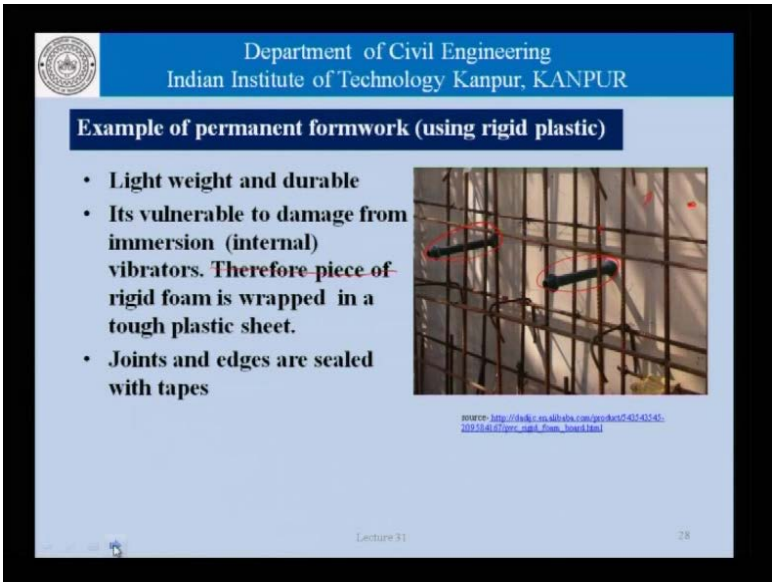

With this discussion in mind let us take a look at some of the examples. Here, we has talking in terms of an example where a rigid plastic sheet is being used as a permanent formwork and we can see normal reinforcement here and these kind of anchors which are going to help the formwork remain as part of the concrete constructions.

So, as far as rigid plastic sheets are concerned, they are like weight and durable. It is vulnerable however to damage from immersion or intern vibrators. So, if we are casting the concrete against this kind of formwork and we use internal vibrators. Those vibrators will obviously impact the form work sheet as well and therefore, unless the sheet are a strong enough able to with standard vibrator impact the formwork sheets a likely to be done and that is something which we need to be careful about either by choosing the concrete that we use properly. We could use self-compacting kind of concretes which do not require internal vibrators and ten use these sheets or we place something to ensure that the joints and edges of the rigid plastic sheet are properly sealed with the tapes.

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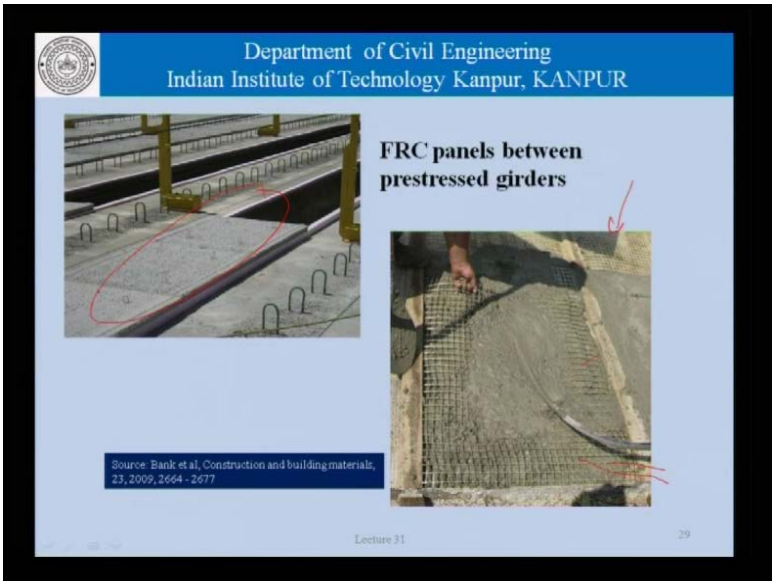

Here is another example where fibers reinforcing concrete panels are used as permanent formwork. So, here we can see these panels which are been placed between pre-stressed girders during reinforce concrete construction. Now, this picture here shows the fabrication of such a panel and we can see these kind of a wire mesh or a fiber mesh and normal cement mortar has been placed and the panel has been fabricated. Of course,

there is a possibility that there can be several layers of this fabric to reinforce the permanent formwork panel.

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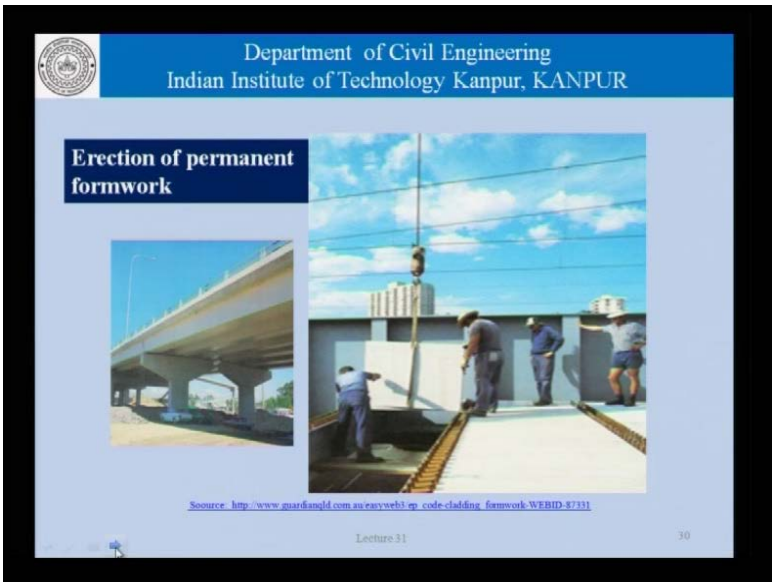

Here an example of erection of permanent form work and we can see how the panels are been placed in position.

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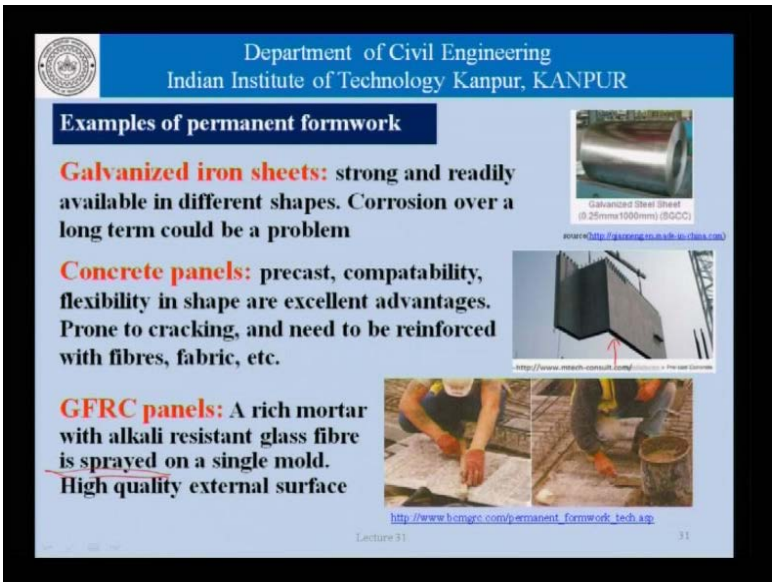

Other materials as far as permanent formwork is concerned could be galvanized iron sheets which are strong in readily available and different shapes. Corrosion over a long time could be a problem in the case of using sheets in therefore, we need to be careful as

to what kind of tests are carried out to ensure the durability of these sheets. Concrete panels which are pre casts, highly compatible with concrete construction.

We have the flexibility in shape are excellent that advantages and that context. However, this concrete finals or prone to cracking and need to be reinforced with fibers and fabric, like this saw in the previous pictures and here as an example of these panels being erected in placed in position for the concrete to be cast. And we have glass fiber reinforced concrete panels in which case we have reach mortar with alkali resistant glass fibers prayer into a single mold and this spraying business remains as of shotcrete and fiber reinforced shotcrete and we have done earlier and panels made in this manner can be used as permanent formwork much in the manner as being shown here.

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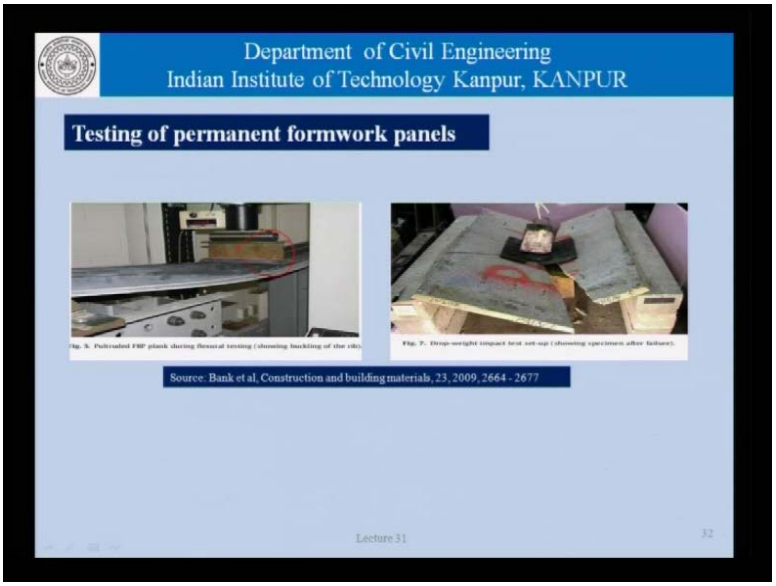

Indeed, when we are trying to work in terms of permanent formwork panels. There have to be tests in order to ensure that those panels can indeed take the kind of load that will act on them during construction and during the early stages when the concrete has not developed whole strength. As far as participating formwork is concerned where that formwork is also expected to be a part of the load bearing action of the concrete member. We need to have tests to figure out how to understand these structural behavior of these columns and this pictures here showed 2 tests, a static test kind of situation here to figure out or to understand how the panel deforms under the application of load and of course, there can also be a situation and other than a static test there we can also be a drop

weight type of an impact setup which is shown in the picture right where, we try to understand the impact resistance of a panel.

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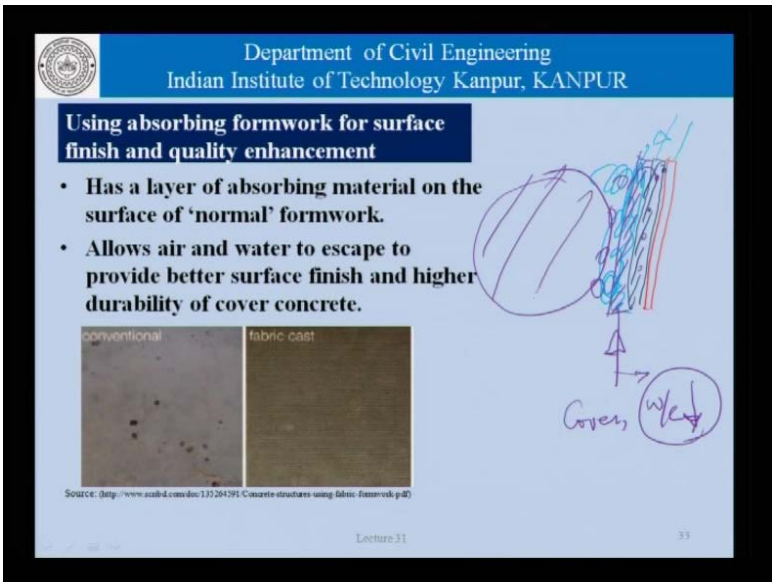

Now, coming to another category of formwork which is not necessarily permanent. We have absorbing form work and in this case we use them to get better surface finish and quality enhancement of the cover concrete. This formworks have a layer of absorbing material on the surface of normal formwork. So, what we really have is a panel of normal formwork on which an absorbing layer is fixed and then the concrete is cast. So, basically instead of casting this concrete against this normal formwork panel, an absorbing layer is in introduced in between which is attached to the formwork and is removed along with the formwork. Like the formwork like the formwork this absorbing layer also has certain number of reputation cycles that it can be reused.

Now, this absorbing layer allows the air and water from the concrete to escape and this provides a better finish and high durability for the cover concrete. So, what is happening is that if we are able to get the water in this part of concrete which is the cover concrete because we have reinforcing bar somewhere here, if we are able to get the water of this layer out from the system, it will enhance the quality of the cover concrete, it will reduce the water cement ratio in that region and that is precise we want absorbing form work does. Water from this region is in absorbed pipe this formwork and therefore, we get a cover concrete which has a water cement ratio which is lower than the water cement ratio

in the main body concrete and that enhances the durability of the structured which is made with this kind of absorbing.

Now, what kind of absorbing material is good? What kind of absorbing material can be used? How many times it can be recycled? What is the economics of the whole process? Is a detailed subject, which cannot be obviously covered when we are just trying to give a bird's eye view of a special formwork and that we can leave to someone who is interested to the kind of feeding.

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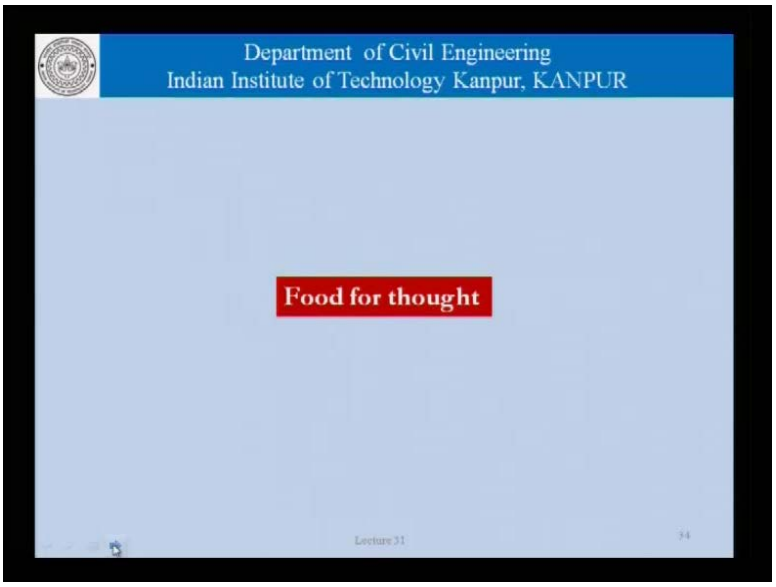

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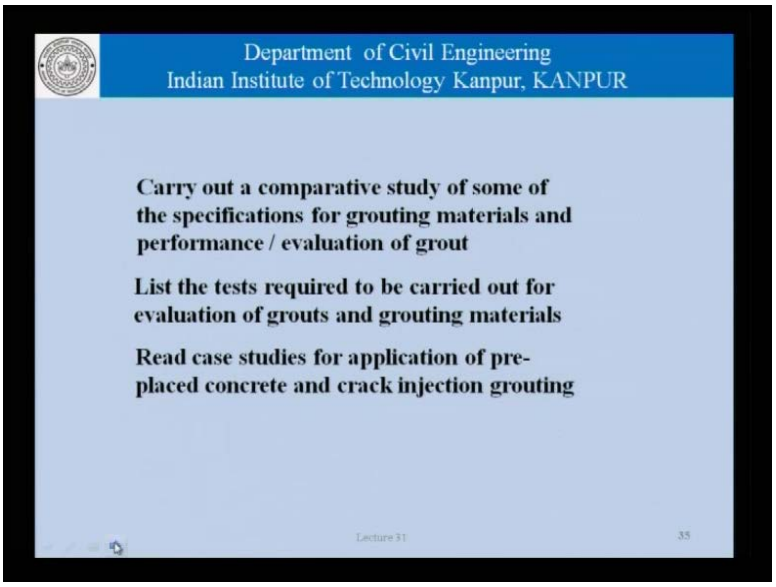

Now, coming to the close of our discussion, let us try to take some questions which we can talk about later on. We could carry out a comparative steady of sum of this specification of grouting materials and performance evaluation of grouts. So, please remember that the grouting materials and the grout are different things. The grouting materials can have different tests, different specifications and grout again can have different tests and different specifications. And what we are talking about here is to carry out the comparative study of some of this specification in this regard. We could list tests which are required to be carried out for the evaluation of the grouts and grouting materials. We could talk in terms of reading case studies for application of preplaced aggregate concrete and crack injection grouting that we saw briefly today.

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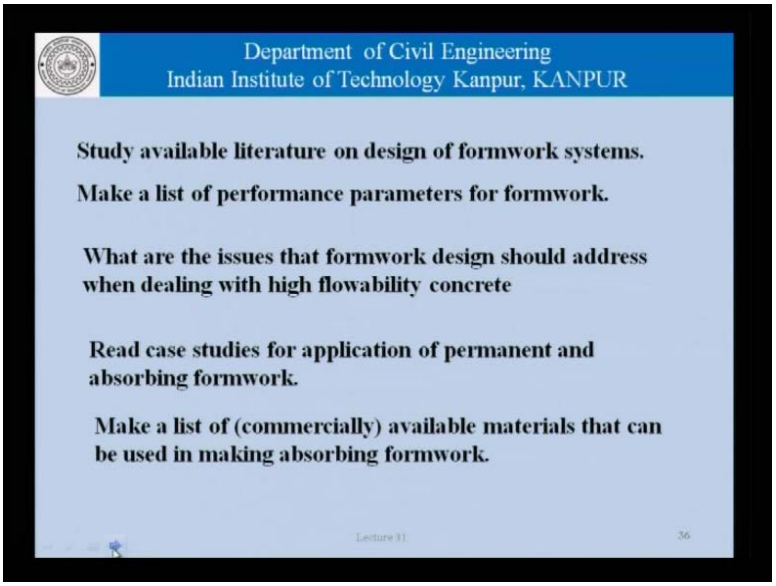

On the issue of formworks, I would request you to study available literature or the design of formwork systems. Very often the durability of concrete structures is compromised because the temporary formwork system is not appropriately designed. We could make a list of performance parameters for the formwork systems and list what are the issues that formwork design should address when dealing with high flowability concretes which are becoming more and more increasingly used in concrete construction.

Now, we could read case studies for application of permanent absorbing formworks and make a list of commercially available materials that can be used in making, absorbing formwork of a that matter. Some of the materials that is available to be used as

permanent formwork, try to study the technical details as well as the economics of their use and there implications in terms of the durability of concrete which is finally achieved. With that we come to an end of the discussion today.

Thank you.