Development and Applications of Special Concretes
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Lecture-29
Improving Quality of Cover Concrete

Namaskar and welcome back to our series of lectures on development and applications of special concretes and we continue our discussion today on improving the quality of cover concrete. We could use permanent form work or we could do something with the normal form work in order that the quality of the cover concrete is improved.

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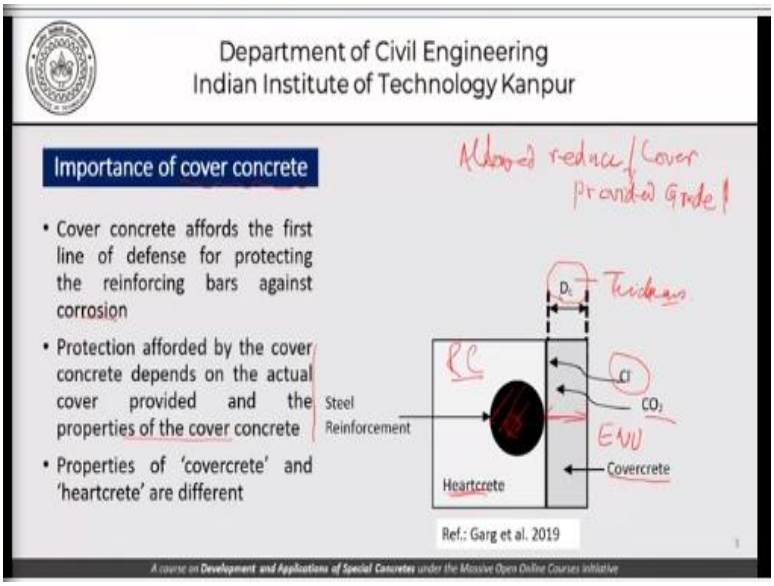

So, what has to be emphasized is cover concrete. And we often talk of cover but today we will talk about the properties of cover concrete. So, this is schematic representation of a reinforced concrete construction, where mild steel is somewhere here and this is the environment. So, basically this thickness here represented by D_c is the cover thickness. And what we are talking about is whether the cover concrete that is the concrete in the cover region is different from what is being called the heartcrete.

So, this cover concrete and heartcrete are terms which we may not see in a lot of literature. But you should understand that yes, we are trying to distinguish between the properties of the concrete in the cover region and in the main body of the structure. So, the cover concrete affords

the first line of defense for protecting the reinforcing bars against corrosion. So, what is being said and it has been assumed is that corrosion of reinforcement.

That is this reinforcement bar here is one of the major problems as far as deterioration of structures is concerned that one of the reasons why we are doing special concretes and we are becoming more aware of is the fact that we need to prevent the reinforcement corrosion. Now indeed the cover concrete, that is this concrete here is the first line of defense against chloride penetration related attack, that is in marine structures and carbon dioxide related attacks that is in normal atmospheric conditions.

The protection afforded by the cover concrete actually depends on the actual cover provided and the properties of the cover concrete which is also obvious. Because the protection afforded is related to the thickness here, what is the value of the cover that we are providing whether 40 mm or 50 mm and so on. And what are the properties of the cover concrete? There is no point in providing a large amount of cover if the concrete is pervious.

Or as in certain specifications in fact you are allowed to reduce the cover thickness, if the grade of concrete increases. So, there is a reduction in the cover thickness provision provided the grade of concrete is higher. So, that is a good point that you should remember, that yes, that ultimate protection is what is important and it is provided by a product or a combination of two things, the thickness and the properties. So, the properties of cover concrete called covercrete and heartcrete are different. Now how they become different is something which we just quickly examine.

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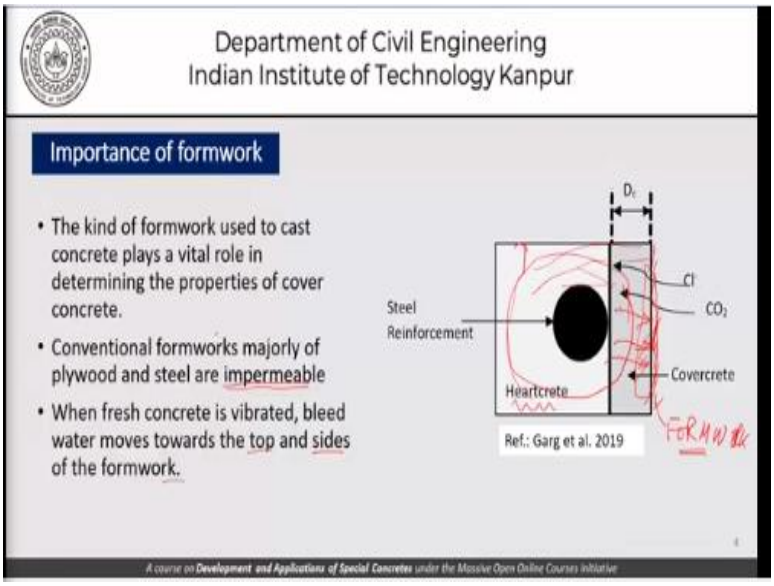

So, basically the kind of formwork used to cast the concrete plays a vital role in determining the properties of cover concrete. You will recall that as far as construction is concerned, how we do it is we put a form work here and this form work. And against this formwork we cast this entire concrete with the reinforcement of course inside it. So, the properties of this formwork are an important factor that determines the properties of cover concrete.

And also, the fact that how different the properties of this cover concrete will be from what we are calling heartcrete here. Conventional formworks majorly of plywood and steel and they are impermeable. So, we do not have permeable formwork most of the time and they are either made of conventional plywood or steel. Now when fresh concrete is vibrated the bleed water tends to move towards the top and the sides of the formwork.

That is the bleeding water within all this concrete tends to move up, the particles tend to settle down and also there is a tendency of bleed water to move towards the formwork. Now because this formwork is impermeable this water tends to collect in this region close to the formwork.

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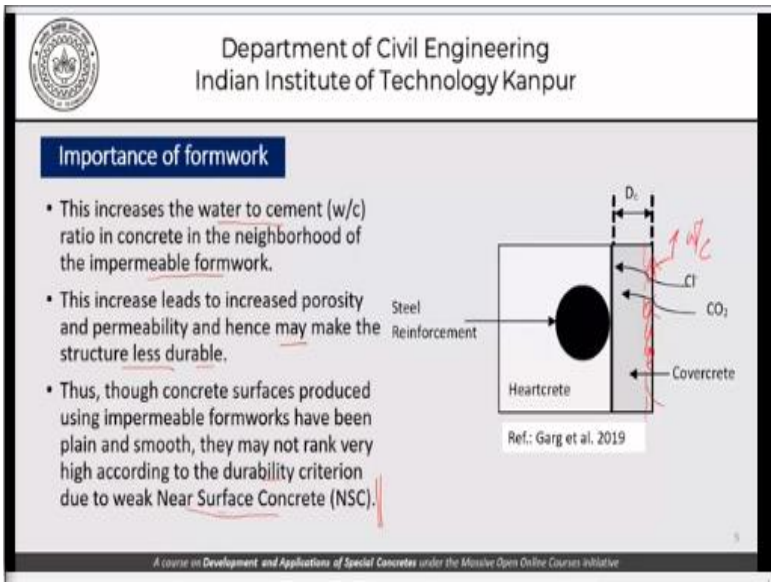

That is what is stated here, this increases the water cement ratio in the concrete in the neighborhood of the impermeable formwork. So, what we saw was? We had formwork here and the accumulation of water in the neighbourhood would obviously increase the water cement ratio in this small thickness around the or in the neighborhood of the formwork. So, this increase leads to an increased porosity and permeability and hence may make this structure less durable, so that is what is the crux of the whole problem?

Thus, though concrete services produced using impermeable formwork have been plain and smooth, they may not rank very high. According to the durability criteria due to, the weak-near surface concrete, this weak-near surface concrete of course is a nuance it is not that the grade of concrete is very low and so on but it is weaker compared to the main body concrete because of the accumulation of water, which is not allowed to escape or is not taken out from the concrete.

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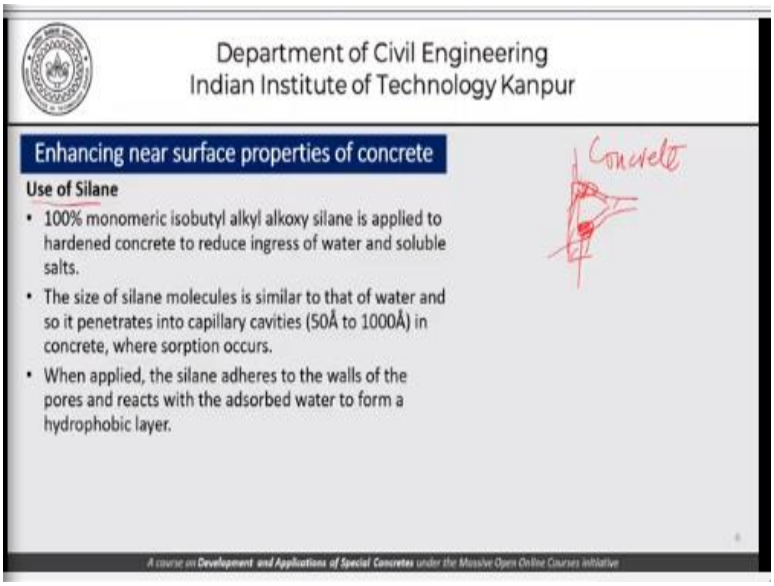

Now how do we go about addressing this problem? One way to address this issue of enhancing the near surface properties of concrete is by use of silane. 100% monomeric isobutyl alkyl alkoxy silane is applied to the hardened concrete to reduce the ingress of water and soluble salts. So, basically if we try to draw a schematic sketch and say that this is what my pores in the near surface region are.

So, what we do is, this is my concrete and this is a schematic representation of the pores, what we try to do is to apply this silane coating here which tends to seal off these pores. And the sealing of these pores results in water not being able to penetrate into the pores of the concrete. The size of silane molecules is similar to that of water, and so it penetrates into the capillary activities in concrete where this option occurs. When applied the silane adheres to the walls of the pores and reacts with the absorbed water to form a hydrophobic layer.

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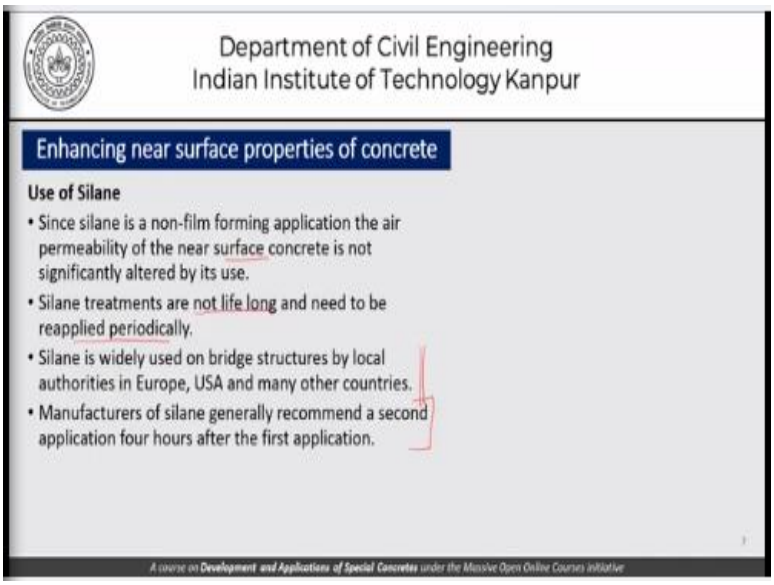

Since silane is a non-film forming application, the air permeability of the near surface concrete is not significantly altered by it is use. This treatment therefore is not life-long and needs to be reapplied periodically. Silane is widely used in bridge structures by local authorities in Europe, U.S and so many other countries. And I would encourage you to look at some literature which describes the use of silane in these structures in these countries.

Manufacturers of silane generally recommend a second application four hours after the first application. So, what is we suggested is that, a quote is applied and then a second quote is applied after whatever absorption or something, that has to occur in the initial period. Then you apply a second coat just to be sure that you have been able to accomplish the purpose that you want.

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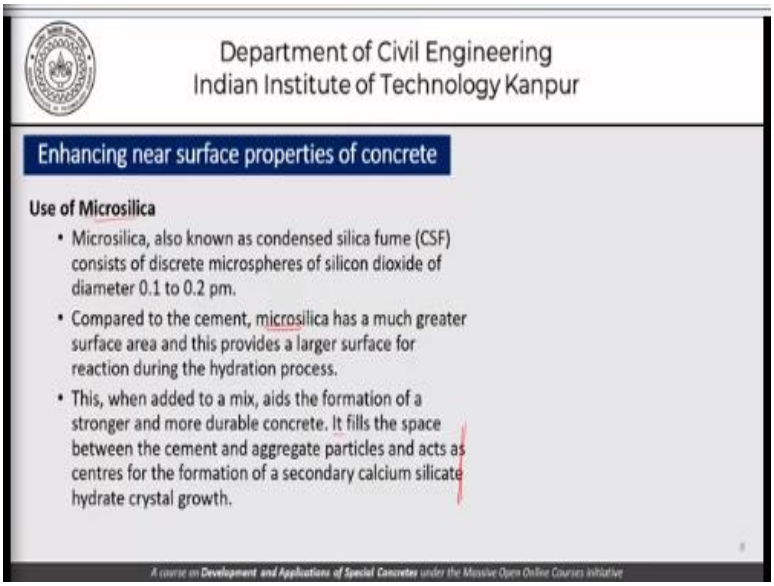

The other option that we have in terms of enhancing surface properties of concrete is the use of micro silica. Now of course microsilica is not an application from the surface, microsilica also known as condensed silica fume, consists of discrete microspheres of silicon dioxide of the diameter of about 0.1 to 0.2 picometers. Compared to cement microsilica has a much larger surface area and provides a larger surface for reaction during the hydration process. So, microsilica is one of the mineral admixtures that is added to the concrete at the time of proportioning itself.

This, when added to a mix, that is microsilica is added to the mix aids the formation of a stronger and more durable concrete as the silica fills the space between the cement and aggregate particles and acts as centers for the growth of secondary calcium silicate hydrate gel crystals. So, this is basically just a description of microsilica participating in the pozzolanic reaction ultimately leading to a reduction in the pore sizes and also the total pore volume.

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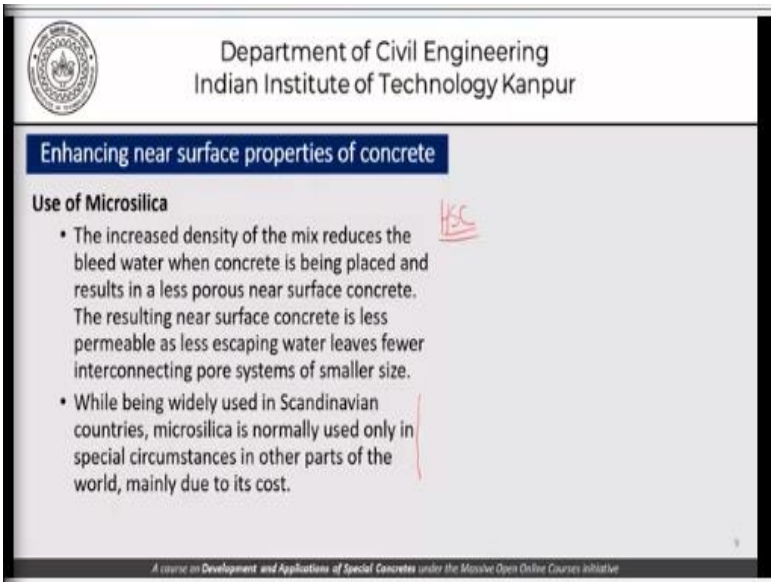

The increased density of the mix reduces the bleed water when the concrete is being placed and results in a less porous near surface concrete. The resulting near surface concrete is less permeable as less escaping water leaves fewer interconnecting pore systems of smaller sizes. So, basically what is being suggested is in this mechanism that the presence of microsilica in the concrete mix makes bleeding itself very difficult or reduces the amount of bleeding.

And therefore, we do not have any accumulation of additional water in the neighborhood of the formwork. While being used widely in Scandinavian countries, microsilica is normally used only in special circumstances in other parts of the world mainly because of it is cost. This again of course can be an assignment and you can look at the cost of microsilica, the history of microsilica and the kind of pluses and minuses which have been discussed in literature as far as the use of microsilica is concerned.

I must also point out that microsilica addition in concrete has attracted a lot of attention not only in terms of improving the properties of surface concrete but also in the context of high strength concrete.

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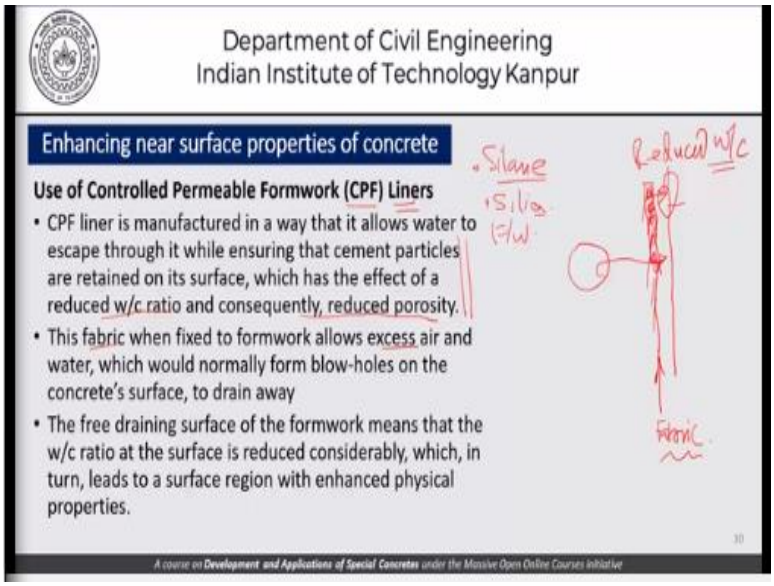

The third strategy which we can adopt to enhance the properties of near surface concretes is use of controlled permeable formwork that is the CPF liners. Now we have talked about silane applications that are an application of a product after the concrete has hardened. We have talked about microsilica which is an additive which is used at the time of construction in the main concrete itself.

And now we are talking of CPF liners which, is a modification to the formwork. CPF liner is manufactured in a way that it allows water to escape through it while ensuring that cement particles are retained on the surface, which has the effect of creating a reduced water cement ratio and consequently reduced porosity. So, if we go back to our old diagram and consider a formwork here, which allows the water to escape but retains the cement particles?

So, the formwork is such that it has the layer or a lining which is a special CPF lining, it allows the water to be taken out but retains the cement particles here. Then if the bleed water moves from this part to this part, the water would be taken out and the cement particles would remain. So, this phenomenon is being explained here by saying that it is not an increased water cement ratio problem but a reduced water cement ratio issue.

Because we have taken away this water which has been taken out with the formwork and we have more cement present here. Because water was moving with the cement, the water has been

removed; the cement has been left behind. So, the water cement ratio has reduced, so this is what has led to a reduced porosity in the neighbourhood of the formwork. This fabric, the CPF liners are typically fabrics like cloth.

This fabric when fixed to formwork allows excess air and water which would normally form blow holes on the concrete surface to drain away. So, now you understand this better, so this is the fabric that we are talking about which is a special fabric and we need to choose those fabrics, evaluate those fabrics and then finally try to use them. These fabrics when fixed to formworks the way you have showed here allow excess air and water to be drained out with the final effect of reduced water cement ratio in the neighborhood of formworks.

So, the free draining surface of the formwork means that the water cement ratio at the surface is reduced considerably which in turn leads to a surface region with enhanced physical properties.

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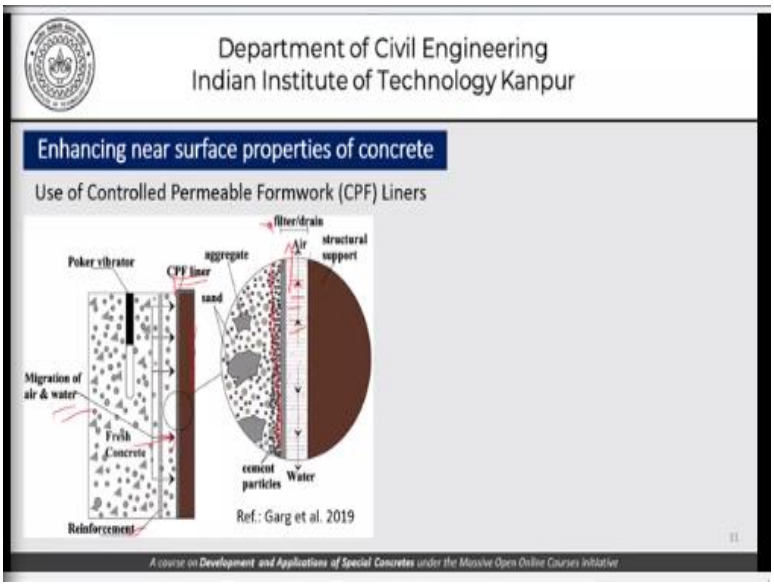

This is a diagrammatic representation of a control permeable formwork or a CPF liner. And we can see this reinforcement here, this is the CPF liner and fresh concrete being vibrated leads to the migration of air and water as shown here. Cement particles accumulating here and air and water being brought into this region and being taken off. So, this fabric essentially acts as a filter and drain, and this of course is the regular formwork that we are using.

So, it could be a steel formwork, it could be a plywood formwork with a CPF liner attached to it.

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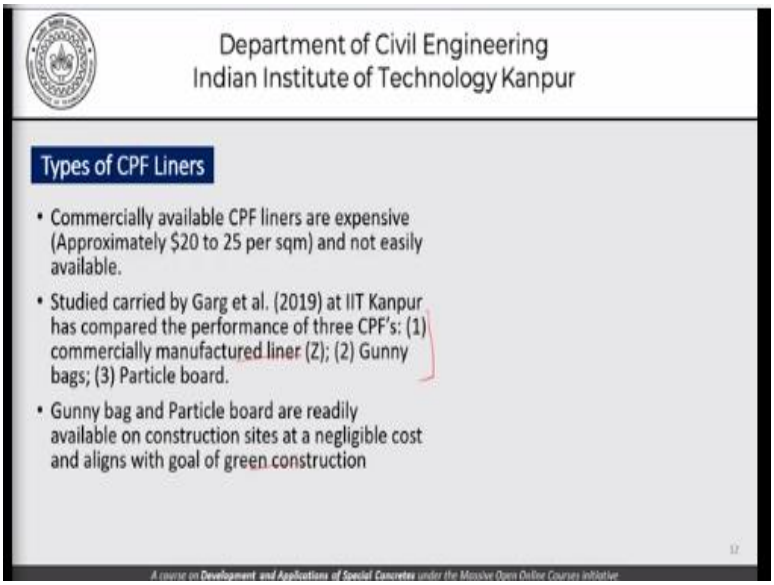

As far as the typical CPF liners are concerned, commercially available CPF liners are expensive and not easily available, more than availability it is a matter of awareness. The people may not use it most of the time, we carried out some studies at IIT Kanpur and I thought I will maybe share the results from there with you. We used a commercially manufactured liner called Z a gunny bag and particle boards.

So, we used three CPFs or 3 materials as CPF and we tried to study their effect or if their effectiveness in terms of the improvement in the properties of surface concrete. So, gunny bag and particle boards are readily available at construction sites at a negligible cost and aligned with the goals of green construction, if you are so inclined.

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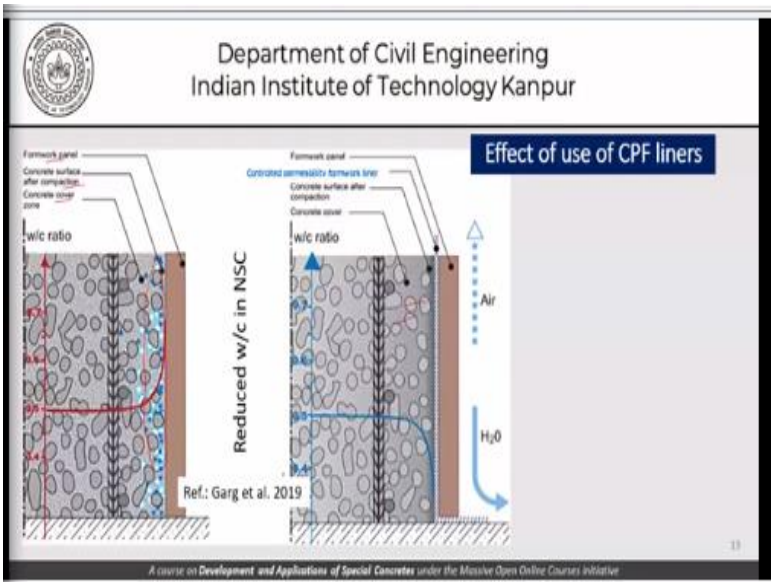

And here we are able to see again the representation of the formwork panel, the concrete surface after compaction and the concrete in the cover zone with this additional water which has been taken out leading to better quality concrete as far as the surface is concerned.

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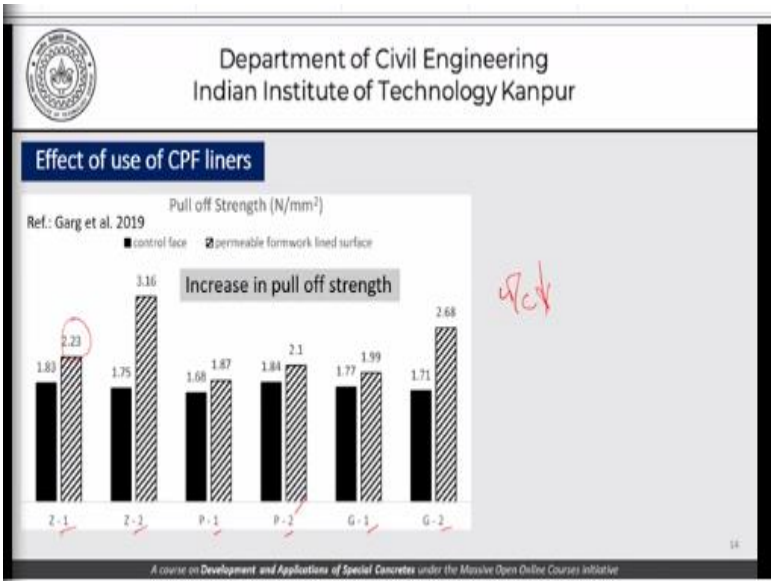

Now here are some of the results that we obtained as far as the effect of use of CPF liners is concerned. We try to do a pull off test from the surface and we found that for the different liners Z-1, Z-2, P-1, P-2 and G-1, G-2 where P is the particle board, G is the gunny bags and Z is the commercial liner. In all cases there was an improvement in the pull off strength which is basically an indication of the fact that the water cement ratio has reduced.

And this 1 and 2 refers 2 different types of concretes which were used in the experimental study.

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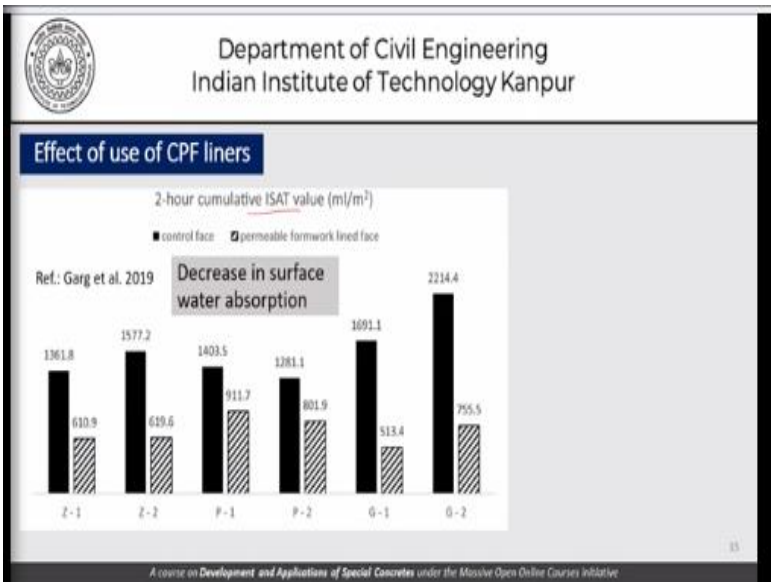

As far as the decrease in the surface water absorption is concerned, we try to carry out what is called a 2-hour cumulative ISAT test. And those of you are interested should actually look up and see how an ISAT test is carried out. And we find that regardless of the CPF liners used the values have considerably reduced, how much is the reduction, how much is the initial value of course is a matter of experimental research, so let us not bother so much about it.

But the fact remains that yes, if we have an appropriate CPF liner applied to the formwork at the time of construction it will greatly help in reducing the surface water absorption which is one of the measures of the permeability of the surface concrete.

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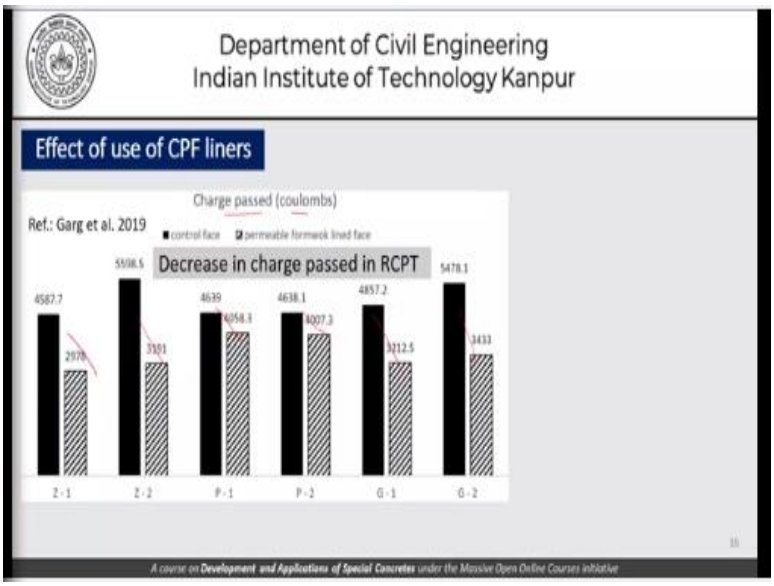

Yet another test we carried out was the RCPT or the rapid chloride permeability test where the effectiveness is measured in terms of charge passed in terms of coulombs. And we found that again the values are lower than the corresponding concretes cast without the CPF liner. Whether this is more effective than this and so on that is a matter of discussion of course which of some of these results are quite obvious.

So, I am not getting into those results because that is not the intent that we are talking about. The intent really is only an exposure to the phenomenon or the use of CPF liner and carrying out some kind of an investigation to establish whether or not a particular CPF liner is effective.

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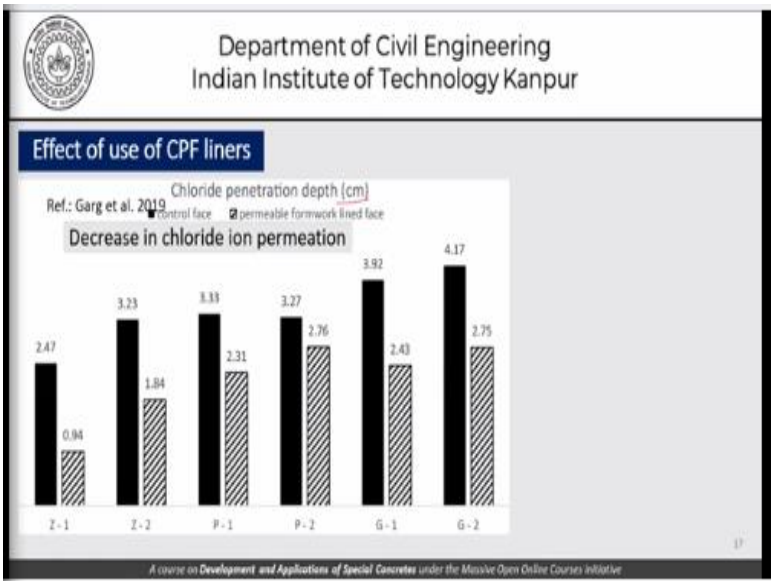

The last test I guess which was carried out was the decrease in the chloride ion permeation. And here we found that the chloride depth being measured in centimeters using a standard test was again much lower in the case of concretes with CPF liners. So, this study essentially established the importance or the effectiveness of using a CPF liner. If the client so permits, if the situations so demands and of course the economics of the CPF liners has to be worked out on a case-to-case basis.

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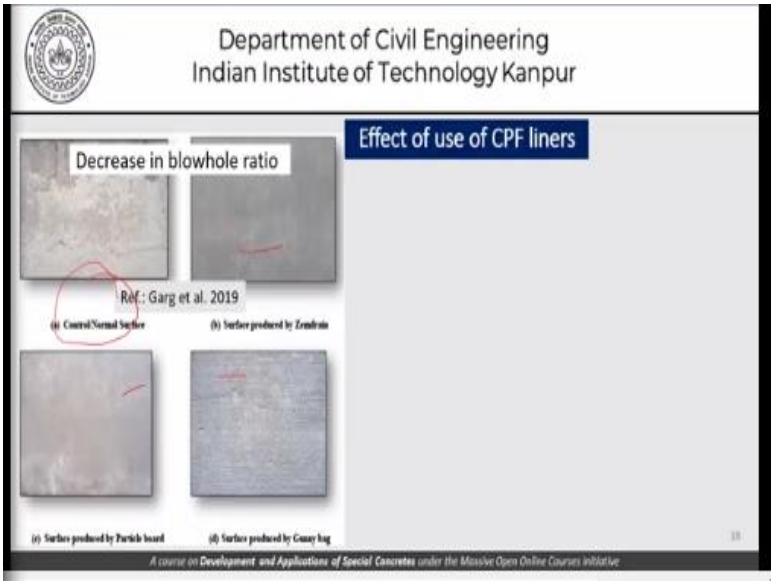

Yet another test which was carried out of course it was not in the same league as the chloride penetration test or the rapid chloride permeability test or the pull off test. That was to see how the surface looked like, now that was examined using the blow whole ratio and we can see that as against this which is the surface for normal concretes. These surfaces had much fewer blow holes.

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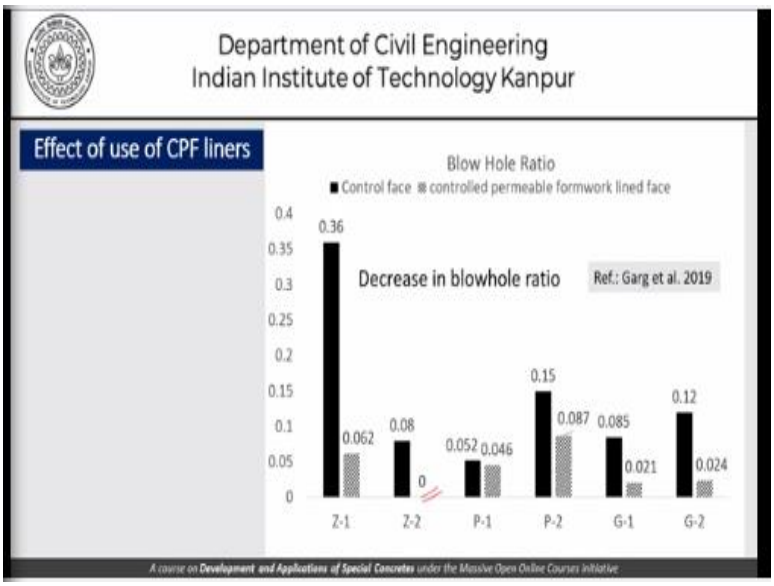

As we can see here the blowhole ratio is much lower in the case of CPF liners in fact it is 0 here. And this is yet another piece of evidence to show how the CPF liners can be very effective in improving the properties of the near surface concrete.

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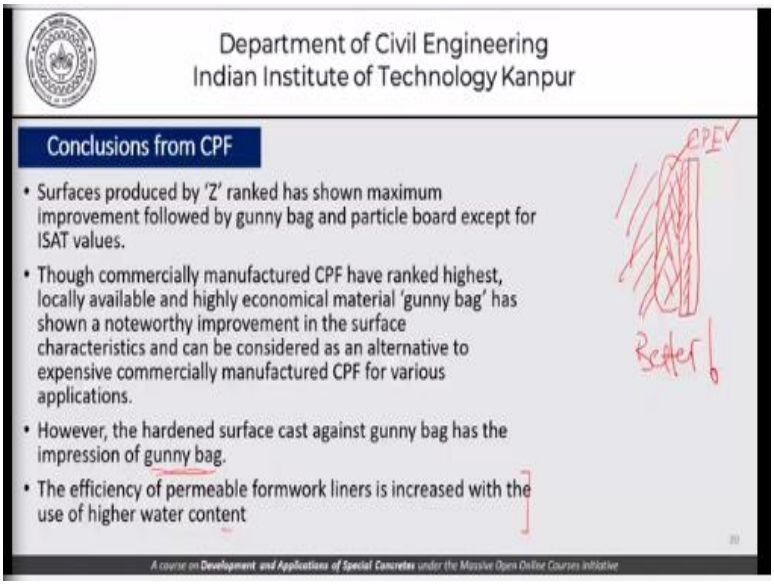

This slide only presents the summary of the results that we got from our studies here in IIT Kanpur. That the surface is produced by Z that is the commercially available CPF liner, they ranked the best. That is, they showed the maximum improvement followed by gunny bags and particle boards except for ISAT values. Though commercially manufactured CPF liner have ranked highest, locally available and highly economical materials such as gunny bags has also shown a noteworthy improvement in the surface characteristics.

And be considered as an alternative to expensive commercially manufactured CPF liners for various applications. However, the hardened surface cost against gunny bags has the impressions of the gunny bag. Now this is something which you can go back to the slide and see for yourself that the surface of concrete cast using a gunny bag has the texture of a gunny bag and one may or may not necessarily approve of it all the time.

The efficiency of permeable formwork liners is increased with the use of higher water content. So, of course this conclusion we have not stressed too much as far as our discussion, today is concerned because that was the P-1, P-2 kind of a discussion. That is when I said that P-1 and P-2 is for the same CPF liner but different concretes. And the different concretes had different water contents, but that is not really a major discussion point today.

Today the discussion has been largely focused on saying that well if I have a formwork here, if I have a CPF liner attached to this formwork then the concrete that we cast here will be better in terms of the properties of concrete in the near surface zone here. These properties will be better if we have a CPF liner. Now what CPF liner to use; of course, the experimental study that I showed that the commercially available CPF liner is the best.

But the gunny bags for example did not prove to be too bad an option especially if you want to consider the economics of the operation as well. Now having completed this discussion with respect to the CPF liners, let us try to talk of something completely different.

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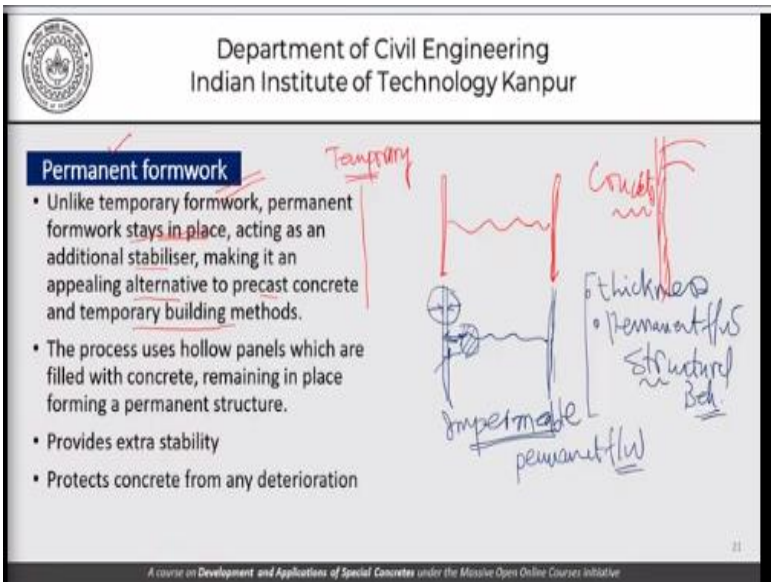

There is this concept of permanent formwork. Now what is permanent formwork? We have to view this against the temporary formwork which we normally use as far as concrete construction is concerned. So, let me reiterate that as far as concrete construction is concerned, we use a formwork, cast the concrete against that and then once it has hardened and so on, we remove the formwork, and we use it somewhere else.

So, the formwork has a certain amount of life in terms of number of cycles of use and so on and so forth. As against this, what can be called a temporary formwork, we are now going to talk in terms of permanent formwork. So, unlike temporary formwork, permanent formwork it stays in place acting as an additional stabilizer making it an alternative to precast concrete and temporary building methods, effectively what is being said here is the following.

If this is my complete thickness of the concrete member, my traditional casting systems would say that well we put formwork here and here, and we cast the concrete here. As far as permanent formwork discussion is concerned what is being said is that we create formworks here which are permanent and will remain a part of this concrete here, how thick or thin should this formwork be whether or not?

So, one part is thickness whether or not the permanent formwork should be considered as a part of the structure as far as structural behavior is concerned. That is a decision with the structural

engineer will take depending on the properties of the permanent formwork. So, those are details which we can work out as we go along, but we are trying to just express to you or explain to you the possibility of using permanent formwork as part of reinforced concrete construction.

The advantage of using permanent formwork is that once this permanent formwork becomes a part of the structure which as the name suggests it would, we can have an extremely impermeable permanent formwork. And that gives me additional protection as far as the reinforcement is concerned. So, this cover thickness here that we are providing has to be interpreted very differently.

So, whether the cover thickness is only up to this point or it should include the formwork thickness, those become questions which need to be agreed upon professionally. The process uses hollow panels which are filled with concrete remain in place forming a permanent structure. Provides extra stability, protects the concrete from any deterioration.

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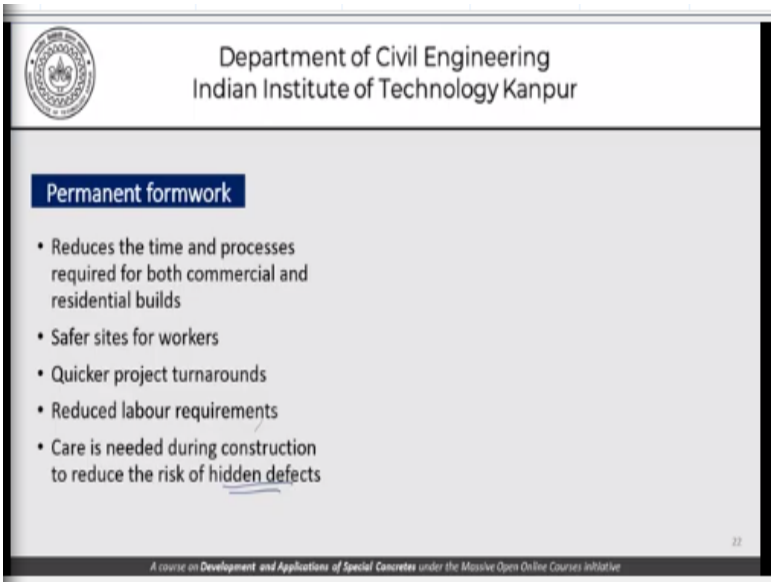

Reduces the time and processes required for both commercial and residential buildings, safer sites for workers, quicker project turnarounds, reduces labour requirement. And care of course needs to be taken during construction to reduce the risk of hidden defects. So, here we are talking of a situation or a construction method where the entire member is not precast, the precast construction the entire member would be precast.

In this construction, part of the formwork or that part which becomes the part of the structure as a formwork is precast or is manufactured somewhere else could be something else brought to site and in situ construction happens as usual. The in situ placing of concrete, setting of concrete and so on happens as usual. Of course, this has its own implications in terms of curing of concrete and that is something which has engineers we need to keep in mind when carrying out a comprehensive evaluation of the construction method.

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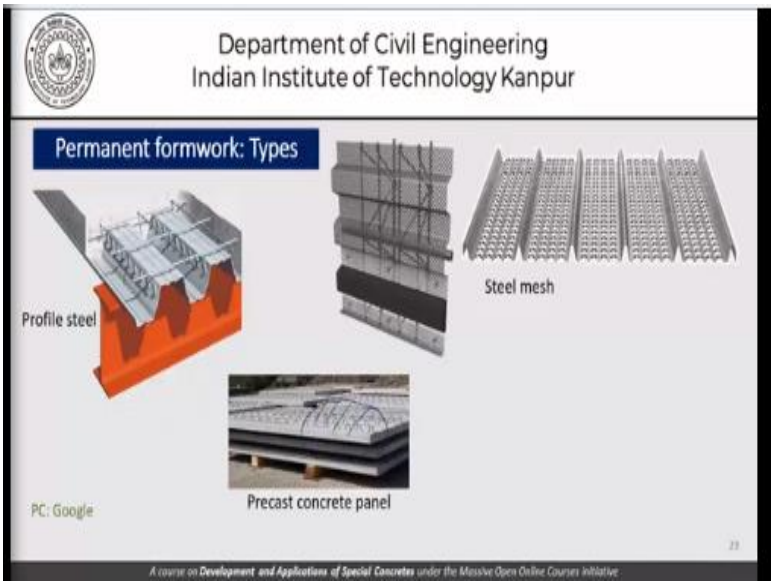

So, we have some examples of permanent formwork given here. This one is profile steel; this is a steel mesh and then of course there are precast concrete panels. So, these panels are the easiest to understand as far as permanent formwork is concerned. So, these panels become formworks and the concrete is cast on the inside of this panel. Similarly, the concrete is cast on the inside of this profile steel; we will see that in a minute.

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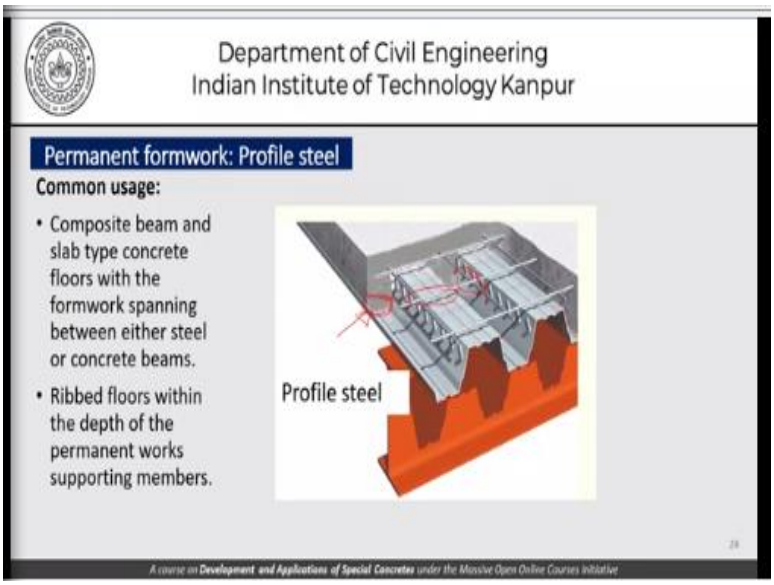

When it comes to permanent formwork with profile steel, the picture here shows how profile steel which is this part can be used to become a part of this slab kind of construction which is being done on top of this. And this formwork of course is not to be removed and steel reinforcement which is shown here can be a part of the normal placing. So, we have this formwork which we do not have to bother to remove.

And that is what I said in the beginning of this discussion that whether or not this formwork should be considered as a part of this structural member. In terms of whether or not it provides any flexural rigidity or how it participates in the load carrying mechanism of this slab. That is something which the designers would bother about and that is something which the designers need to understand better.

As far as construction is concerned, we understand that well, this is steel which becomes a part of the concrete construction adds to the durability of the steel in the near surface area. So, basically the common usages shown here is composite beam and slab type floors with formwork spanning between either steel or concrete beams, that is what is shown here; ribbed floors within the depth of the permanent form supports the members.

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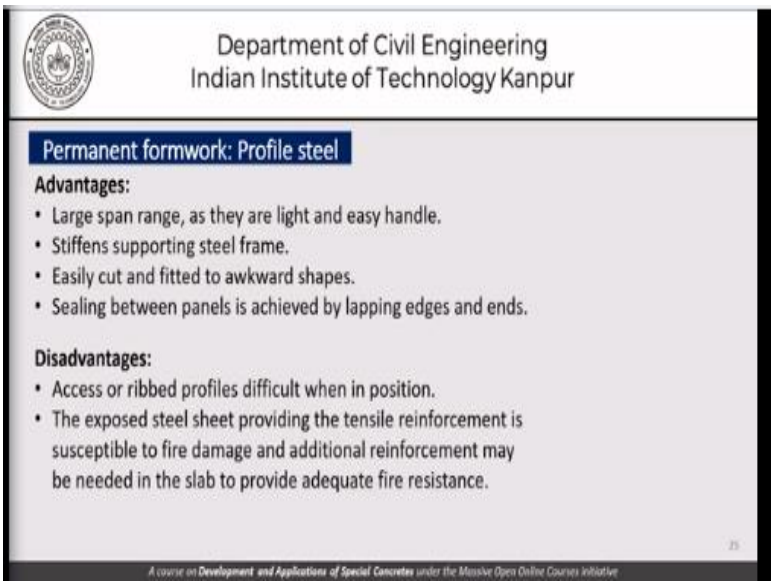

The advantages of using profile steel as permanent formwork are listed here. Large span range, they are light and easy to handle, stiffens the supporting steel frame, easily cut and fitted to awkward shapes, sealing between panel is achieved by lapping and edging the ends. There are disadvantages as well; there are always two sides to the coin access or ribbed profiles difficult when in position.

The exposed steel sheet providing the tensile reinforcement is susceptible to fire damage, an additional reinforcement may be needed in this slab to provide adequate fire resistance. Those of course some things which as I already mentioned have to be taken care of in the design process.

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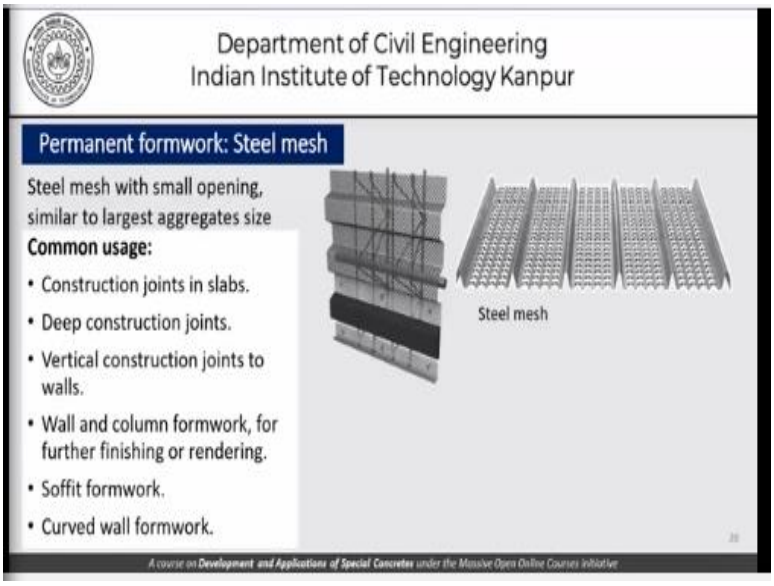

Then we have the next type of permanent formwork which is been mentioned here. That is the steel mesh, pictures are shown here for you, the steel mesh has small openings similar to the large size aggregate meshes. And they are commonly used in construction joints, in slabs, deep construction joints, vertical construction joints from walls. Wall and column formwork, for further finishing and rendering, soffit formwork, curved wall formwork.

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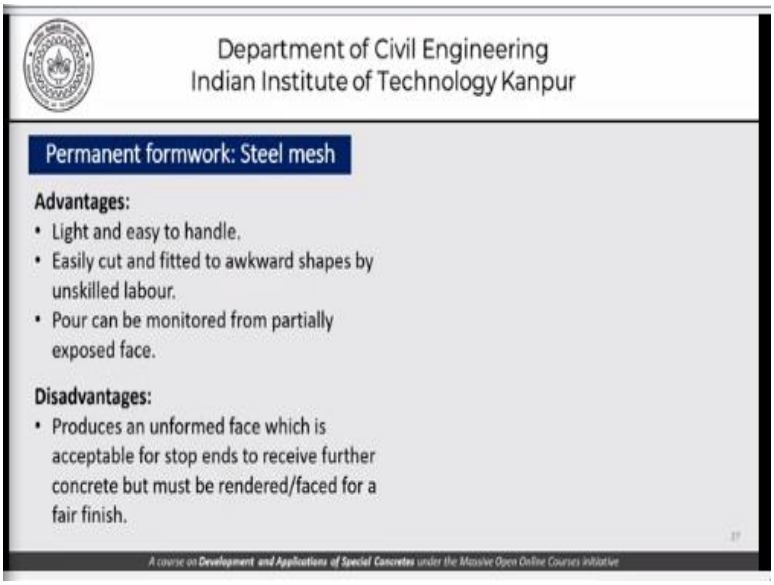

So, as far as the advantages of using this steel mesh formwork as a permanent formwork is that it is. Light and easy to handle, easily cut and fitted to awkward shapes; by practically unskilled labour. The pour can be monitored from partially exposed surfaces; we are talking of the pour of concrete. And the disadvantages of course are it produces an unformed phase which is acceptable for stop ends to receive further concrete what must be rendered or faced for a fair finish.

So, the finishing of a concrete with a steel mesh is not necessarily the best and we may need to be careful if we are using it in those areas. But as far as joints are concerned it is perfectly a fair finish.

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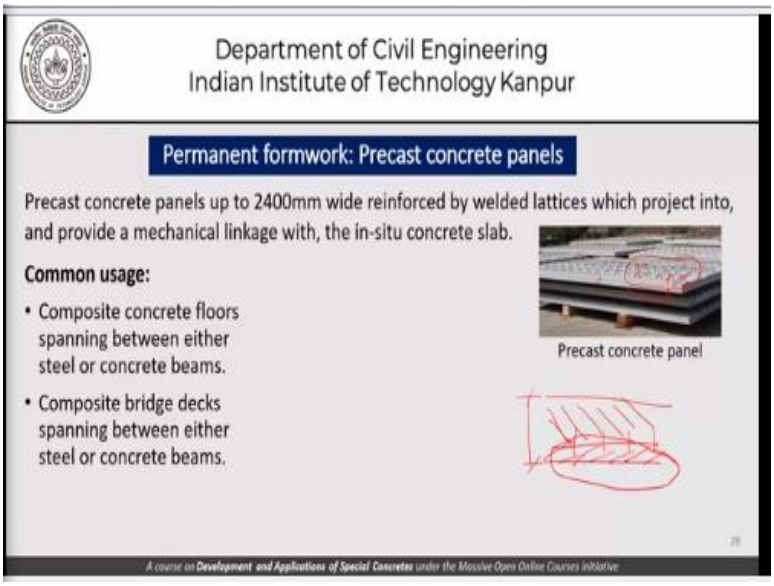

Coming to the third type of permanent formwork that we must discuss today is the precast concrete panels. So, these precast concrete panels up to 2.4 meters wide reinforced with welded lattices which projects into and provide a mechanical linkage with the in-situ concrete slab. So, what is been suggested here is that these slabs which will have a certain length and of certain width, the thickness of course is something which you can see from here.

And then these are the hooks which have been provided to provide some kind of an anchorage or prevent any slippage between this formwork and the slab. So, what we are talking of a slab construction we all have this kind of a precast formwork with some kind of hooks the way they are shown here and on top of this we cast the normal concrete. So, this precast concrete becomes a part of this overall slab.

The common usages for such a situation could be composite concrete floors is planning between either steel or concrete beams, composite bridge decks spanning between either concrete or steel beams.

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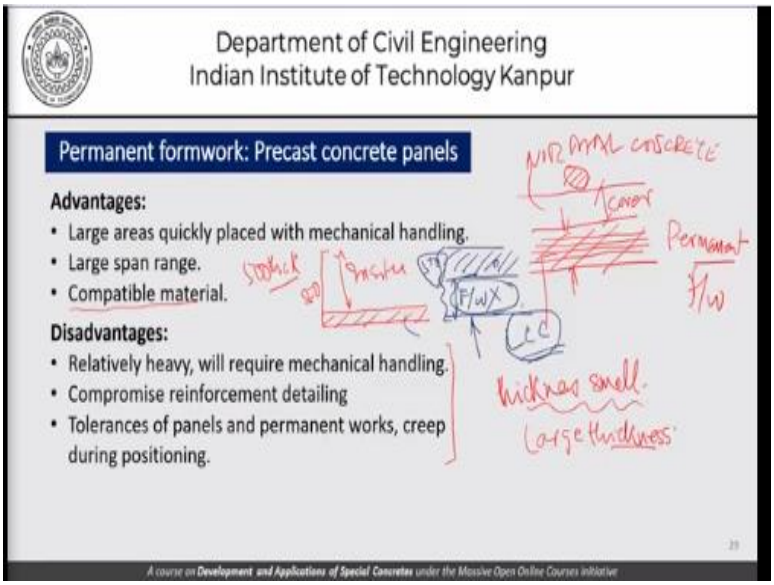

And the advantages of using this kind of formwork could be large areas could be quickly placed with mechanical handling. The formwork placement is much easier, large span ranges could be easily covered and the material is compatible. So, we do not have to bother about material compatibility because on both sides we have essentially cementitious mixes. Also, we can surely control the permeability of my permanent formwork by using special concretes.

In these formworks because we are dealing with a small volume and not necessarily a very large volume and we could reinforce it with special materials which will add to the impermeable nature or make this concrete more and more impervious which could be such an advantage when we are really talking about the cover thickness here because the reinforcement is going to be somewhere here.

And this very impervious kind of permanent formwork is equivalent to several times the same cover thickness which is provided for normal concrete. So, these of course please remember is normal concrete, which has a permanent formwork using a special concrete. There are some disadvantages as well. They are relatively heavy which requires mechanical handling, compromise reinforcement detailing and tolerances of panels and permanent works creep during positioning.

So, these are some of the problems that you will face when you are trying to deal with permanent formworks in the form of precast concrete panels. I would leave it to you to look at more options as far as the precast concrete panel is concerned for permanent formwork. We have covered only one thought process where we have talked of precast panels acting as formwork. So, basically what we are talking about is the thickness is relatively small.

We can always talk in terms of a large thickness here, in which case there is no reason to not have this permanent formwork. We will say that ok, half the member is precast and we are only adding the remaining half as far as in situ construction is concerned. So, to explain this concept once again; with the illustrative numerical example suppose we have a 500 mm thick slab which we need to cast, so this is 500.

Now if the formwork thickness or the permanent formwork thickness is just about 20 mm or 25 mm and the rest of it is being cast in situ. Then the third process would indeed be that yes, there is a 20 mm formwork with 480 mm in situ concrete and the total thickness of this member is 500. As against this if I have a 200 mm thick precast panel and we are casting the remaining 250 at site. Then it is difficult to dismiss this or call this just a formwork that would be at injustice.

That would be composite construction with part of the construction being precast and part of the construction being in situ. So, it is a matter of nomenclature but that nomenclature one has to be careful about that well the spirit is the same. That in both cases what we are trying to do is improve the quality of near surface concrete. So, of course in this case it is not only near surface concrete which is being improved.

But one half of the member is being improved, it is expected but the performance of one half of this member will be very different. Of course, the 500-thick member will behave or is expected to behave monolithically and that is something which the designers will take care of. So, the designers will actually come into picture when we are trying to use such construction methods. So, one of the very important takeaways from this discussion is the fact that construction technology which is developed based on new materials.

For example, in this formwork here we could be using very different kinds of materials in order to make the concrete impervious or reduce it is permeability and so on. That development has to be ultimately incorporated as far as the structural behavior of the member is concerned. And unless, that happens the economics will not necessarily work out. So, if this is taken into account from the economics point of view not only at the initial cost of construction but also considering the life cycle cost.

So, obviously if a structure is more durable the life cycle cost will be lower, there will be lower issues related to maintenance. And that could possibly justify the investment in permanent formwork or for that matter even the CPF liners.

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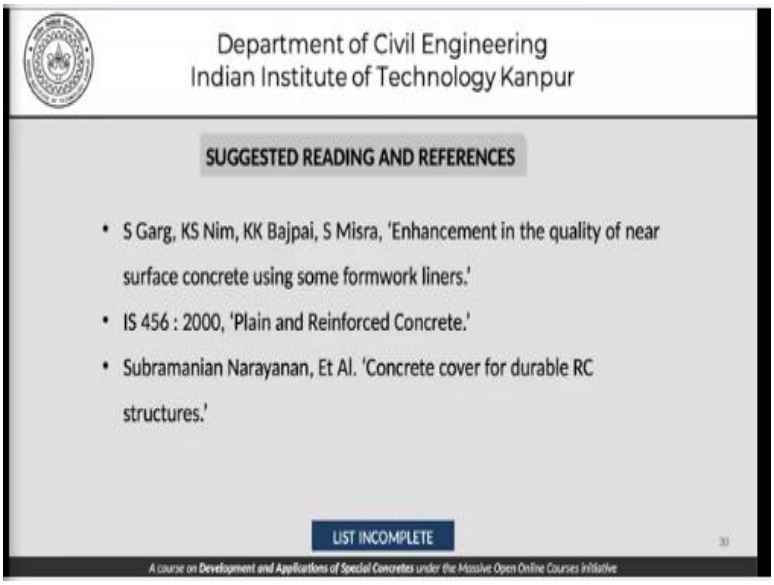

So, with this we come to an end of our discussion today and here is a list of some of the papers that you could read including the document that we discussed about the research at IIT Kanpur. And I am sure you will find it interesting from a point of view that is not necessarily special concretes in one sense. But the application of the special concrete thought process as far as an improvement in the performance of reinforced concrete members is concerned.

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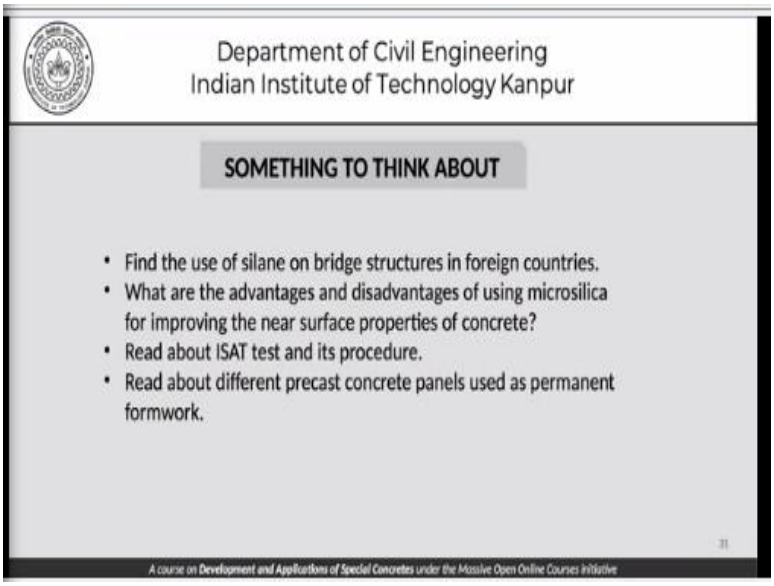

These are some of the points that I have already talked about today, and some other new questions for you to think about in order that you understand the subject matter slightly better. With that we come to an end of our discussion today and I look forward to see you once again in a later discussion when we will be talking about some other special topics relating to concrete construction, thank you.