Sustainable Materials and Green Buildings
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Lecture 46
Insulated Concrete Form and Tunnel Form

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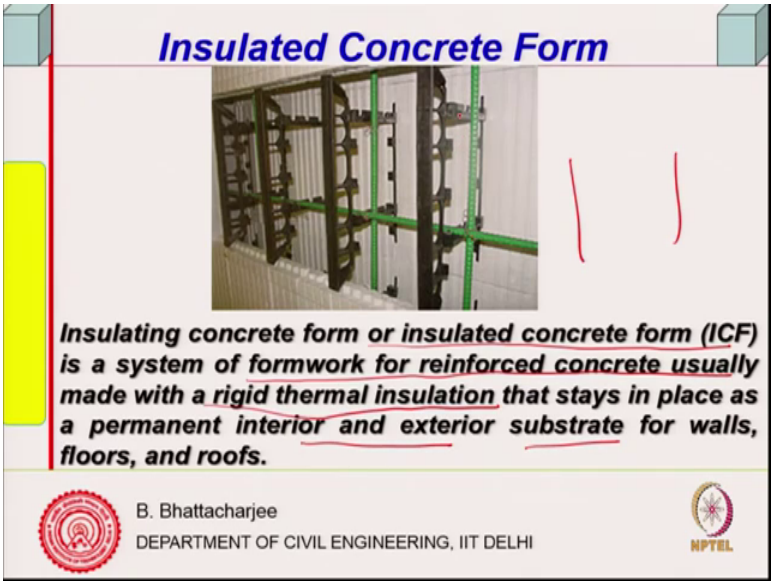

So last along this line is. Insulated concrete Form. Now, this diagram of course we will come to later. Insulated concrete form or insulated you know as the ICF as you call it. Is a system of formwork for reinforced concrete usually made with rigid thermal insulation, so the formwork is made of Thermal insulation and that stays in place as a permanent interior and exterior substrate four walls and roofs. That means here it is other way round. Earlier I had two (())(1:08). And then the core was insulation. Here the formwork itself is formed by insulating material.

And it remains there, it does not go away, it is a part of the system itself. So you are actually saving on to your formwork cause because formwork itself is going into the construction itself. So stays in place something like this. Something like this, but supported by steel frame you know metal frame frames or such system. So first you have installations on this side and this side. Which are supported the metal frames should be removed, but the insulation remains and concrete is inside.

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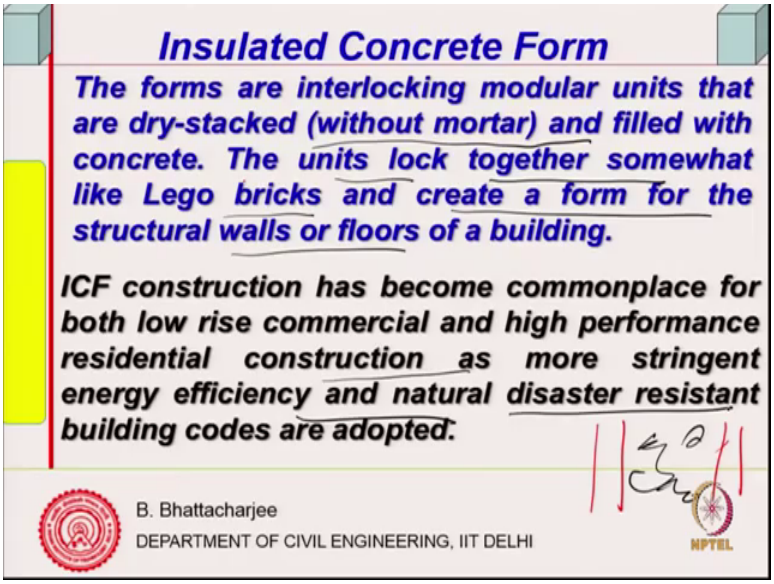

These forms are interlocking modular units. This, you know the forms are interlocking modular units that a dry stacked, without water stack them up and filled with concrete. For example, if you have Polystyrene, expanded polystyrene. Expanded polystyrene here, expanded polystyrene here. And then fill in concrete material here and this remains, obviously they will need some finishing on top of that. You need some finishing on top of them.

So they form actually interlocking units because one panel and another panel they have to be interlocked. So that are dry-stacked and filled with concrete. The units lock together (sometime) somewhat like Lego of bricks or create a form for the structural walls or floor of a building. So ICF construction of course is a commonplace for low rise and commercial buildings and high performance residential construction as well, because you can design the system accordingly.

You know, if you are looking for high energy efficiency. Then this kind of systems are must. Also for natural disaster resistance buildings.

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So this is how it looks like, so you can see the formwork the reinforcement inside, reinforcement in side. And then concrete and we poured into it. Then the whole system goes away you know this is of course in (())(3:38) straightaway in (())(3:39). So it remains there straight away. So the wall is created by sandwiching concrete between each of these layers designed to provide stronger more comfortable quiet and highly energy efficient structure. So that is all it is. So here are the, as you can see the first level of the wall has been constructed straight away here. This is (())(3:56), right.

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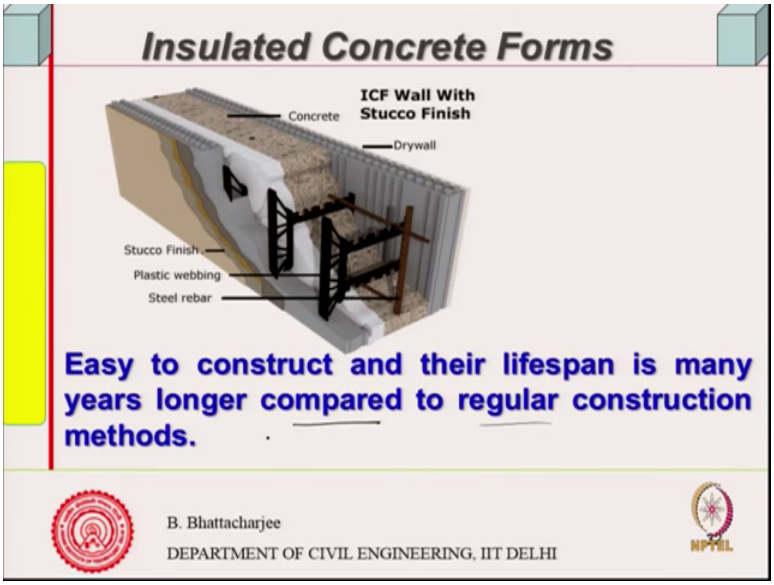

So it looks something like this ICF wall looks like this, this is your concrete, this is the drywall and they are separated out you know stacked and some finish you will have to have on top. Some plastic webbing of course you all have to do and steel rebars are also inside. So essentially it is other around, earlier one of the core being insulator, insulation, here the form itself is insulation and that remains. So easy to construct and their life span is many years longer compared to regular construction methods that is all right.

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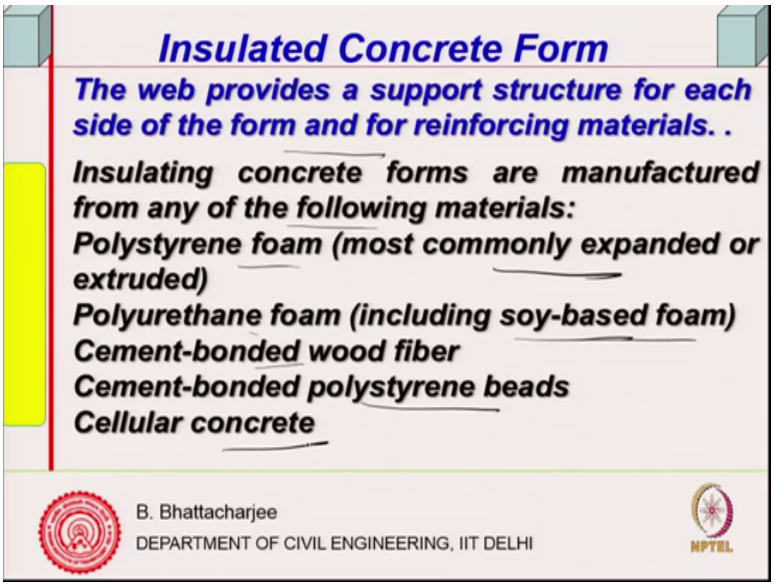

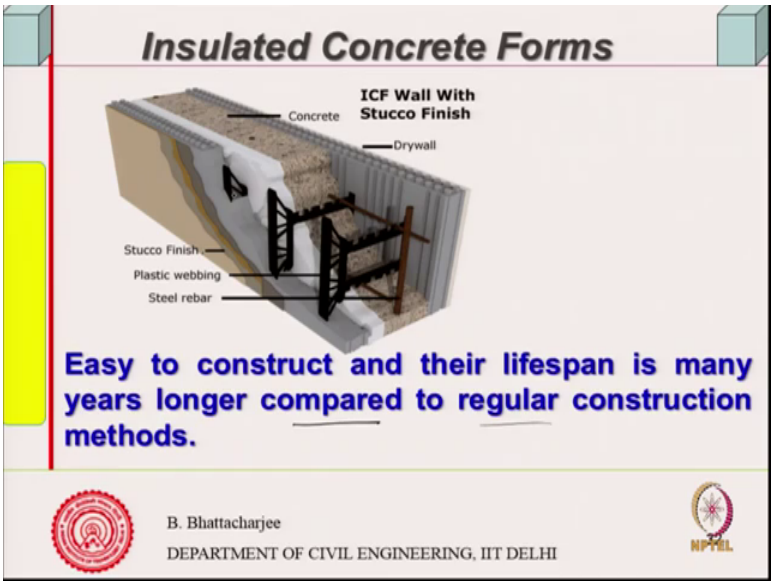

So, the web provides support structure for each side of the form and for reinforcing material. So this this one's they provide actually support structure for both the types of forms and

reinforcement you know supporting the reinforcement they will remain there, they will also remain there right and that is what it is. So insulated you know they are manufactured from any of this material. For example, you can have polystyrene foams as I said expanded polystyrene thermacoles like things or polyurethane foam. So like, soy-based foam.

Cement bonded wood fiber, so you can made wood fiber as well. Cement bonded polystyrene beads. Cellular concrete, so all the other kind of insulating material can go into forming this foams.

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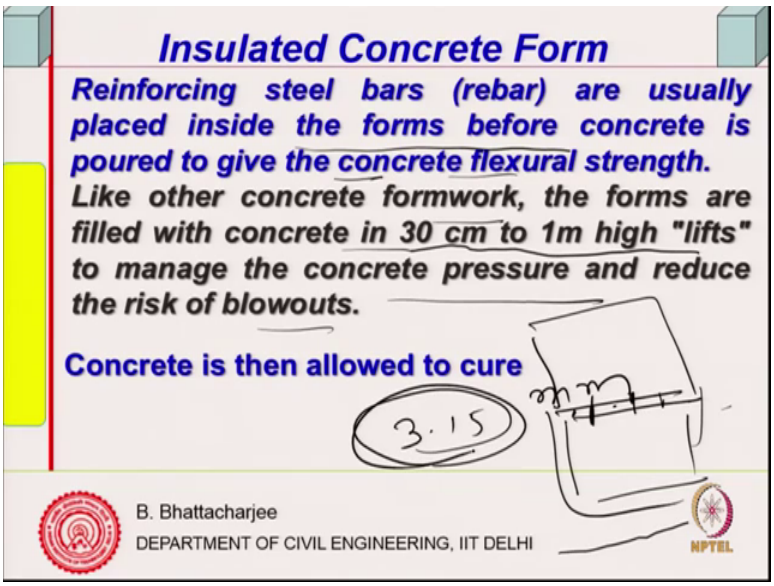

Reinforcing steel bars are usually placed inside the forms before concrete is poured to give the concrete flexural strength. Like other concrete formwork the forms are filled with concrete in 30 centimeter 1 centimeter high lifts as we know a normal casting to manage the concrete pressure and reduce risk of blowouts that is one thing. Because the form is not as strong as normal steel form let us say, you know in steel normal formwork that we use in castings (())(6:02) quite often is 3.5 mm what we call a BP sheet particular steel, but this is used deliberately thinner once.

Because you do not want it to be heavy and you will have normally, normally only you will have angles at the 600 by something like 600 by 400 panels they will be bolted if you remember somewhere you might have studied you will have angles at the end and there will be of course this will be bolted here, angles for connecting the next panel. So they are in panel forms of steel they are panel forms of steel usually.

And two of them will be connected like nuts and bolts. So simply we will connect them, tighten them up so that their concrete does not lose out so that is the conventional formwork. Now this is 3.15 millimeter thick the conventionally used in India or you can have even smaller ones perhaps but this has been conventionally used.

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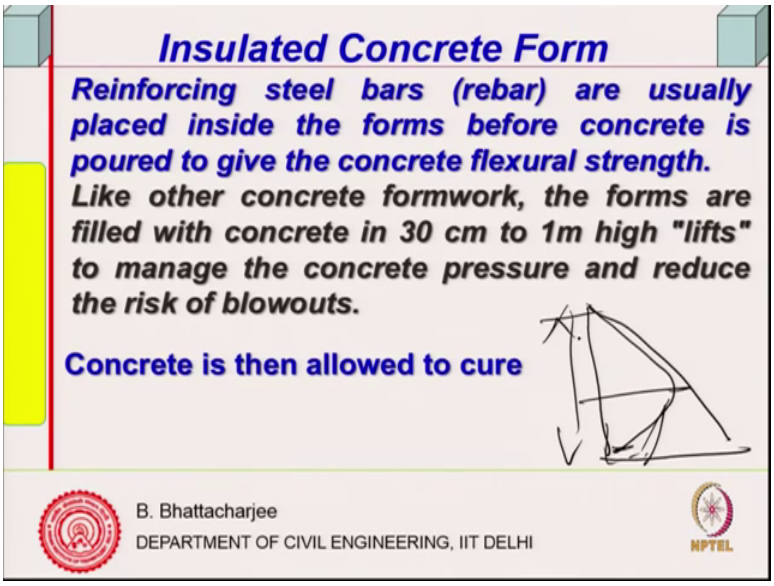

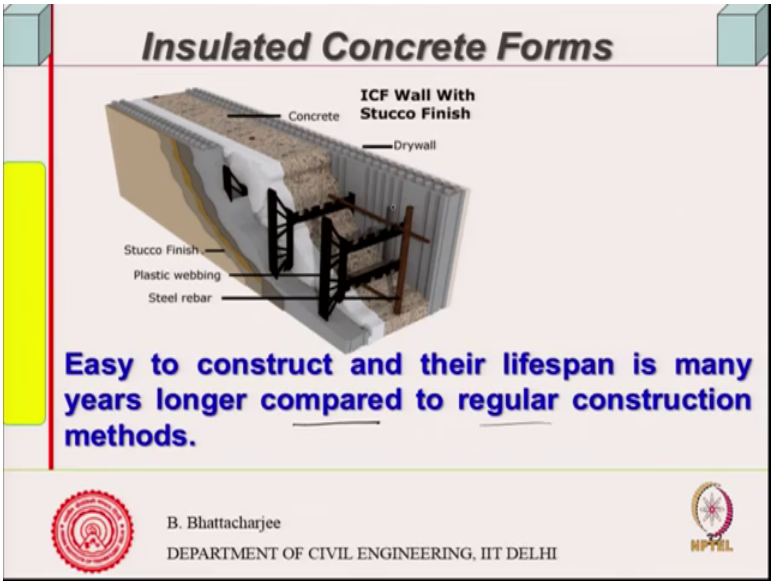

Now pressure on the formwork is something of this kind. Pressure on the formwork is something of this kind hydrostatic is not exactly hydrostatic pressure. That like this you know so fresh concrete does not offer hydrostatic pressure as such. Why? Because the time you pour it sets some amount of setting would occur, so the bottom concrete it can withstand on its own, so you

do not get a full pressure at the bottom. It is I mean not exactly this, something like this it would be, so somewhere in between you will have the maximum pressure, right.

So wet concrete density into the GH that will be the rho GH will be the pressure, pressure is something of this kind. Now it depend upon therefore the height. Now here the your form is not as strong as the steel plate. So your lift thickness has to be conveniently thought of considering both the web you know this this web connectors and the insulating form that is there. So it has to be designed accordingly, designed accordingly right so can be 30 centimeter to 1 meter high lifts to manage concrete pressure and reduce the risk of any blowouts. And then of course concrete can cure in (())(8:39) no problem.

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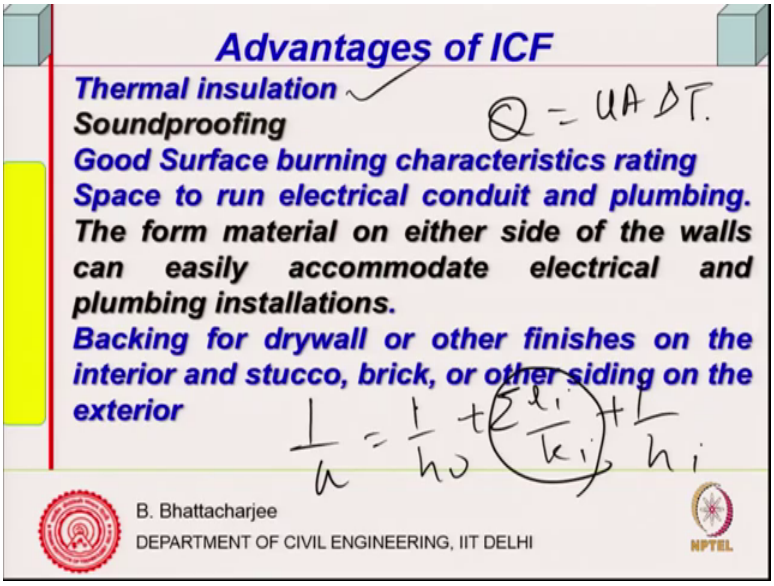

Thermal insulation obviously but it is something different it is in a slightly different manner because now you have the insulation is on the periphery, right. As an insulation it will perform equally good because as you know 1 by U is equal to simply 1 by H O plus sigma li over Ki Plus 1 by Hi. So sequence does not matter here, this side or that side or core it really does not matter because it is L by K.

So whether this side that side it will not matter. But it matters in terms of decrement and time lag, right it would matter in terms of decrement and time lag. Why? Because if I have a high storage material at the outside first it will store and then allow the heat to go.

So storage obviously in this kind of material storage will be relatively less but they are insulating, so you know the amount of heat coming in which is Q is equals to UA Delta T as you know. So, if I look at the thickness through which it will pass K you know L over K etc etc, if you look at it. So it will not allow much heat to pass through, but storage will be less. So accordingly time lag would depend upon the mass of the concrete that is structural concrete which is inside. But U value it is going to, you know it is going to be (())(10:26) because it is insulating itself.

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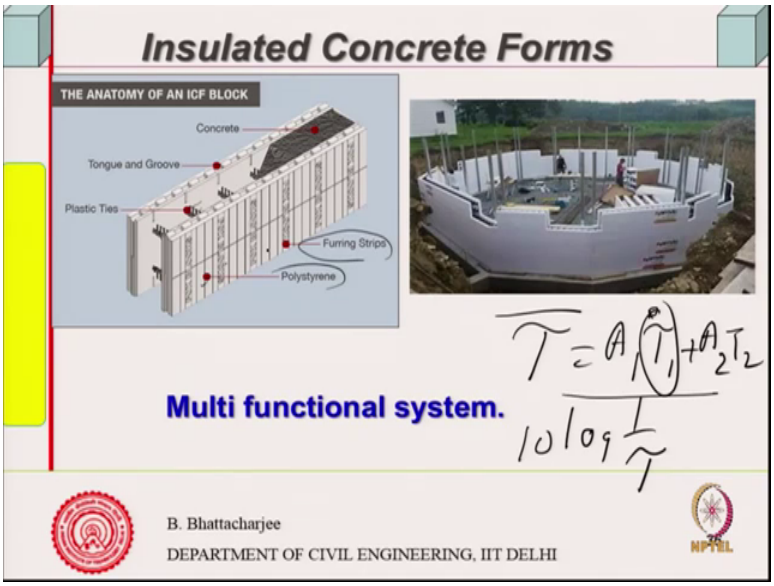

So that is how it looks like so this is how you know so you have got this plastic ties plastic ties are important rather than Steel the reason is if you put in steel acoustic insulation will reduce. Acoustic insulation would reduce because Steel transmit sound right to transmit sound and if those who have done a course on building energy acoustics etc. etc. you will remember that Tau bar what is transmission, transitivity of sound, average transmit of sound is a function of A 1 tau 1 plus A 2 tau 2.

So the transitivity of one of the function is very high then insulation quality you know an insulation quality is given by 10 log 1 by tau right. So this steel plate if you are steel connector then that is not a very good thing from acoustic insulation point of view even from heat transfer also but then the area is small so will not affect so much but transitivity is quiet quite reduces. Significantly one can show by simple calculation.

So therefore, preferably you put in plastic connectors like plastic ties and therefore groups can be there right and this is the concrete so some sort of Strips Polystyrene is here and some sort of strips and you can give kind of look as you want. So this is typically something looks like this.

So it is also multifunctional system, it is also multifunctional system both thermal design for thermal acoustics as well as load bearing system themselves, right.

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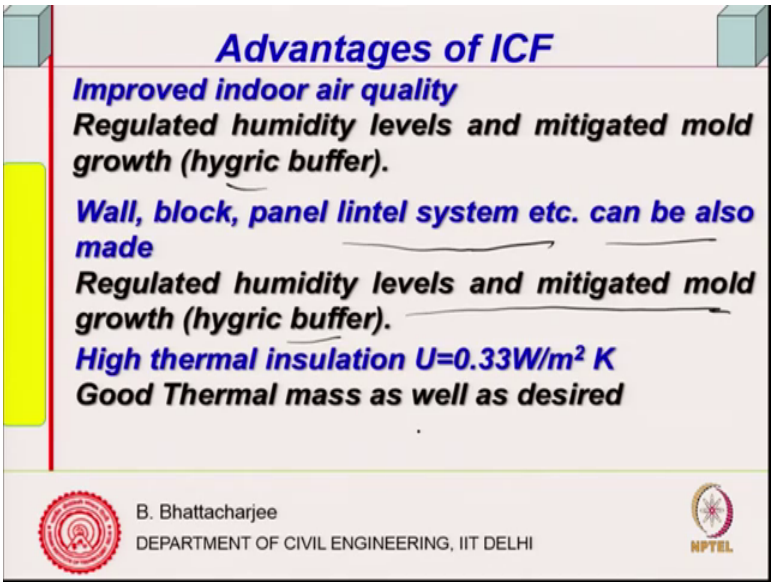

They do improve indoor air quality, regulated humidity levels and mitigated more algae or more growth can act like a hygric buffer, wall, block, panels lintel systems etc. can also be made. Regulated humidity level and more growth if you have humidity level is maintain then obviously you will not have more growth such things. High thermal insulation that is what I said and good thermal mass if you desire because mass will come from the core the concrete part of it thermal mass will come from the concrete.

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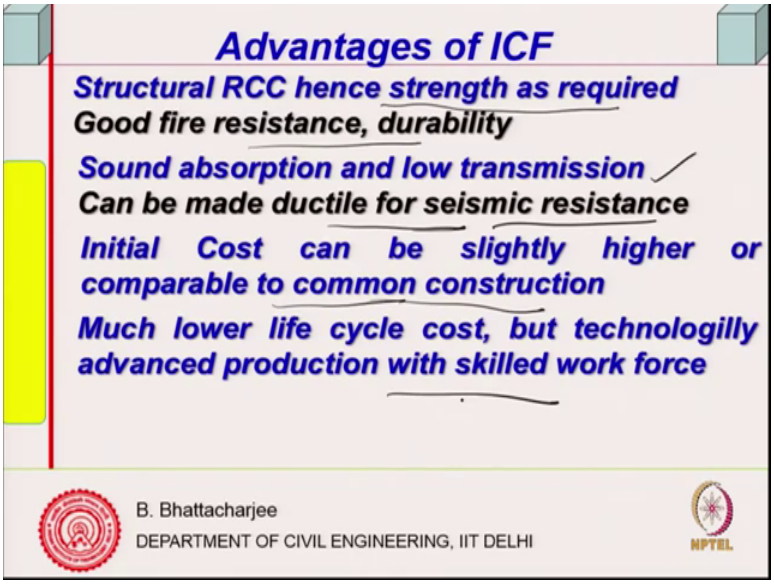

So, structural RCC hence strength is strength as required. Now fire resistance, the insulation material normally and not good fire resistor, thermocoal will simply you know they will, in fact they will add to the fire load. They are carbonaceous material they will add to the fire load, they are good insulation. So you have something the finish itself has to be fire resistance kind of finish that would be there on top.

Sound, as I said sound absorption and low transmission and you can make ductile because core concrete and its reinforcement will make it ductile for seismic resistance. Initial cost is slightly higher than conventional and one thing you are reducing is a formwork cost right it is a part of the system itself. So formwork cost you are reducing, lifecycle costs is much lower so that is why it is and technologically advanced production is required.

You cannot make it cast (())(14:19) construction is usually semi engineering or non-engineer that cannot be done you have to do with skilled workforce, who knows, who know about it.

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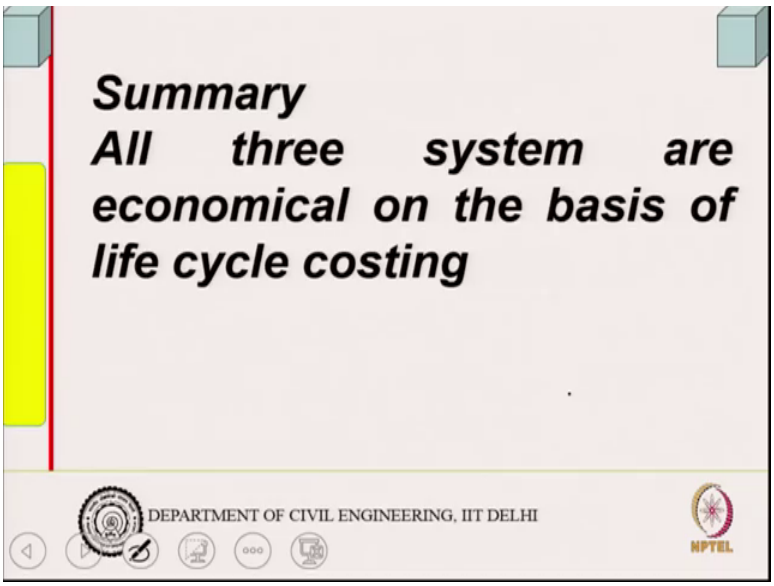

So these are kind of systems which can make sustainable concrete, you know which can make sustainable construction system and then let us look into one or two more of the system as you know similar systems which are there we will look into this, one of them of course is the modular, one of them is a modular concrete construction.

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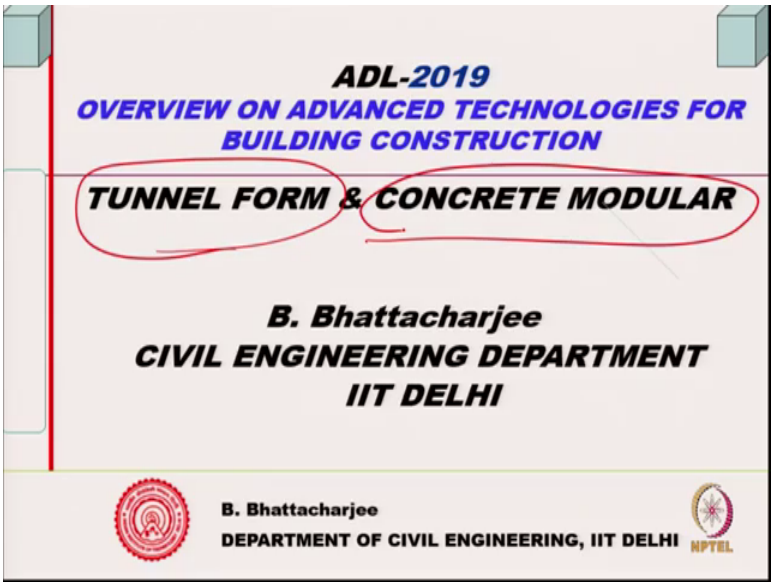

But just before that you know there is this sort of framework I think you might be some of you might be familiar with this, this one used in India for quite some time. we call it tunnel form I think I have not discussed this, I will just discuss this and then discuss it a little bit, yes last class

I must have mentioned something about this. But this has been used in India since 1990s. I mean at least used somewhere. And this is a 3 dimensional system.

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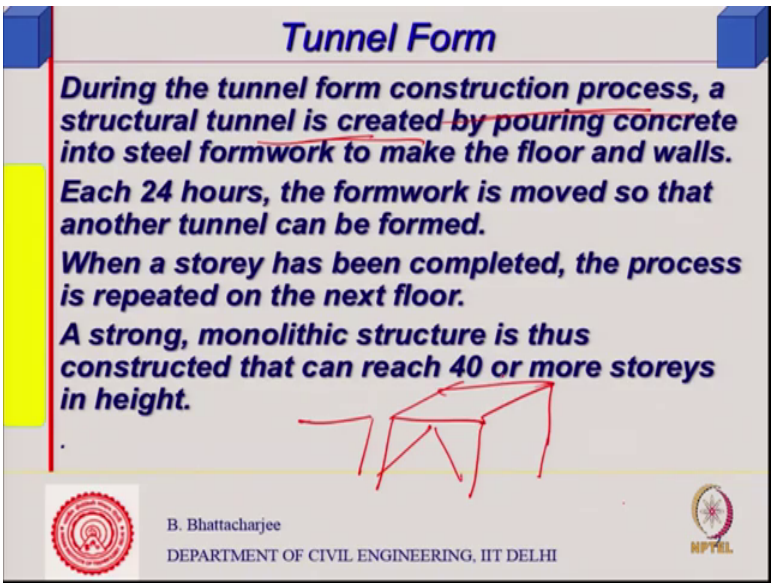

So, let us look at them now tunnel form construction process structural tunnel. I think I must have mentioned this in the last class, did I mention this? I think I did mention this tunnel you know this this one. Structural tunnel is created, so we create a structural tunnel looks like this as usual see later on simply looks like this. Formwork looks like this, so you will have this the inside of the form and another one and it would be propped up.

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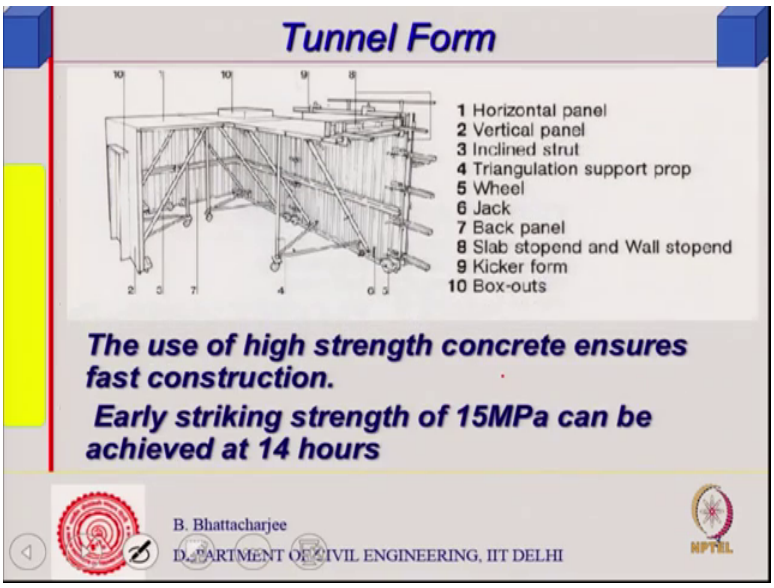

So it looks like a tunnel like, looks like a tunnel something like this. So this is the form, this is a form and this so it actually can form you know it is a cut, it is a cut shown.

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So these are all on wheels, this is the bottom of the slab. This will form the wall or let me see if I can show it better something like this maybe, no this is a starting point not really I will come back, yeah.

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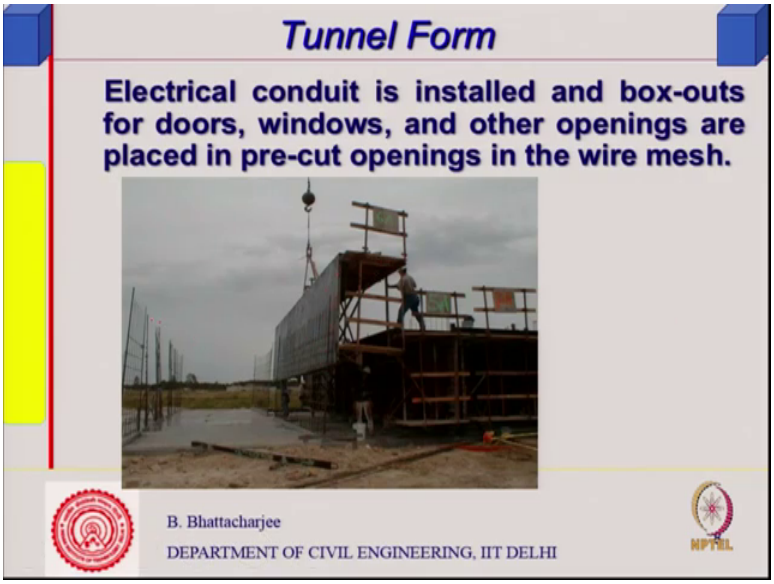

This is the part of the form there will be similar sort of one on the other side.

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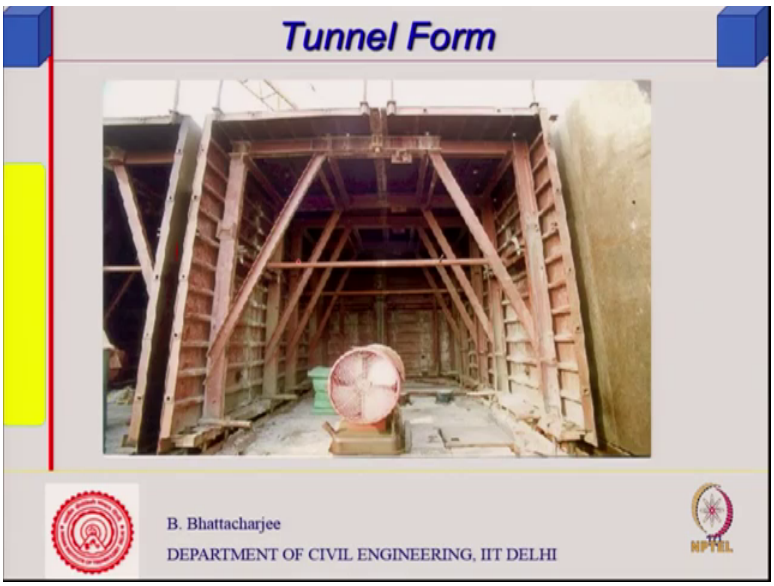

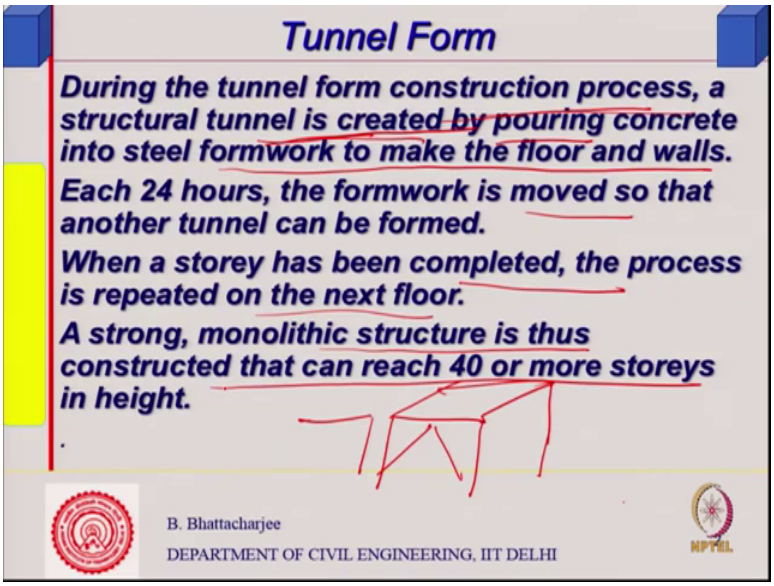

And just let me see a better diagram, yeah, this is a better diagram, so this is the formwork. This is formwork, this is the other formwork, this is a wall which is cast monolithically with the slab and this is the other one already cast already it has been cast. You will have reinforcement placed here, reinforcement placed here, cage is formed, complete cage and do the concreting that means this and this is supported prop etc etc and there is a turn buckle arrangement each you know skipping the space. So basically it is like a tunnel and once you have finished you can collapse it, roll it out, roll it out a little bit. A crane can lift it and place it in the next one.

So speed of construction goes very high, speed of construction is very high, so in this one speed of construction is very high and a structural tunnel is created by pouring concrete into steel formwork to make the floor and walls. So basically you have floor and the walls they are all monolithic. Therefore, you can reduce down the material consumption and since the whole system is shifted from one point to another point not a panel and you know normal formwork therefore, production process or construction process is pretty fast.

So each 24 hours the framework is moved so that another tunnel can be formed, so you pull it out, put it in the next place. Now the concrete has to then harden by that time I mean it should finally set and should be able to take its own load. So what is done is heat curing so you actually heat curing is done. So you have a heater inside that tunnel as I will show you later on. So when a storey has been completed the process is repeated for next floor. So strong monolithic structure thus constructed can reach 40 or more storeys in height. So therefore, you know you can you can actually make relatively taller building with this.

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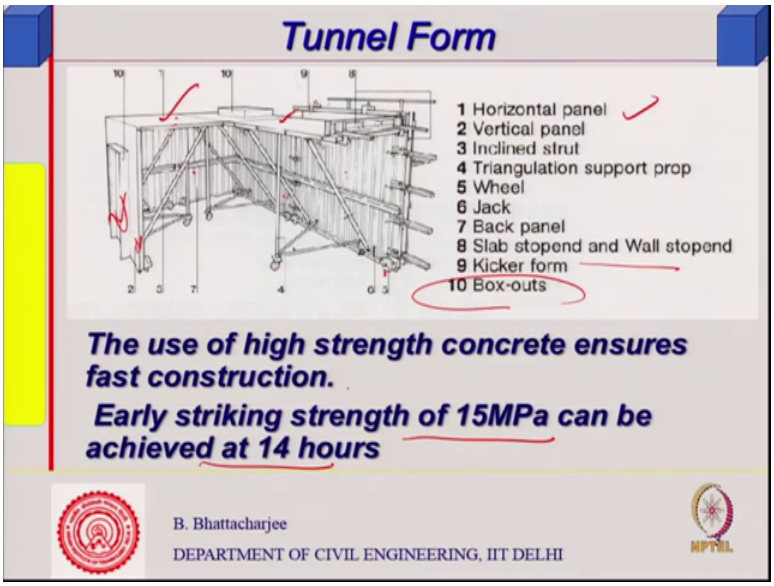

This is what it looks like, so if you look at it there are horizontal panels so these are horizontal panels, make the floor bottom of the floor, bottom of the floor right bottom of the floor. Then vertical panels, so vertical panels are this one. Concrete will come on the side, concrete will come on top of this. Incline struts so these are inclined struts which will support the foam and

there they are on wheels so we can separate down make it a little bit collapse and pull it out whole thing is together.

Triangular support prop, there are triangular support props are there, wheels are there, so it is on wheels so they can move easily, they can move wheels whole thing can move easily. Then there will be Jack right there is a Jack which you know which can actually do a pressing press press and things like that. And back panel this is the back panel other side. Slab suspended and walls stopped so therefore, you know this is the slab for end of the slab concrete has to finish so that is what it is.

And Box-outs anyway 10 is, 10 is box outside if you have a kind of a you know like kind of insert into the wall itself because the concrete will come here, concrete will come here, concrete will come here. Thus, you can use high strength concrete to ensure fast construction. For example, if you make 80 MPa concrete then its 24 hour strength will be also proportionally high so you can shift it out, I mean you can design the system accordingly. Heat curing, make it high strength so that you can remove the form early, so early striking at 15 MPa strength, if in 14 hours if you achieve then you can simply remove this formwork, right.

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So that is how it looks like the same one photograph, so here the concrete will come and here the concrete will come, here the concrete will come, this is the portion which is supporting the slab part of it.

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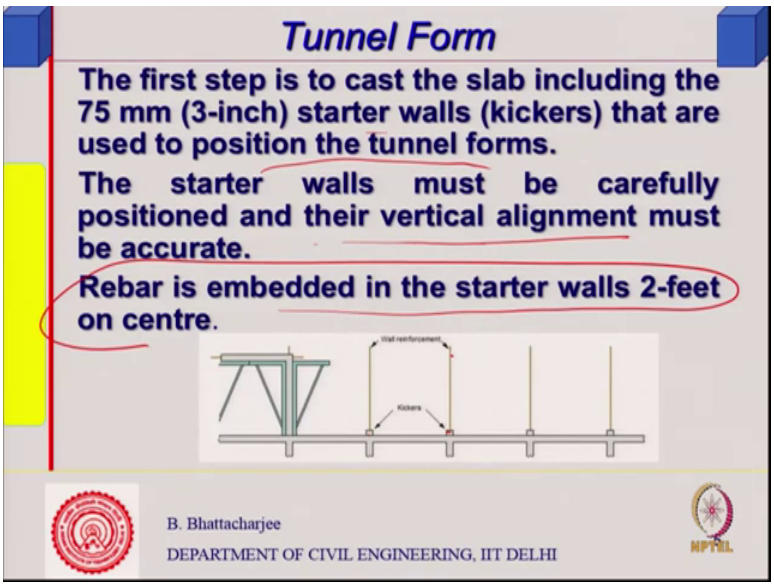

So the first step is to cast the slab including the 75 mm starter walls at the bottom the ground floor level that are used to position the tunnel form right. So this is, these are the ones and then tunnel form is placed on top of it you know tunnel form is placed on top of it. The starter walls must be carefully positioned and their vertical alignment must be accurate, then they come here on top of it. Rebar is embedded, starter walls 2 feet on center, so that is what it is reinforcement comes on top of it.

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This the ground floor level.

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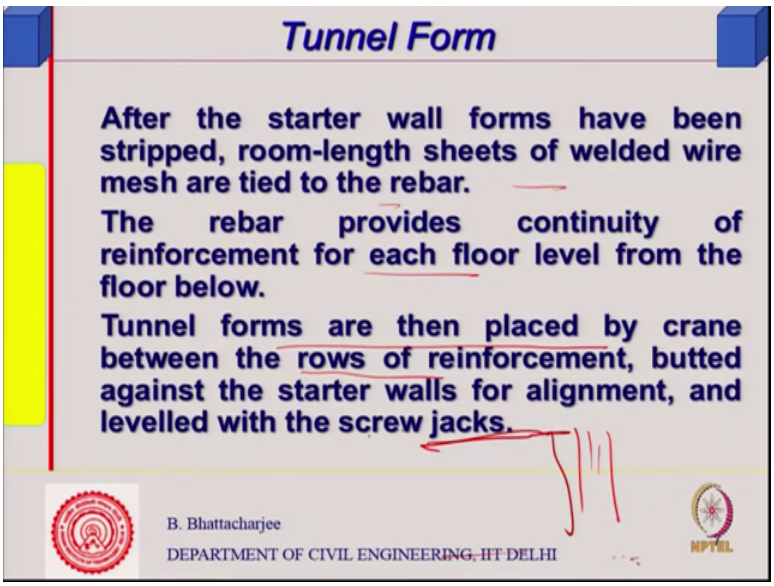

After starter walls forms have been stripped, room length, sheets of welded wire mesh is tied to the rebar, the rebar provides continued reinforcement for each floor level to the floor level below. So at the, from the bottom one you know the rebar are connected to the top one, then placed by cranes, so this is the crane can handle things, so one crane lifts it up, puts it straight away between rows of reinforcements. So, reinforcement has been erected you these are the let us say reinforcement cage, now tunnel form comes here, tunnel forms, tunnel forms can come here, already construction wall, constructed wall might be there right and tunnel form comes here the crane just puts it there. So you know and aligned and level with screw jacks and things like that that is turnbuckle arrangement.

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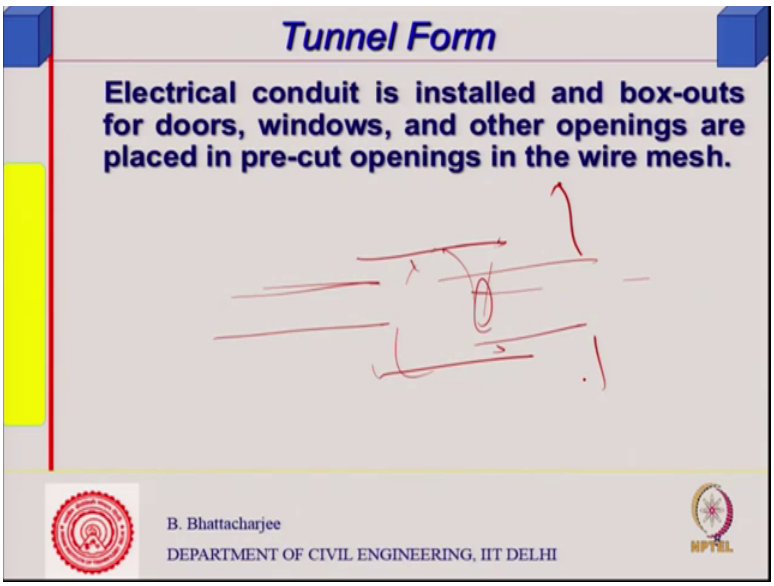

Turnbuckle arraignment will have it you know like something like you have a rod, then you have a there will be there they will be inner threading in this one and from this side you have this one which you will have a thread here and then handle you can, you will have some handle as you rotated it goes inside and you know rotate it either clockwise or anti clockwise to spread cause this spread turnbuckle to spread, you know those who may not have seen ever in the site, this is what a turnbuckle look like this does not have this.

This will show you know something like the spreader actually they will spread this is not here also so they basically turn that sort of spreading arrangement can be there and alignment can be maintained. If you have electrical conduit you can always place them there, installed in the box-out also you can have a box for doors.

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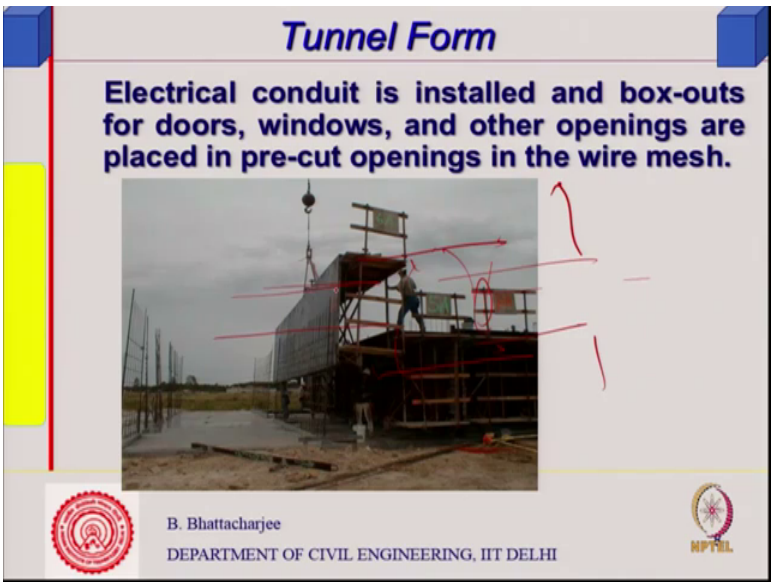

So this is whole thing is being lifted by a crane at the ground floor level so any openings you require you can always have pre-cut. And wires reinforcement is precast I mean pre-cut actually.

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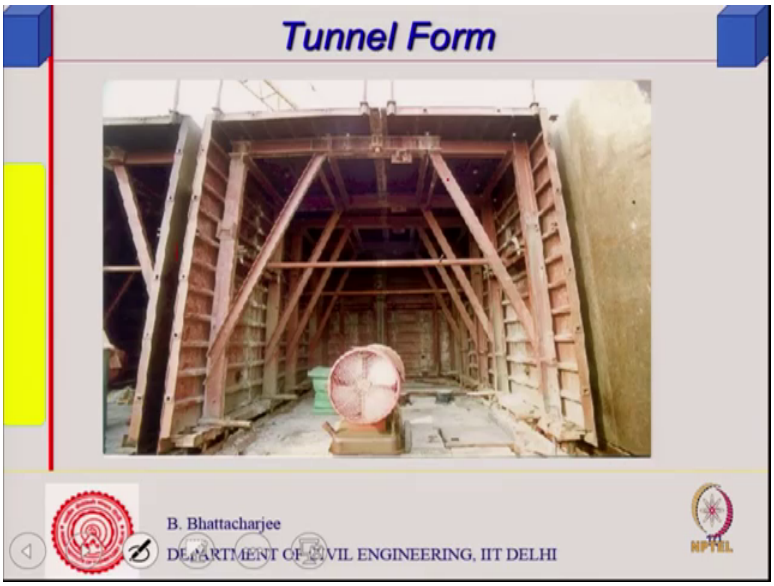

For example, this and this are fan you know heater and a fan, this is a turnbuckle, turnbuckle has took out, these are turnbuckle, so you rotate this you can see there is a rod sort of a thing this is actually handle. So, if you rotate this either it will close or it will open because there is a threaded portion inside here and there is a out you know thread inner inside thread and outside thread, there is a slip on which there is a thread and this is a rod on which there is a thread so you

rotate it. And this is a fan which is blowing actually the heat so that fast curing can occur, just a minute let me show you the door yeah.

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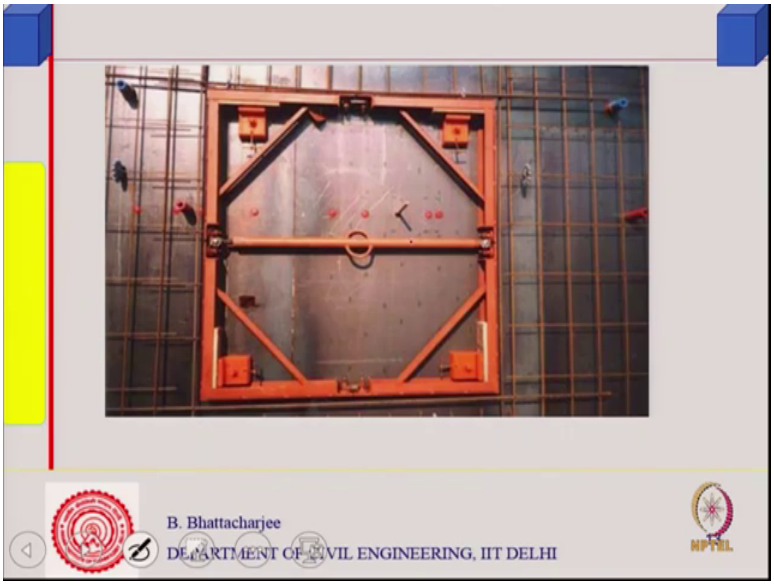

So this is the window, one can have a cut for the window right and wires are cut accordingly.

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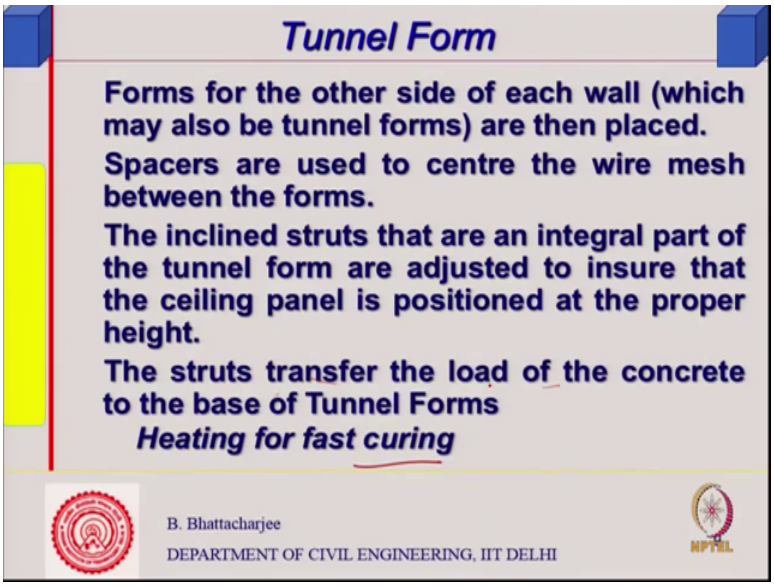

So either side you know then placed ok etc. Heating and fast curing as a struts, struts actually transfer the load of the concrete to the base of the tunnel forms.

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And this is how it is it looks like, did I miss anything out? Just a minute yeah this I said.

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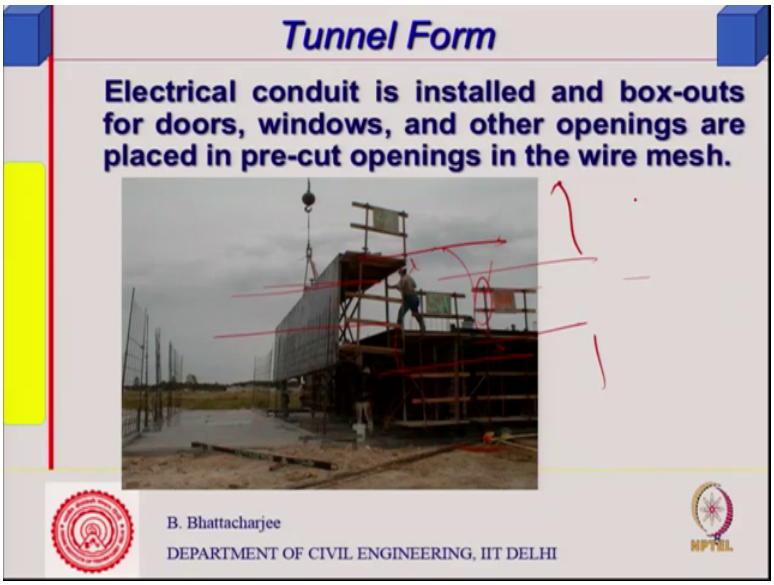

Electrical conduits can be installed box out windows etc you can put in and so on. So heating I have already mentioned to you.

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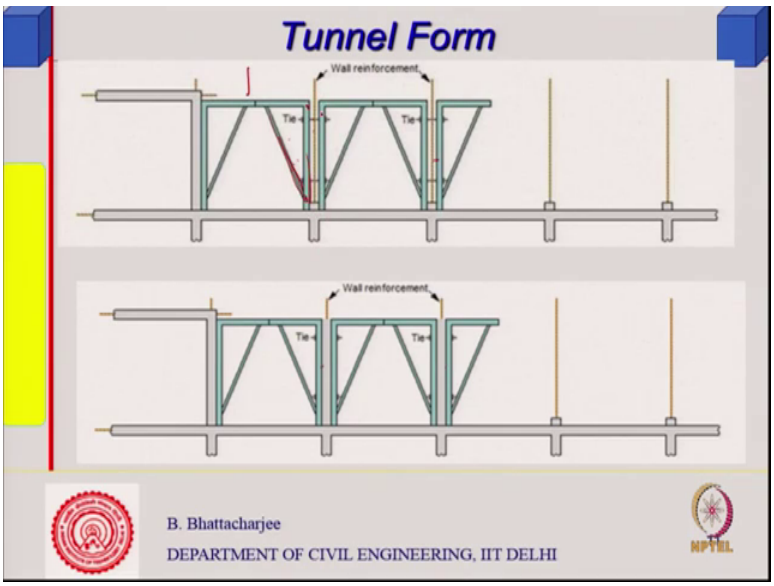

And this how it is, so this is what is cast already now this will be cast the tunnel form has come this maintains the you know this this actually carries the load, transfers the load to the from the slab to this and to the bottom kind of a bracing and then putting the reinforcement, reinforcement, reinforcement the concrete comes in and here is a concrete has now come in wet concrete, it has come in here. The rods of course protrude out for the next level and so on.

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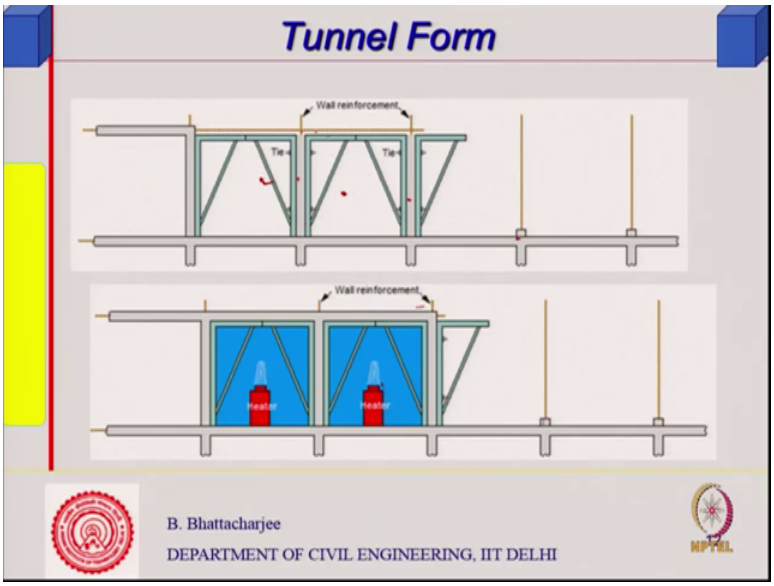

So this is already existing floor and so on, then there must be heating, so heating in order to get it fast cured. And the slab reinforcement then you put in, first is the wall reinforcement, then slab

reinforcement, cast the slab, the slab is cast and once this box is complete, then follow it up on the other side and so on so forth and this is heat cured.

So first step would be to place that rod here which is already existing just tight up maybe or if it is already you know the sufficient length is there that might be there then you put the tunnel here tunnel here, cast this, cast this, put the reinforcement here cast this portion, ready for, heat it, heat cured, cause this to collapse a little bit, pull it out, so it is a very fast construction and monolithic slab and wall construction. This side has to be filled in with some sort of infield material like AAC or something of that kind.

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So they can, they can combine this is a fast construction actually and sustainable in the sense that you can make high strength concrete reduce down the materials and material cost, right.

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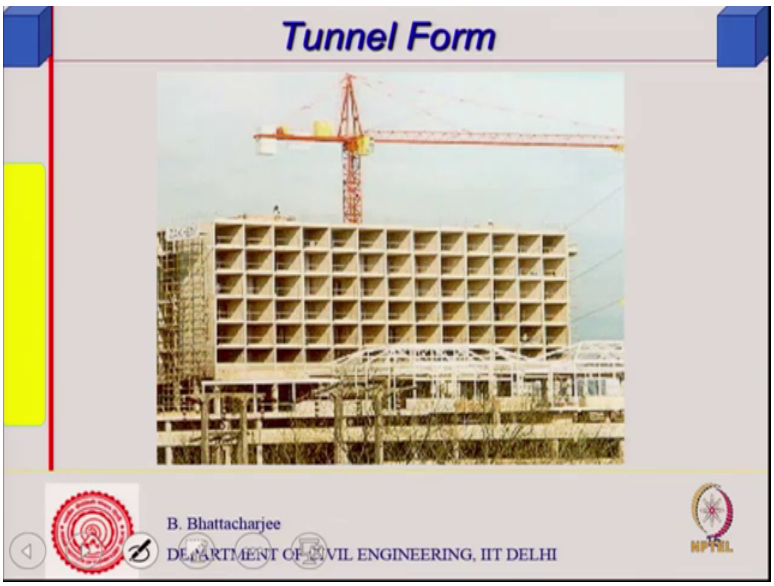

So even you know something like this hotel buildings one can construct out of this. Similar of course it has to have a similar shape and size and that is what it is.

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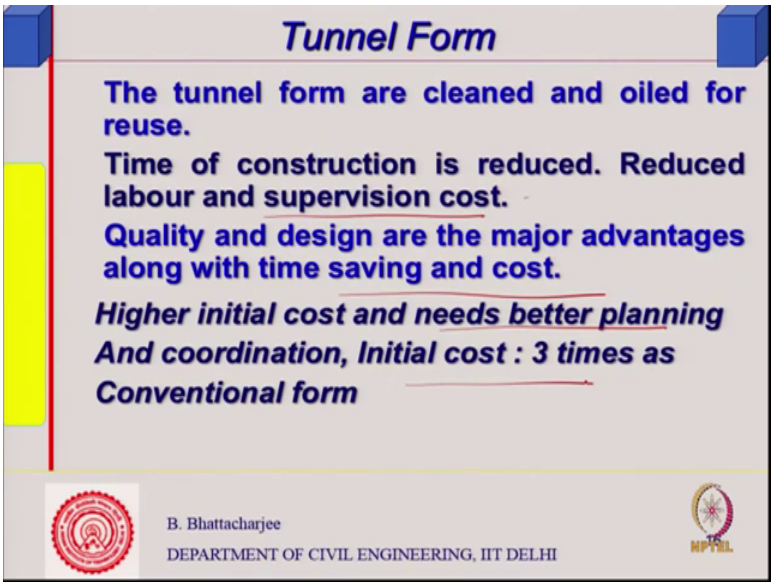

So tunnel form a clean and oiled for the reuse. Time of construction is reduced, reduced labor and supervision cost, quality and design are the major advantages along with time saving or cost, initial cost is higher. In all this initial cost is a little bit higher. Better planning and coordination. You know initial cost can be 3 times than conventional form.

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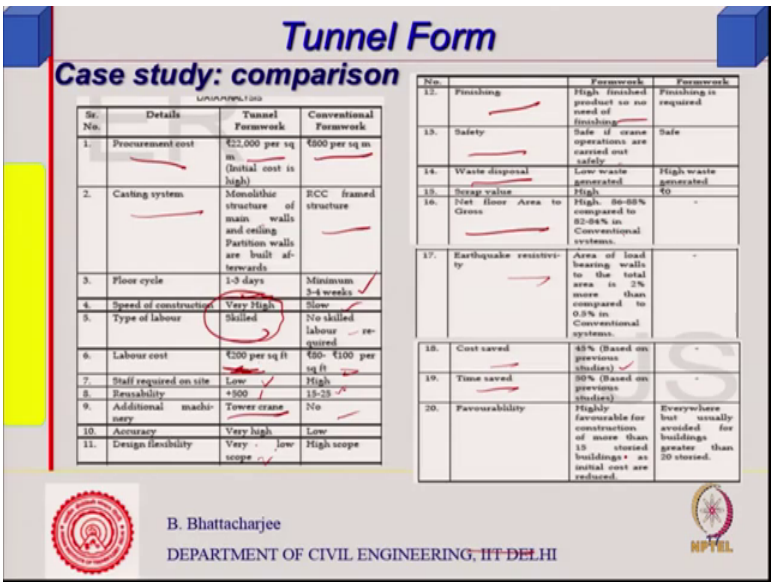

So somebody has done a case study in India and this case study is very interesting. Procurement cost was 22,000 per square foot I mean square meter for this one. Conventional 800 per square meter, so you can see 800 to 22,000 not 3 times is much higher. Casting system, monolithic etc etc RCC framed structure and this is monolithic slab and etc, floor 1 to 3 days this requires 3 to 4 weeks.

So the time is the factor you can finish a particular floor in 1 to 3 days and 3 to 4 weeks and very skilled labor, speed of construction is very high, slow non skilled labor obviously quality will be poor. Labor cost relatively less here because they are skilled people you have to pay more, staff required is not very high but they still have high. Reusability, many of times even use them because a much (())(29:32) system.

So it is more than 500 times plus that is what is being said, this 15 to 25 repetitions and then you need the crane you need to here you would not need anything accuracy is very high, design flexibility is not much actually in terms of because you have all shapes are you know dimensions are fixed, room sizes are fixed so very good for a hotel, very good for similar sort of construction where you can use them.

Finishing, yes good finishing. Safety, you have to see the crane and construction safety is very important. Waste disposal hardly any waste comes in and scrap value of course is high, because that you know the formwork itself can (())(30:14). Net floor area to gross very high because wall

is thinner and then earthquake resistance and etc that would be high. Cost saved 45 percent based on you know you can save. Time saved that is very high and you know highly favorable where you are doing more than 15 storey building and you want to do it in very short time.

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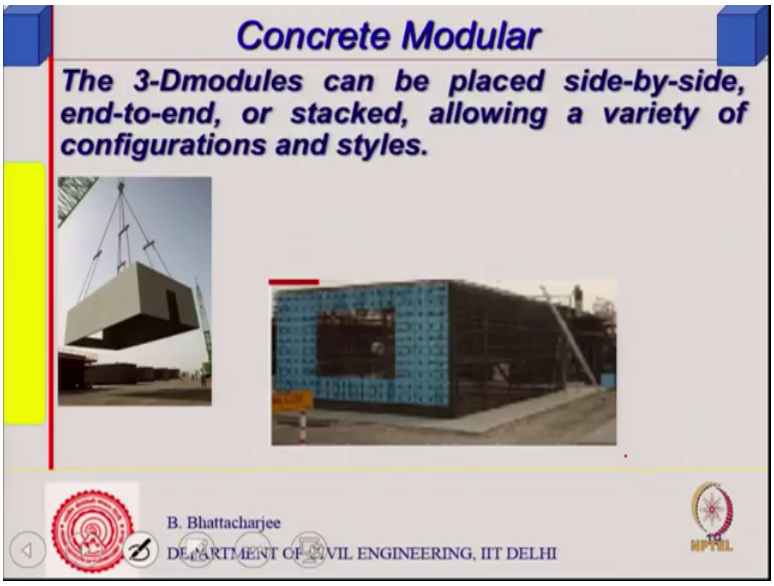

So that is what is tunnel form I think we will stop it here, and we will look into concrete modular in the next case and I will not going to this, so this you can understand it is a modular box, complete box, modular box and you can built lot many things in this so this is 3D modular system and we will look into some similar advance industrialized construction in the next class.