Sustainable Materials and Green Buildings
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Lecture 45
Autoclaved Aerated Concrete, Insulated Precast System and Insulated Precast Forms

Okay, so we will look into some of the, you know modern construction techniques related to building, which are, which contributes to sustainability or sustainable. As we have seen in the last class actually we saw last time when we talked about that if you want to construct large number of houses over a short period of time it has to be industrialized construction right. When we are looking at the affordability of house and things like that so it has to be. So some there are different systems, so one of the system is autoclaved aerated concrete right. This is well-known system, then insulated precast system and insulated precast forms so the formwork itself is insulated. So this technology is very much important.

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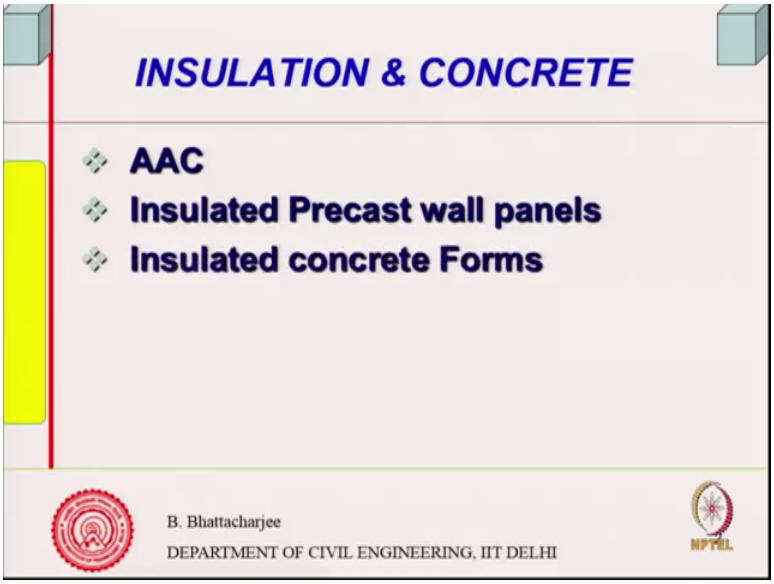

So you know autoclaved aerated concrete, insulated precast panel and insulated, this is what it is to discuss.

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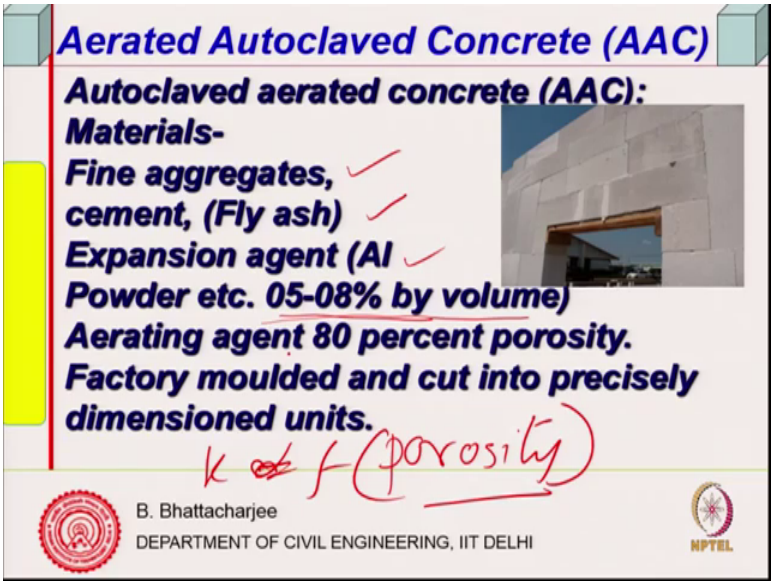

So, autoclaved aerated concrete generally how you produce? Essentially the components would be you see its purpose is that it has got very low thermal conductivity. And this is very much used in India now, because almost you will find the blocks have gone. There are manufacturers who produce this and that is what it looks like. You know you look at it. That is what it would look like right. And obviously you will have some fine aggregates, cement, and cement fly ash.

And generally since we have seen earlier the thermal conductivity is a function of porosity, K is a function of you know, K is a function of porosity and higher the porosity thermal conductivity is lower. So it acts as an insulation. Therefore, we tried to increase the porosity by doing what? Putting an kind of agent, expansion agent or forming agent you can talk about. Generally people have been using aluminum powder right. So this is the percentage by volume. Now this aluminum reacts with calcium hydroxide. Actually so this is it can give to 80 percent porosity and factory molded cut into precisely precise dimensioned units actually. So basically that is what it is.

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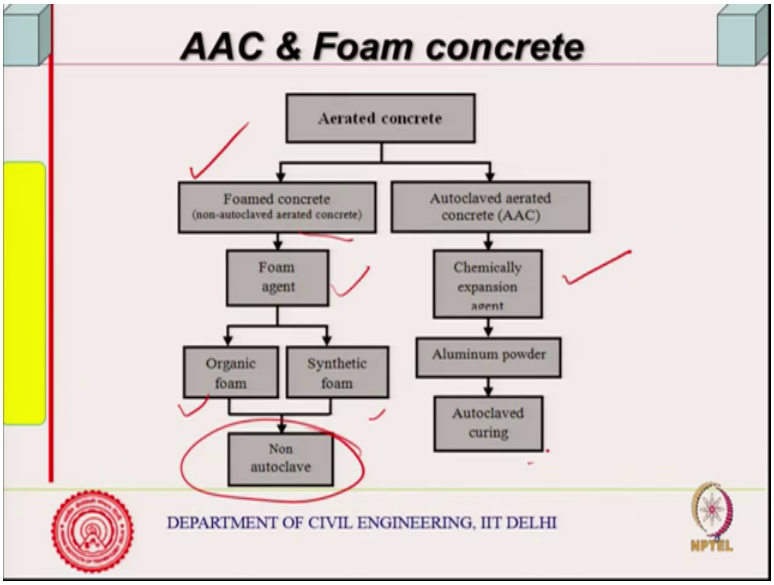

The other variety is foam concrete. Foam concrete will evolve foaming agent. So we pass the foam into the concrete while making it in green state. So this is not autoclaved. And foaming agent you add some organic foam, synthetic foam and that is how you get a lightweight concrete. Conductivity can be very low (02) 0.2 watt meter degree you know watt meter kelvin. And this is chemical expansion agent or some sort of agent which will react. For example, aluminum powder as I said and then you have to do curing at high temperature and pressure so that is AAC, right. So that is kind of a system is there.

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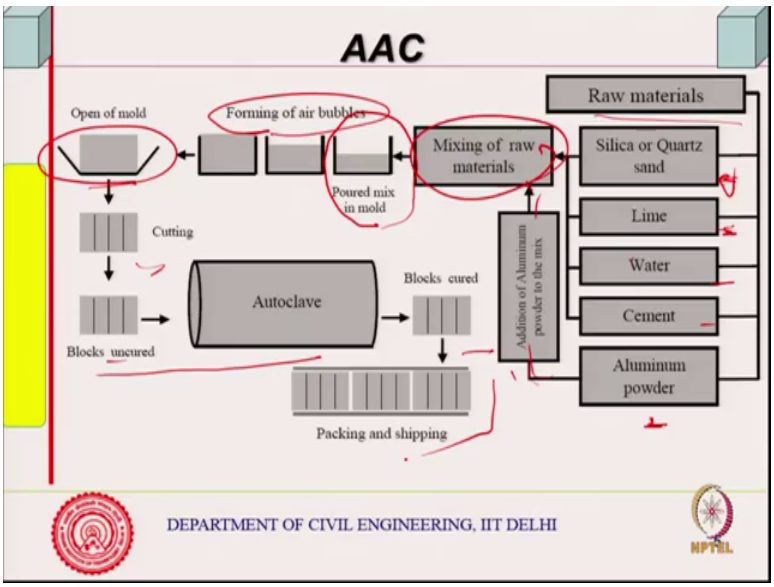

This is you know essentially you start from here raw material, generally silica or quartz sand. In fact in Delhi, people were earlier using even Yamuna sand. So some silica or some sand, lime, water, cement, aluminum powder, so you know this is what it is. So this aluminum powder together with all these raw materials are mixed, mix the aluminum powder and put it into the mold, there will be formation of air bubbles.

And this mold, in the mold you get large units which is cut into pieces. These blocks are then put into the autoclave, cured, then packing and shipping. In fact, it is almost an automated process. It is almost an automated process. You can see that this will be automated process. In fact there will be large tray kind of thing where they will be doing this. There are a number of factories say even around Delhi these are there. So essentially they are lightweight.

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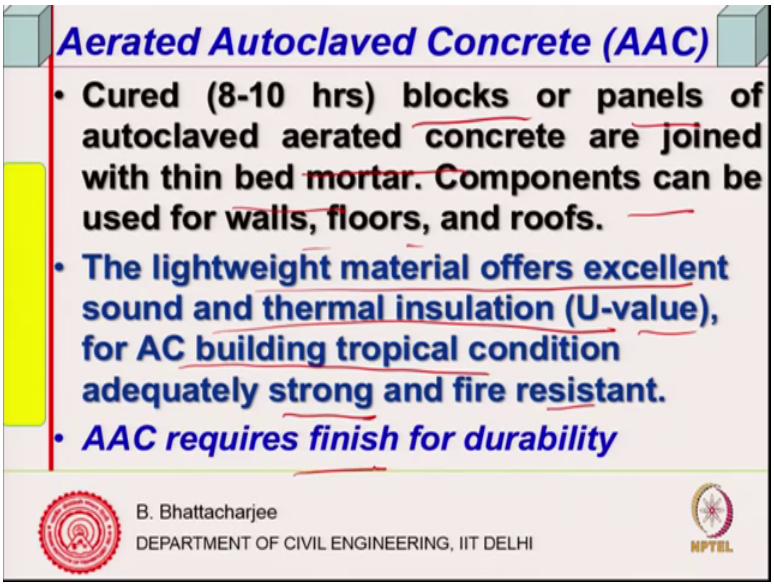

Generally cured for 8 to 10 hours blocks or panels of autoclaved aerated concrete are joined with mortar because then they are masonry units. Components can be used as walls, floors even roof and the lightweight material offers excellent sound and thermal insulation. So that is what is the thing, so it is a multi-purpose serves the purpose of multifunctional, serves is the purpose of envelope and then all kind of insulation. So this is adequately strong and good fire resistant. It of course requires some finish because otherwise it is so porous moisture may penetrate. So you might give a finish to it for the purpose of durability right. So this is the system. Something like this will look like this.

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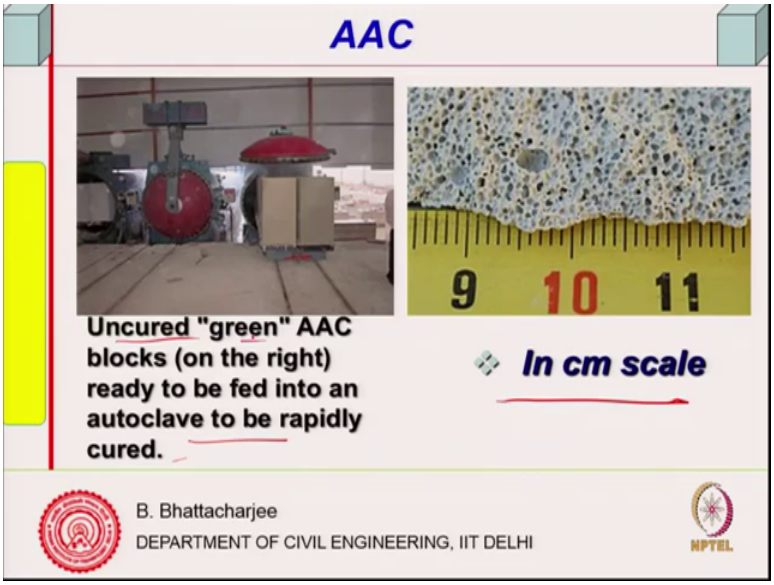

So this is the production system uncured Green AAC. It is here and in centimeters scale if you look at it right 9 to 10 centimeters so the boards are of this kind of sizes right. So this is ready to fit there are rails on which it goes and then autoclaved to be rapidly cured. It can be fully automated and you know so basically multifunctional as I said.

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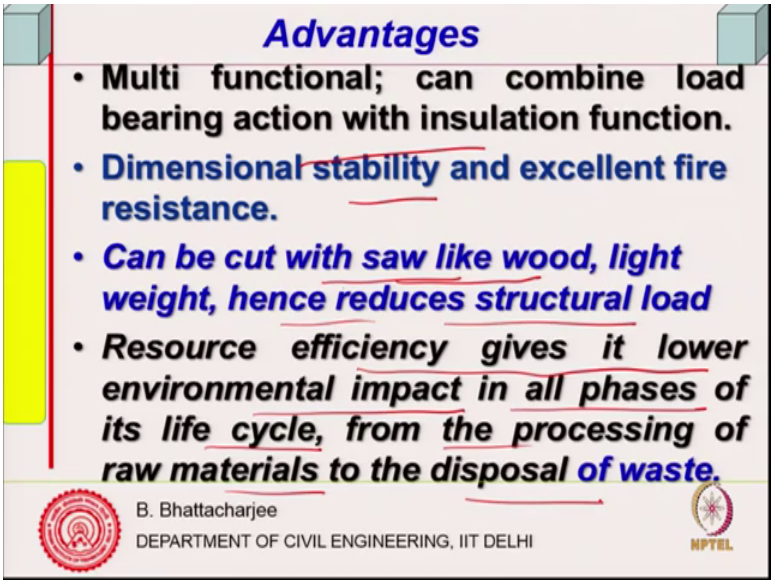

Combine the load bearing action with insulation function also load bearing. But then generally not use for load bearing structure in one storey structure you might use one or two storey, dimensional stability. Generally aluminum powder will react with calcium hydroxide producing

hydrogen. And this hydrogen forms the bubbles which remains there you know kind of (())(7:01) and they give you this action.

So you can actually started, all started with basically you are trying to get replacement for wood AAC replacement of wood long back not today in 1925 trying to replace wood with a cementitious sort of a material which should be cut, which one can cut into shape. So that is how actually originally it developed added the chemical and therefore it can be easily saw cut like wood, lightweight and hence reduces the structural load. Resource efficiency give it lower environmental impact in all phases of its lifecycle from the processing of raw materials to the disposal of waste. So these are the advantages.

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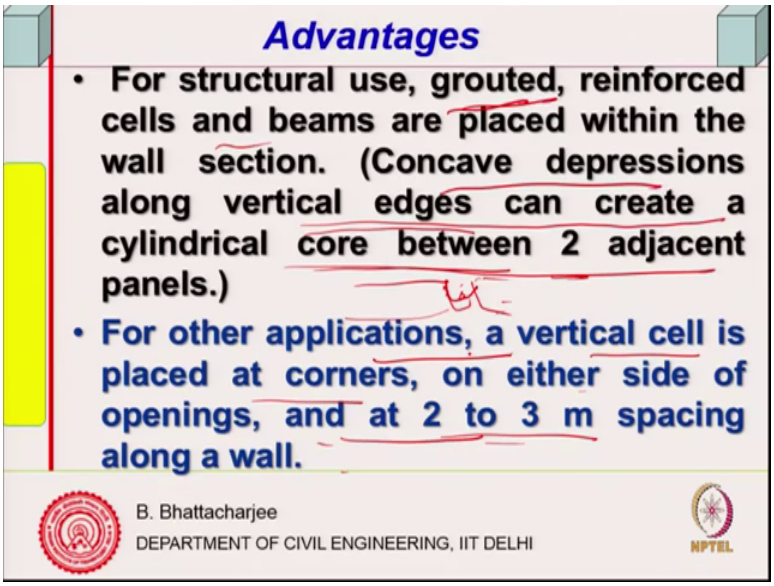

For structural use of course you have to do reinforcement right or maybe grouting. So in the cell so what you will have? So, you will have a cell in which you will put the mortar on the grout and the reinforcement and AC blocks will be around there right. So generally supposing it is a flexural member. So you will leave a concave depression right. Concave depressions along the vertical edges and can create a cylindrical core.

You know and then you know between two edges. For example, you might have a panel like this and another panel like this. And then you know reinforcement could be here something like this something of this kind. So concave depressions along vertical edges can create a cylindrical core between two adjacent panels. So, if they are, basically if it is for floors or slab. This cannot take

the load. So you have to reinforce it. So you can create concave depressions where you put the reinforcement and that kind of thing.

For other application a vertical cell is placed at corners on either side of the openings. And at 2 to 3 meters spacing along the walls. So for walls basically if you want to have you know like you can have you know the corner so you can have a cell so you can actually innovatively put reinforcement wherever you like by putting additional mortar or similar sort of thing right or grouts.

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So being light is handling is easy. In fact possibly manually it can be handled. So small crane sometimes even manually can be installed as done for masonry unit, so interior will look something like this, you can a good finish. The panels are here. If this panel large size panel and you can see that it can float. So density is very low, right could be varying from 400 kg per meter cube to 1600 kg per meter cube depending upon how much aeration you have done, so it depends up on that. So you can make it lightweight.

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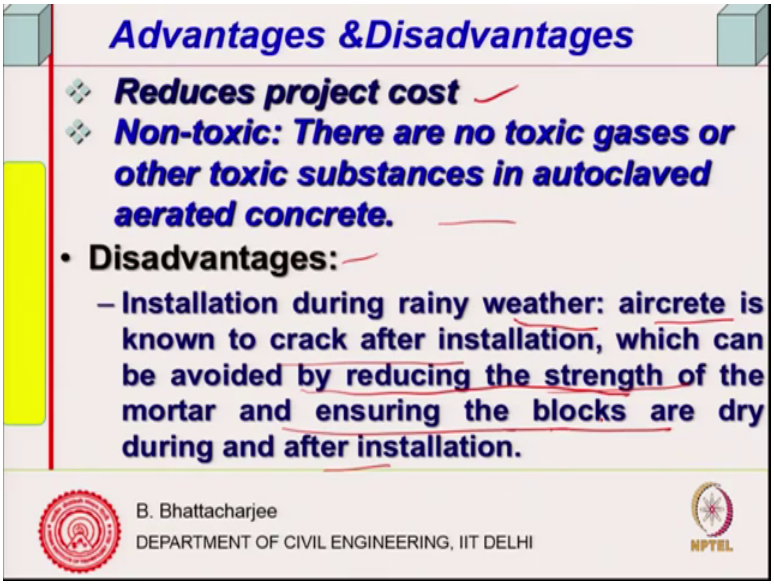

And obviously it is non-toxic. Project cost can reduce and most importantly as we have seen the brick you know production is extremely inefficient both in terms of emissions as well as energy. This on the other hand is cost effective and not neither of you know it does not generate any toxic material, no toxic gases or other substances in autoclaved aerated concrete. So no emissions and that is the advantage.

Disadvantages, if you have to install during rainy weather this is known to crack after installation because moisture will penetrate and relative moisture difference differential moisture condition might result in cracks, so reduce seeing the strength of the mortar, ensure blocks are dry during and after installation.

Other thing in brick masonry system it is actually the differential movement of the mortar and units as we call it masonry units. That is important for failure, even your regular load bearing machineries. If we look at their failure, they do not fail because big fields under crashing or something of that kind. What happens is Poisson's ratio of the mortar and the masonry unit is different, right. Even after harden states, so when you have applied load one would tried to expand more. Another will try to expand less, inducing tensile stresses.

So that is one thing or if there is a kind of differential movement of any form, shrinkages for example, the mortar wants to shrink the masonry does not shrink, which is already in case of any one of the, even in case of clay bricks they are already you know vitrified. So there is sort of you

have already you know like the stable condition. So mortar if it shrinks it will induce a kind of stress onto the brick unit because brick will not like to shrink so that is why it is important for mortar to have low shrinkage that is why you do not use too much of cement in any kind of mortar.

So similar situations are here also, mortar strength should be relatively low and it should be compatible with the strength of the blocks. In fact you know weak mortar is what is generally if you look in to because Poisson's ratio elastic modulus, etc all are related to strength empirically, empirically related to strength as we measure. So, and also blocks should be dry during and after installation.

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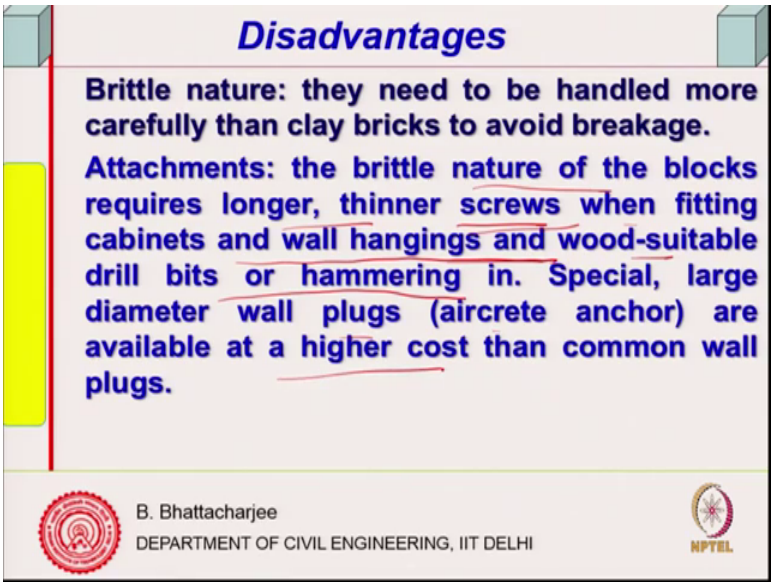

Nature is obviously brittle, this would be there. So therefore, more carefully you have to handle to avoid breakage and brittle nature of these blocks requires longer, thinner screws if you are trying to fix in something.

Because if you have, if you are trying to do nailing for a wall nailing property is important, so thinner screws or nails so that is what it is. You know for wall hangings and wood suitable drill bits or hammering in it. You know so you can do drilling and then screw it like you do it in wood. Special large diameter wall plugs are also available, but their cost is slightly higher. So that is one thing.

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Ok. Generally first course will be laid and leveled, blocks are stacked together with a thin-bed. Mortar in a running bond with a minimum one in 150 millimeter overlaps so that is the construction practice. Walls are obviously should be in plumb and things like that levelled and squared with the rubber mallet etc. And openings and odd angles are cut with a handsaw or band saw. So saw cut, we can cut them as you wish.

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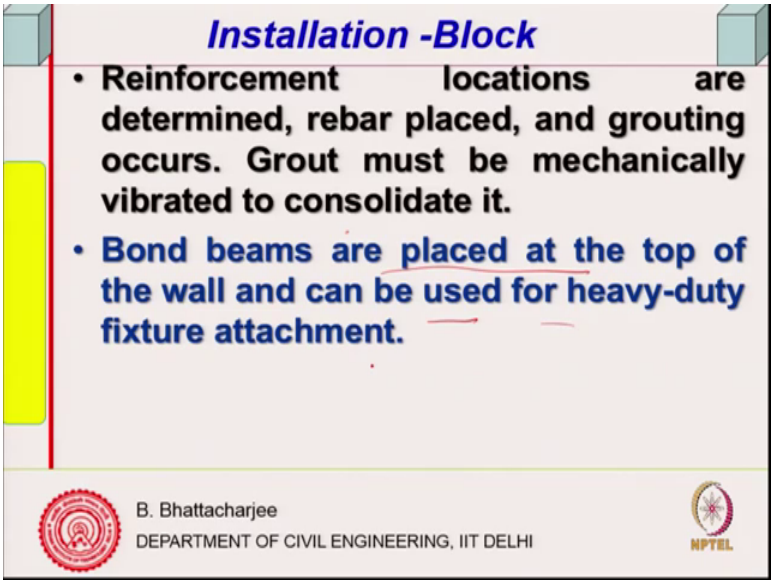

Reinforcement locations are determined you can put the rebar because if it is a flexible member you need some rebar. And grouting can be done. Grout must be mechanically vibrated to

consolidate. For example between two panels or in a panel you have a grout and then put the reinforcement, put the grout and vibrate it that is what it is. Bond beams are placed on the top of the wall. And can be used for heavy duty fixture attachment. You know if have a wall put a beam. And then the system, alright.

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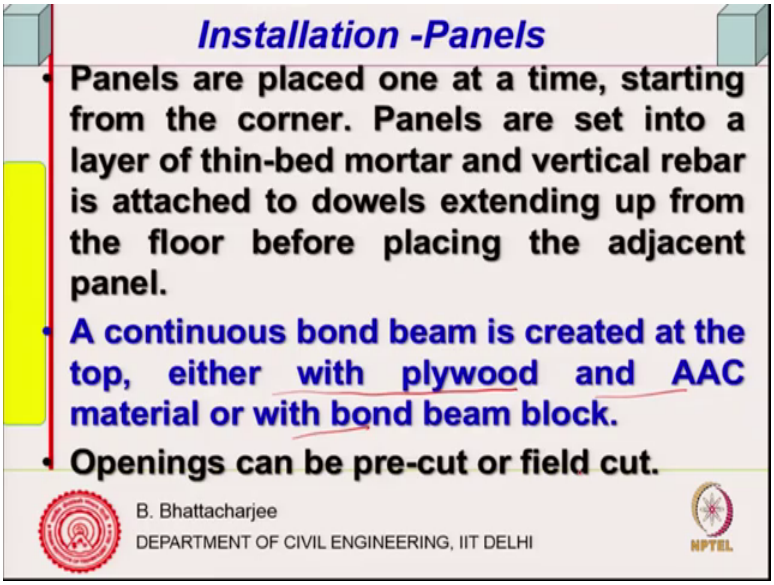

A continuous bond beam is created at the top either with plywood or AAC material with bond beam block. And openings can also be put in in the set of wall form. So pre-cut or field cut whichever way you like. That means field cut means you will have to cut the X of.

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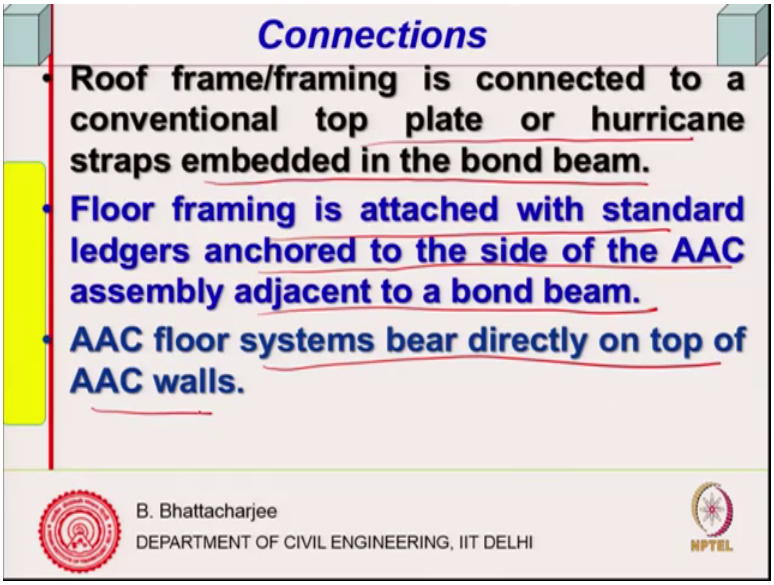

So roof, frame and framing is connected to the conventional top plate or hurricane straps embedded in the bond beam. So floor framing is attached to the standard ledgers anchored to the side of the AAC assembly adjacent to the bond beam. AAC floor system behind directly on top of AAC walls. So we can have, but you cannot go very high rise. This will be for low rise building, it can completely replace. This is not pre-cut system except for the you know if the wall I have made it fully precast which usually is the blocks and blocks are there form like mortar. So the space of construction is not very high like precast system which we will discuss a little bit later. Ok.

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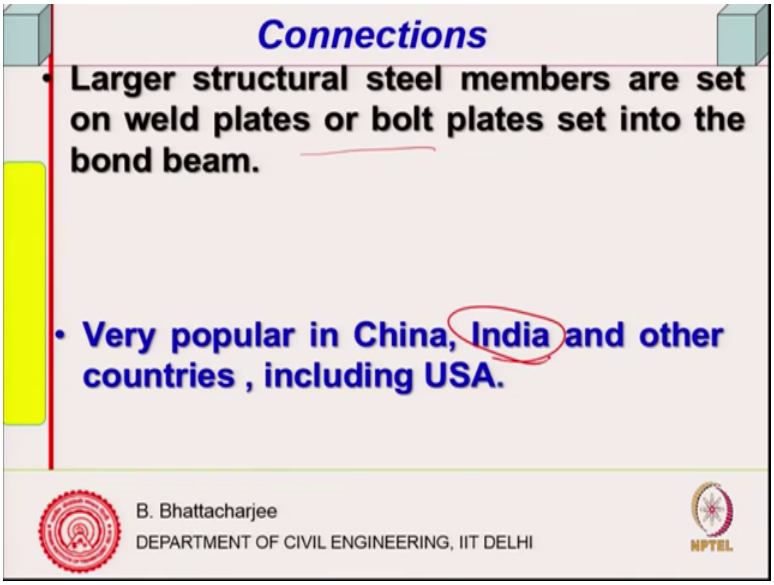

Larger structural steel members are set on weld plates, bolt plates to connection and obviously as I said it is now quite popular in India you find but they are used as largely now used as sort of you know in fields. Not necessarily for structural purpose, but for in fields and commercially the number of the amount produced so this is quite popular.

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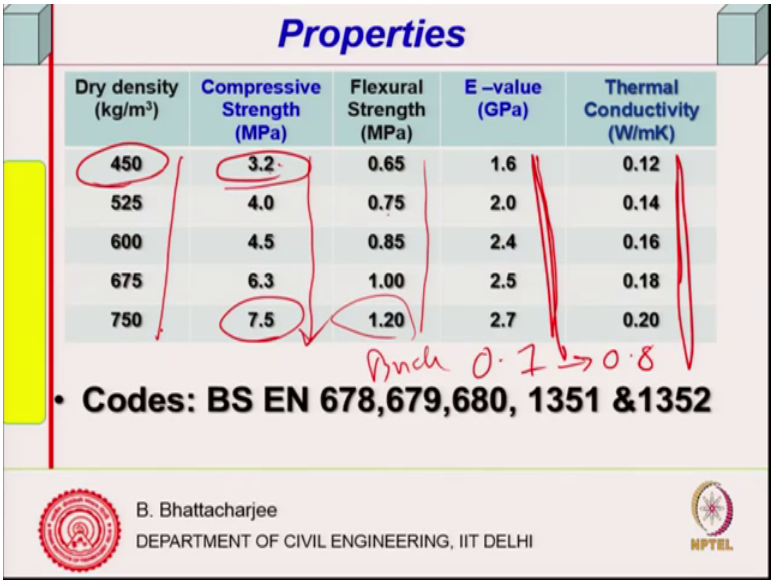

Now properties if you look at it density as I said varies from 450 to even 1600. But Let us see 450 to 750. The compressive strength will be 3.2 ampere which is you know lower class break actually, right. And this is somewhat better from the bricks. So as density increases, strength

increases this we can understand very easily and flexural strength would be proportional. So they you know it is roughly around if you can see it is around 5 percent of this one you know.

So approximately you get 5 or 7, 10 percent even flexural strength is usually 7, 8 percent of the compressive strength for any of such materials. Any such material flexural strength is about, tensile strength will be even lower, direct tensile strength. So this flexural strength and if you see E values they are now this order. But what is the most important thing is this part. Thermal conductivities are quite low.

Some of them with say much lower density with foam concrete can go even less than this. So they are of this order while normal concrete bricks we have seen is of the order of 0.7, 0.8 and bricks, clay bricks 0.7, 0.8 and density being low even if they are using them as in field actually they will reduce down your structural dimension of structural system right because the load would be much less. So they reduce down the load onto the structural system itself so that advantage you get in fact it would give you overall cost saving. The codes of course BS EN this ones are there. So European codes these are available in details.

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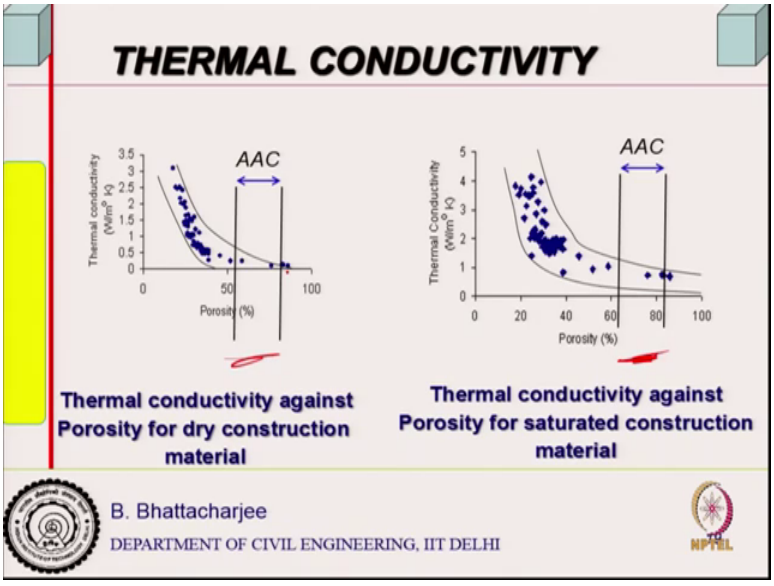

Now this you remember I talked about the Thermal conductivity part. AAC stand somewhere there in case of dry state and in case of saturated state, somewhere porosity can go as good as 80 percent and so on. So foam concrete you know or AAC block their thermal conductivities are much lower. So that is one of the biggest advantage and you can combine together.

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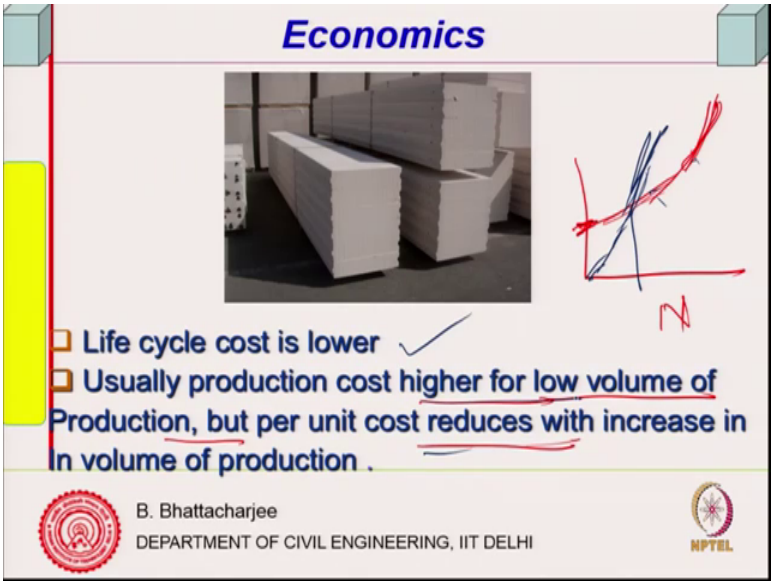

Economics, lifecycle cost will be lower. Usually production cost is higher. Because you have to have a mechanized system to produce this. So, if we have low volume of production then obviously cost would be you know if you have low volume of production costs would be higher because you have to get you know initial investment is higher. So breakeven there is a breakeven number. After a certain volume of construction costs reduces, sometime later and I might talk about breakeven number related to this.

What do you mean to say is as you need material cost and you need labor cost is much less. But you have an initial investment compared to other form. So but you have an initial investment. So as if I calculate all of them together using engineering principle or economics principle, per unit cost will be lower as the number increases. So typically the curves are something like this is N initial cost for 0 you will have some initial cost then it increases you know in this manner and beyond a point of course it starts again increasing.

But, if you have cost in other options the other kind of system where they are 0 to start with because they are not you know you do not have any investment involved cost in C2 sort of system or big of course (())(21:27) you will have some investment as well. So you will find that beyond this point this is cheaper, beyond certain point again even the precast system or similar sort of system tend to increase the cost if you go beyond their capacity because you have to put in more resources in terms of equipment and lever to produce higher.

So therefore, that is why the curve is sometimes you know non-linear. So basically lifecycle cost will be lower, production cost is higher for low volume production, but cost reduces as you increase the volume of production.

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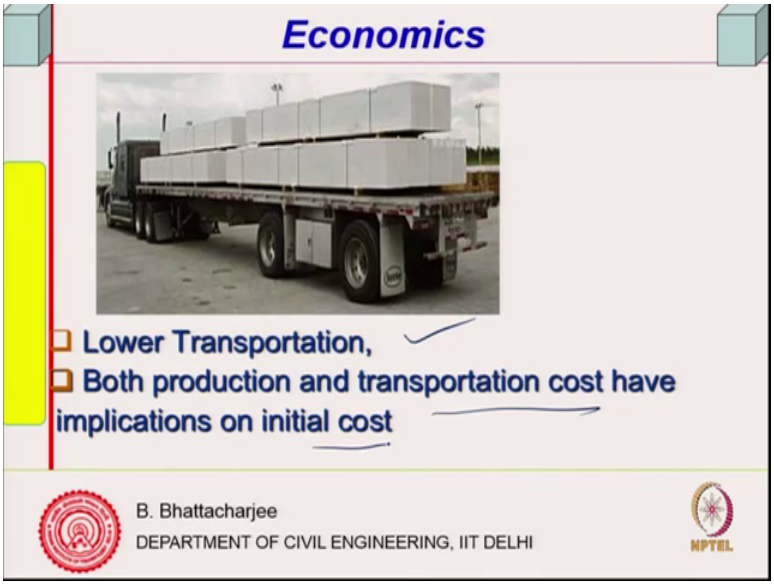

So this is what shows transportation cost is lower. So you can see that when you talk of sustainability which we talked earlier, it (())(22:15) pretty well because transportation in the embodied energy transportation was also a part since it is lightweight transportation cost per unit volume would be also lower and both production and transportation cost of implication on initial cost of course, right. So that is what it is. Ok.

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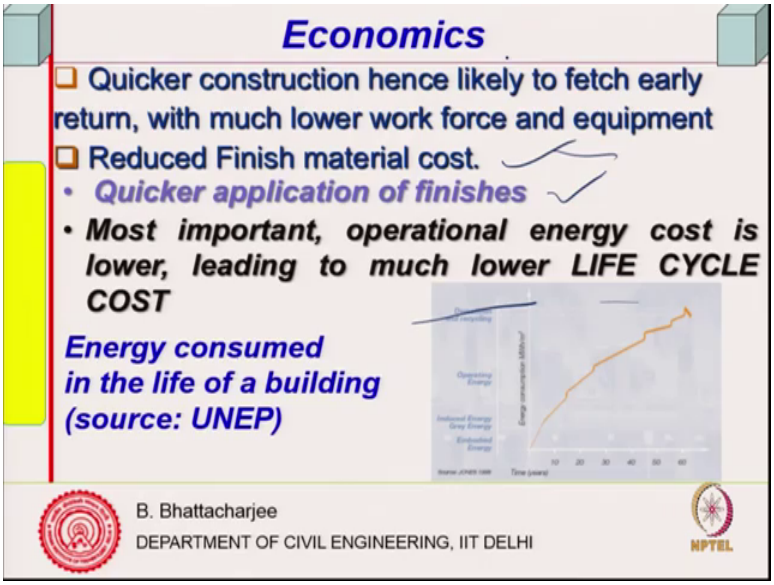

Quicker construction hence likely to fetch early return with much lower workforce and equipment. Because you can finish you know you can finish the job earlier right. Reduced finished material cost, quicker application and finishes. Most important is of course reduction in operational energy in case of a condition building. So lifecycle cost would be obviously lower. So you know this kind of technology do help because this I think I have shown you already. So this already I showed you. So this is what it is.

So this kind of material they have their advantage. In fact some places you may not get in fact clay bricks these days. For example, Hyderabad the quality of clay is so bad they have not been produced. But then they are not necessarily using AAC. Using some sort of block, but AAC has got real good advantage in terms of that.

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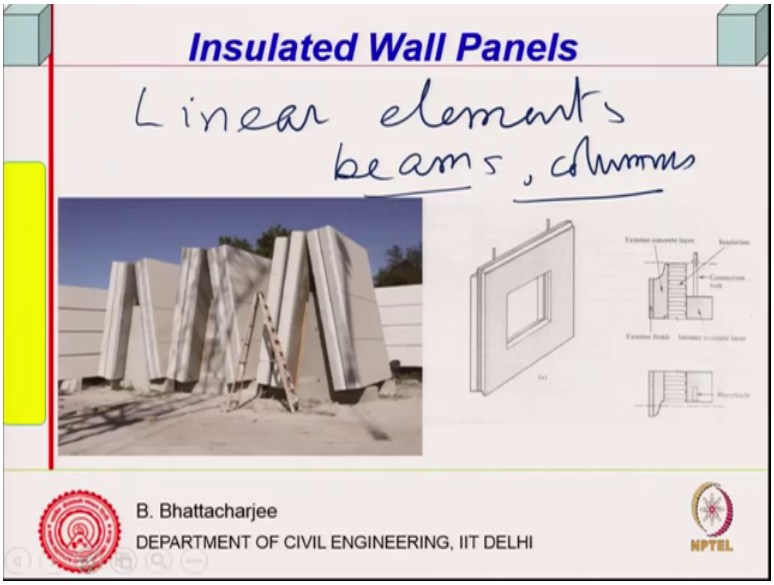

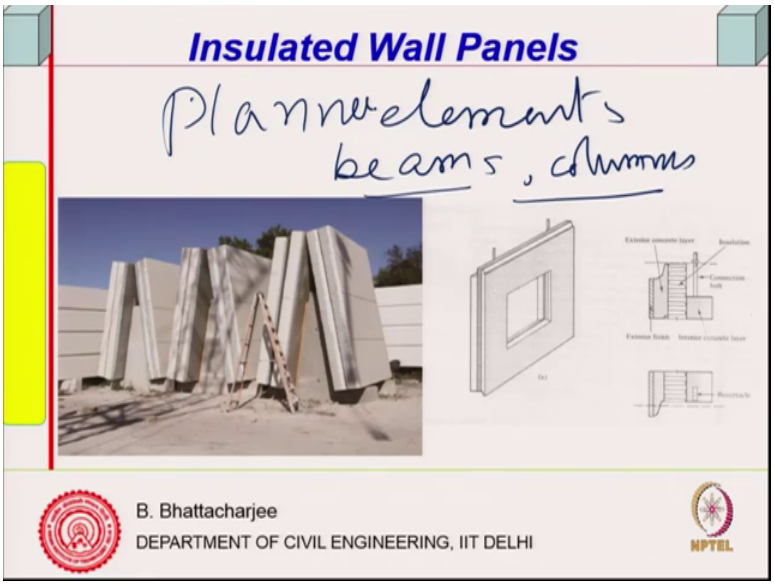

Ok. Insulated wall panels, sandwich wall panels these are other kind of thing. Now basically last class sometime I was mentioning that in pre-cut system you can have linear elements. That would be individual beams, columns which I will not discuss here, etc. And slab would be always planner. Slab would be a planner element. Now this one's a joined together to form the portal or frame, right.

Now as opposed to this planner system, planner elements as we call them. Planner element which is two dimensional, so I can have wall as well as slabs of the same and I think I must have shown you Holocaust slab last class or if I have not shown I will just come to that maybe.

Basically these are called planner elements. So these planner elements they can combine, they can be multifunctional. So for example, in this one a sandwich panel, sandwich panel will have two leaves, outer leaf and the inner leaf and an insulation material in between.

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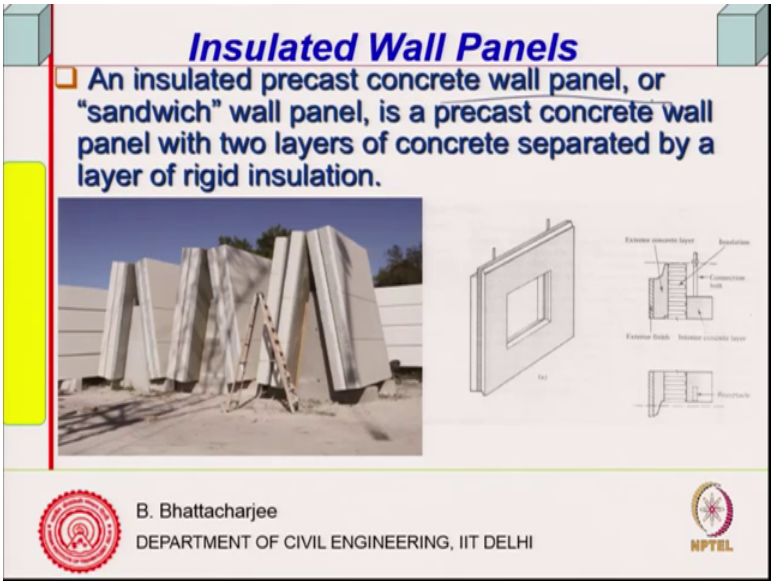

Now purpose of this an insulated precast concrete wall, sandwich wall panel is a precast concrete wall panel with two layers of concrete separated by a narrow rigid insulation. N

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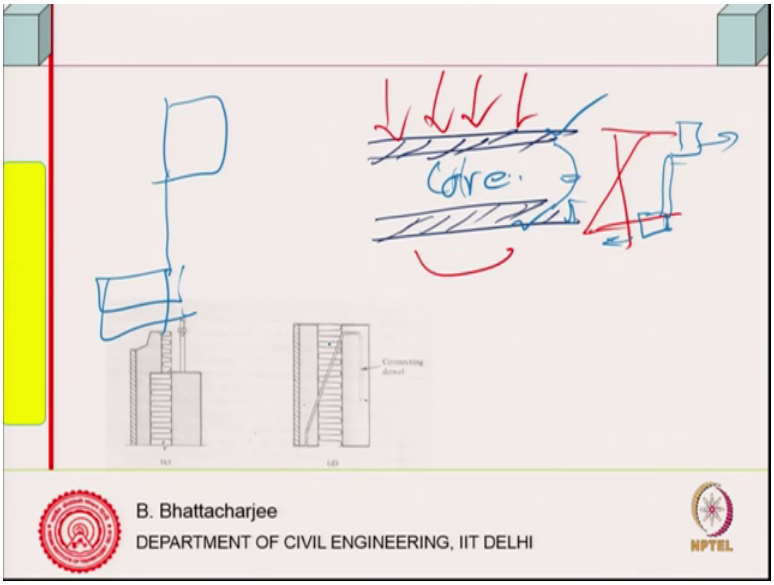

Now just I will come to this but consider this sort of a thing. Let us say there purpose normally would be to take the (())(25:52). Wall are supposed to take local (())(25:57) loads right if it is in low rise building. I am mean sorry, if it is in a frame construction, but supposing wall themselves is a part of the integrated part of the system that means you have a wall and that is connected to the slab. So you have to make it 3 dimensional.

Then this would act together. Then in all cases I have got a small leaf here and there is another leaf right. I got another leaf. And if it is flexural loading let us say flexural loading let us say, as we know if I look at the strain diagram of course they will look like this. Strain diagram will look like this because you know the top layer moves as it bends. Top layer moves, bottom layer moves and there is a compatibility of movement. So therefore, strain diagram would be something like this, but the stress diagram if I look at it, it would be something of this kind. Stress diagram would be something of this kind you know this would take I can neglect this portion.

So this is let us tension and this is compression. So this zone you know and I can just simply neglect their effect. They are only causing shared transfer. So share diagram of course you will have something like this you know so because the material, the top material you know will slide over the next layer of material since it is bending. So that you know share force has to be transferred from the top layer to the middle and middle to the bottom and as we know bending share is maximum at the. So this in-between core allows through share developing share stresses allows transfer of load from top to the bottom and you know it is it allows because it will resist the sliding of the top one and then so on so forth and bottom again.

So this bending so the core does not have to take the flexural tensile stresses not the compression. So I can model it in this manner two rectangular stressed blocks and that is actually that is how it behaves. There will be of course there will be some amount of stresses in this one also but I am not worried. So these materials are stronger. The leafs are stronger they carry the load but this I can make a little bit weaker. But provide they can provide thermal insulation. So that is how it looks like. So you have a outer leaf maybe inner leaf finishing and then you have kind of a material and which are bonded. You know connected also. So that is what the sandwich construction looks like. That is what a sandwich construction look like.

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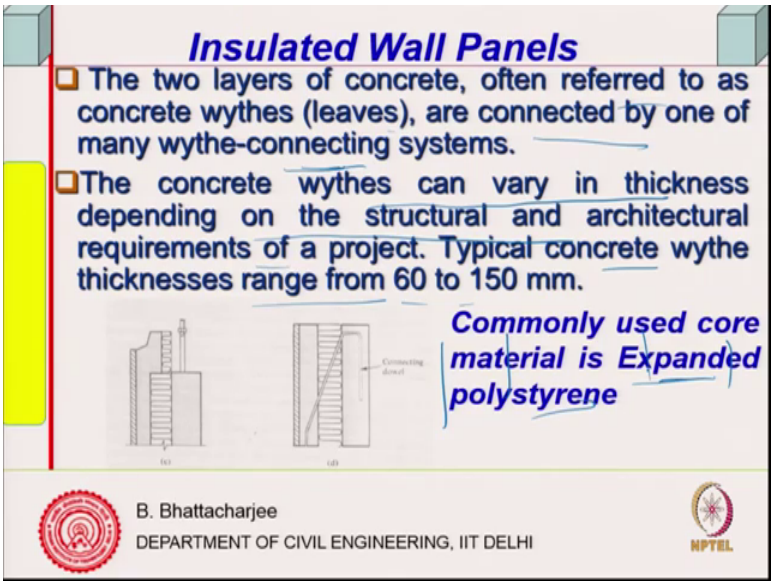

Two layers of concrete often referred to as concrete wythes leaves basically they are connected by one of the you know wythe connecting system which could be you know any kind of, for example polyurethane foam or similar sort of thing right. So the concrete can vary in thickness depending on structural load requirement and architectural requirements of the project. So generally thickness range from 60 to 150 mm that means you have about 150 mm thick concrete and it can be all precast. And there is a in between insulating material, right.

So this thickness of this one will depend upon the flexural load carrying capacity. Because they are the one which carries the flexural load as I showed through the stress block they are the one. So the concrete carries the flexural load. The share transfer takes place through the core and which also acts as a insulation, so it is a multifunctional system and can do you know expanded polystyrene or polyurethane foam resist this is thermocol as you know something of the similar kind you can have and this is what you know this can make it a multifunctional system.

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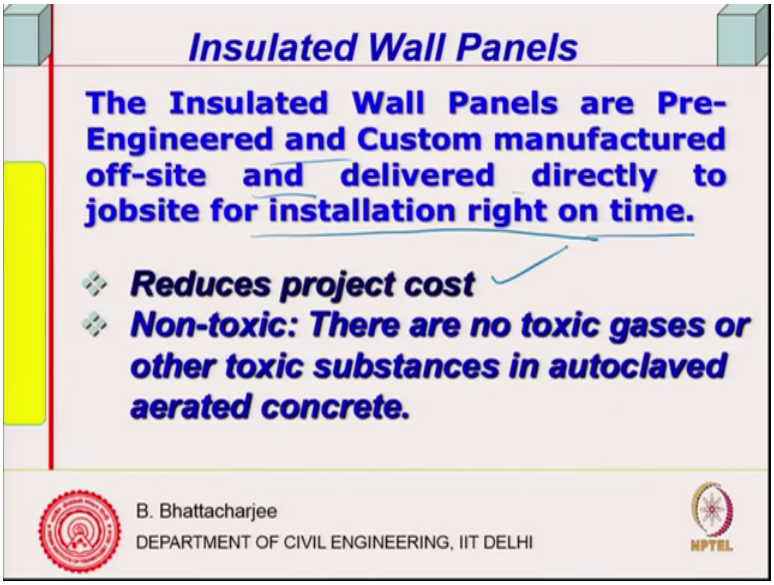

So, insulated wall panels are pre-engineered and custom manufactured. Off-site and delivered directly to the job site for installation right on time. Project cost to reduce obviously non-toxic right. It does not produce anything.

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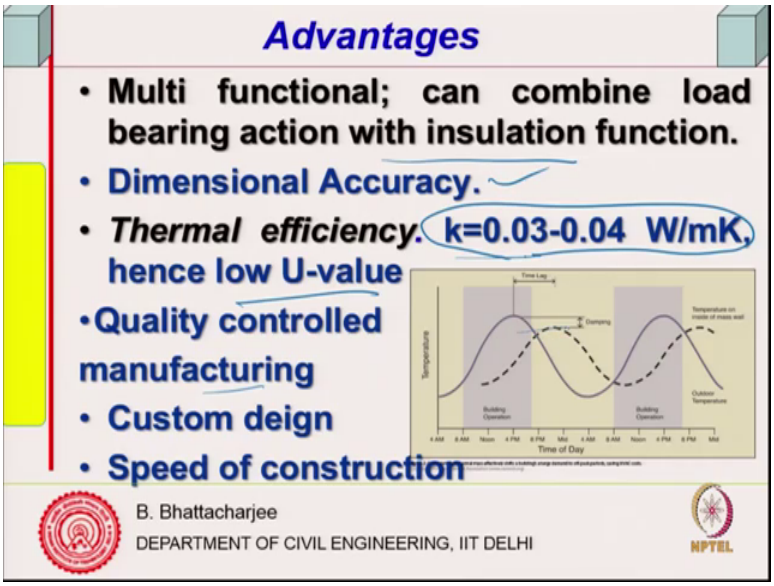

And multi-functional. So advantage is multi-functional right and can combine load bearing action with insulation function. Therefore, you know operational energy consumption will be much less. So dimensional accuracy of course you require it has to better engineered. Thermal efficiency obviously K of the foam material will be 0.03 to 0.04, you can decide on that.

Conductivity of the core you can decide. Hence you can have low U-value. And quality control in manufacturing and if you remember we can have time lag. Maybe I have mentioned some time phase time lag because whatever heat comes from outside it will be stored and sent inside later on particularly good in desert type of climate. So you can design the system for thermal efficiency and minimum energy consumption, right. So this is this is what we call amplitude decrement or damping. So you can get you know amplitude decrement, decrement in the amplitude of the temperature wave because this is time of the day. This temperature so inside temperature, outside temperature time is lag and there with amplitude decrement as well.

So I can design this system to get right kind of U-value and right kind of time lag and decrement if I want. Because in case of warm humid climate I may not need that much of time lag while in case of desert type of climate I might need good lot of time lag because diagonal variation of temperature is very very high and I can design the system custom designed it. Obviously speed of construction will be very high because parallel system precast.

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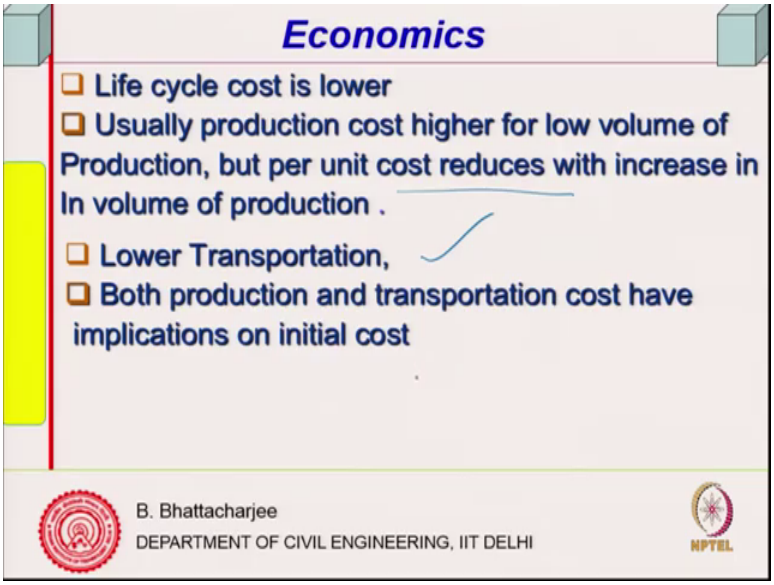

And economics, lifecycle cost is obviously lower. Production cost is higher same, low volume for low volume production, but per unit cost reduces with increase in volume of production. So lightweight can be you know lower transportation. Besides that if you overall building mass would reduce, if you are using the wall effectively for load bearing situation. Earlier you know

enough if I mean what I mean to say in case of a frame building the walls actually do not carry the load.

But even in a not very high rise building, even in low rise I mean moderately rise building if you are able to take, if you are able to make the wall load carrying, then overall material cost would mortar material consumption would reduce and therefore it makes it sustainable. Lower transportation cost and same. Same as I said earlier

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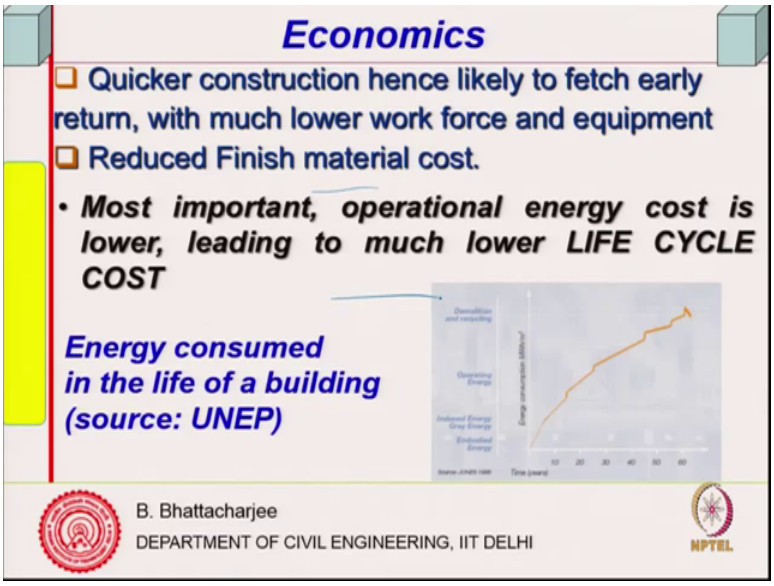

Same quicker construction and reduced finished material and life cycle costs will be lower and this is the same thing.

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So next, we will look into insulated concrete form. This is a form or which is insulated, we will look into this in the next class, ok.