Fire Protection, Services and Maintenance Management of Building
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Lecture – 06
Process of Combustion: Flashover condition

So, then we follow it. There are based on this kind of concepts, one can find out what is the condition for flashover to occur.

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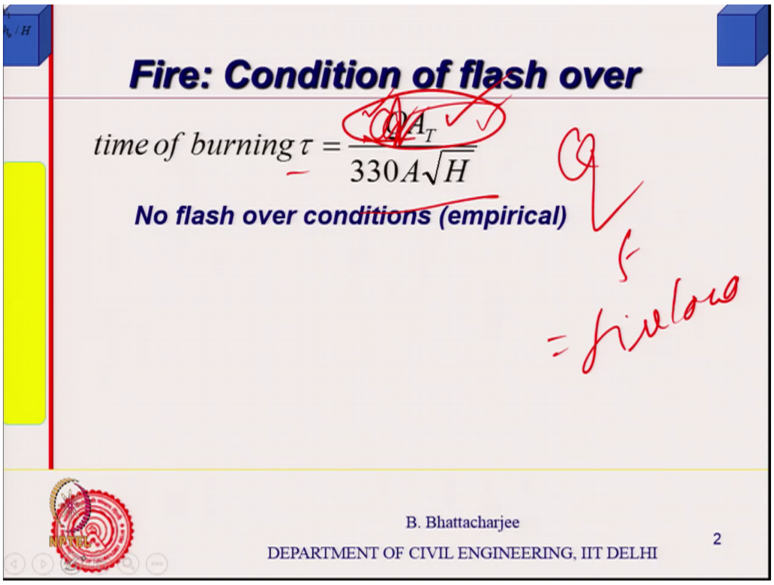

So, time of burning; I have already said, if you know if you know the totals area, you know total area, if you know total area total area of the room in and this is the fire load. I should have used small Q actually because, this is. So, this Q or small whatever is small that is actually. The fire load fire load per unit area multiplied, let us say total floor area if I do or whichever way. So, this essentially is the total quantity of fire load in the room divided by this. This will give the time of burning; that I have already told you.

So, tau time of burning one can calculate out based on these formulae.

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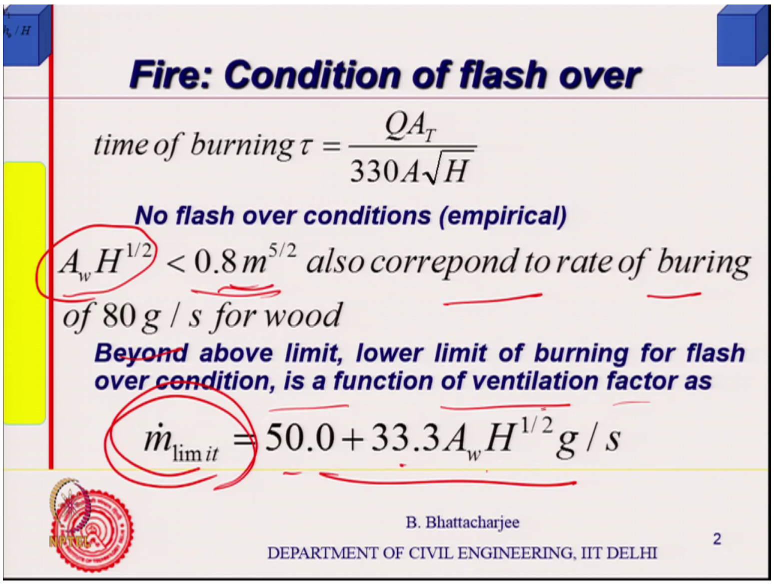

Now, empirically people have seen no flashover condition occurs if A w H to the power half is less than 0.8, right. If A w H to the power half, then no flashover would occur because, you will not have simply sufficient oxygen to cause burning off all the fuel in the room. What is flashover?

Flashover is that point where everything starts burning. Now, if I do not supply oxygen, it will extinguish itself. So, that is the condition also this corresponds to rate of burning gives to 80 grams per second for wood. Actually from this, approximately one can calculate out rate of burning and this is 80 grams per second. So, if the rate of burning is less than 80 grams per second, it will not have flashover. It will just extinguish itself.

Beyond above limit, lower limit of burning for flashover condition is a function of ventilation factor. So, beyond above the over, this you know limit of burning of for flashover condition is a function of ventilation factor and this limit is given as that 50 plus 33.3 A w H to the power half grams per second.

So, if it is less than 80 grams per second, rate of burning which you can calculate out 09 you know, 09 A w H to the power half, It was there you know it is that formula that we talked about 0.9 grams per second. There was it grams per second or kg per second; it was kg per second; so kg per second. Now, multiplied by obviously point you know. So, accordingly, you can find out what it is. So, if you find out that m dot is more than this value, then this is flashover condition occurs. So, at this burning condition flashover will occur. So, you can find out that actually one can find out this.

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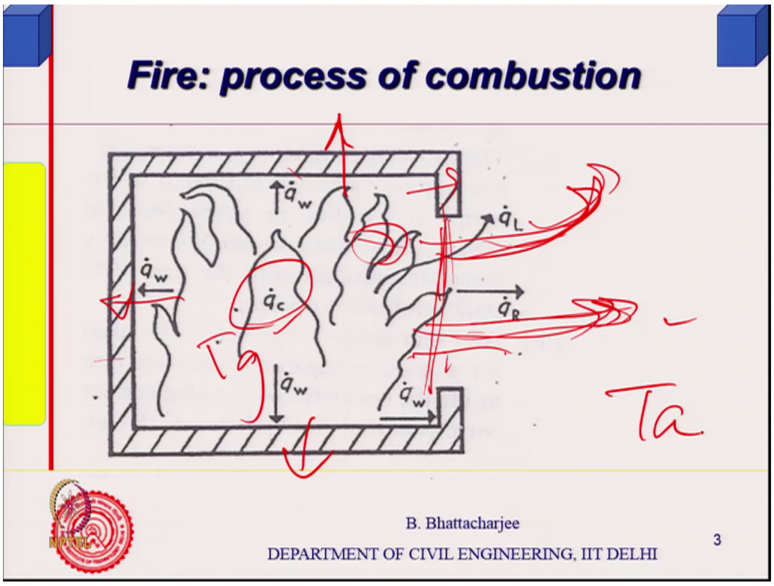

So, these are again empirical.

Now, using this, people have tried to model the temp time temperature curve; if I know now rate of burning.

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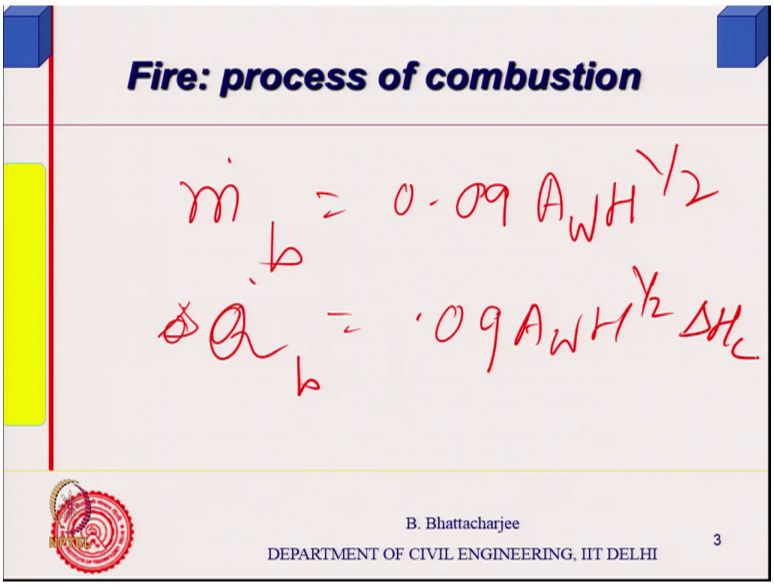

As I said, I know m dot b which is rate of burning of the fuel which I know I said 0.09 you know it was sorry 0.09 was 09 was offered this one only oxygen was 5.5 to 6.09 A w H to the power half.

Now, then the amount of heat generated will be delta you know like the Q would be Q for burning rate of heat flow would be point 0 nine A w H to the power half into delta H c. Now this heat has to dissipate to the outside this is the rate of heat generation this is the rate of heat generation Q dot rate of heat generations. This is the mass burning and delta H is the heat of combustion. So, that is the rate of heat generation.

So, rate of heat generation this must be you know this is the heat generated here. This many books uses them as small Q c heat of combustion. This must go out through this by conduction through the wall ceiling roof whatever it is to next room or if this has got good fire resistance, it will not go to the next room or next room. And then what will happen? Hot gases, goes out through this, hot gases goes out through this. So, there is some kind of a heat flow taking place because, the temperature of the gas that is going out is high.

So, if I know the rate of that amount of gas going out, that multiplied by the temperature difference into specific heat mass into specific heat into temperature difference. So, hot gas goes out it takes a heat along with it how much is it is heat content. It is this mass. Now, mass flow rate; rate of heat that is going out multiplied by the specific heat of those gases into the temperature because, it goes to the atmospheric temperature.

So, this much heat will take out because, temperature is higher. So, like ventilation heat gain ventilation heat gain you know ventilation heat gain amount of air coming in it comes at some temperature and if the room temperature is different, it will like that take the heat or if it is hot air. The room will actually room air will get heated up. So, that is equals to mass into specific heat into that temperature difference or here mass flow rate.

So, what gases flow rate if I know some heat will go out by this, some heat will go simply by radiation heat exchange. So, this is a not exactly a convective phenomena, but related to the convection hot gases go out and radiative heat flow would also be there because, this phase surface is hot. This is hot actually.

Air enters here. This is also warmer. So, this fresh air at room temperature enters. So, this is hot gases. So, at the hot gases there will be temperature difference. So, radiation heat gain is there. So, heat generated is actually transmitted to outside by conduction through the surfaces radiation from the flame and the hot gases going out. So, I can write an heat balance equation.

Now, what is my unknown the inside temperature gas temperature which changes with time. So, time temperature curve if one wants to find out one will you to solve that heat balance equation because T g the gas temperature is unknown outside temperature is known and one can solve for this. Now, this solving would be real complicated because, they are non-linear equation. I am not going to do that for you, but I just want to say people have developed such model and C F D model uses this.

So, if you want to use C F D model somewhere. Some of you are using people do use them. They do modeling without understanding the physical behind it. I am trying to give you the idea of physics behind it, right.

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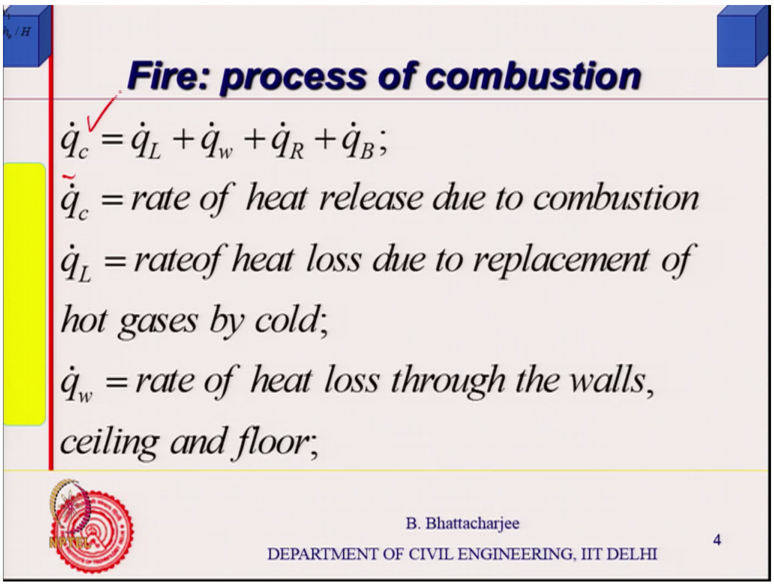

So, that is what is done the heat balance equation is written. So, total heat generated must be equals to heat loss by you know rate of heat loss due to replacement of hot gases by cold. Cold gas comes in from bottom. Hot gas goes out this is the conduction rate of heat loss through walls ceiling floor. This is the radiation heat loss radiation heat loss and this is some amount of you know.

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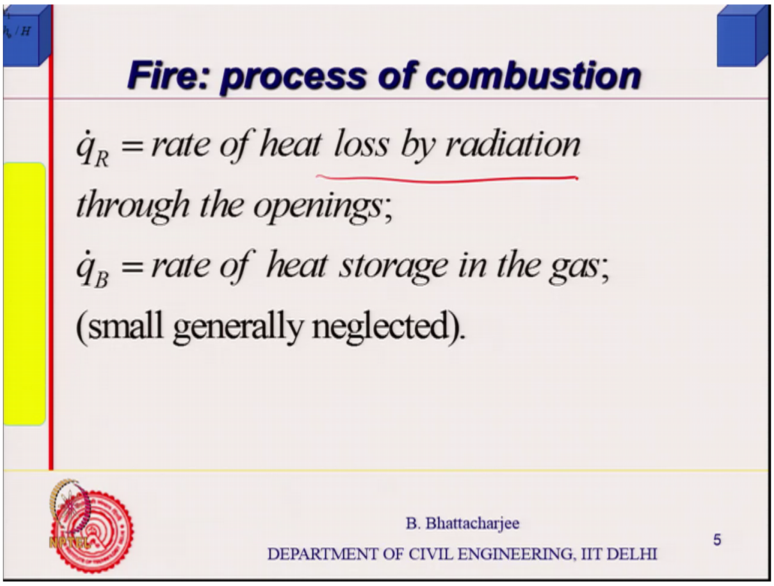

The some amount of heat loss would be there q R is a rate of T to radiation rate of heat storage in the gas.

So, because what is heat storage? Temperature of the gas is increasing temperature of the gas is increasing. So, if I know the mass of the gas inside it is specific heat in temperature change in unit time that I can find out this is known to me, because we know rate of burning.

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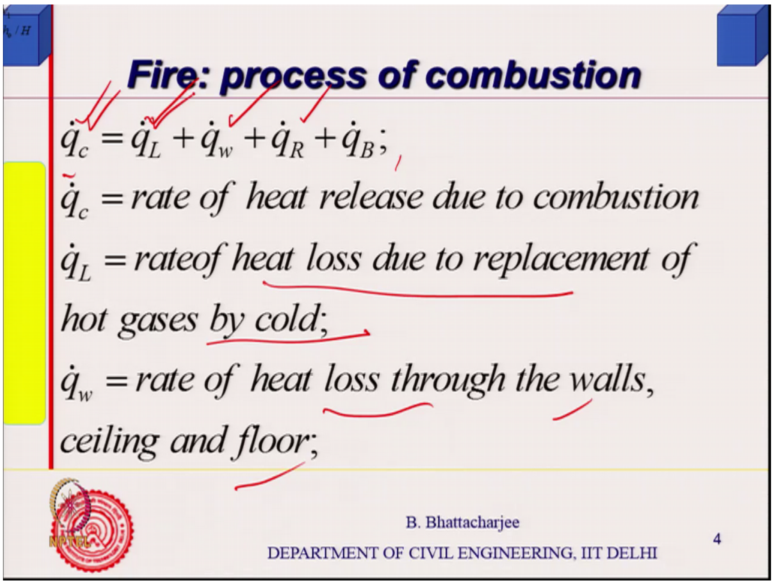

This I can find out; I mean I can get an expression for this in terms of the inside gas temperature. This also I can find expression in terms of inside gas temperature. This also only involved inside gas temperature. We will see these expressions. Some of you have not done possibly as you know any course related to heat transfer. I will quickly give you some idea and this is also related to the inside gas temperature previous time to next time, right.

So, one can express this in terms of finite element or finite differences because, there were differential equation involved. Let us see how it is. Now, somebody might neglect this or whatever it is.

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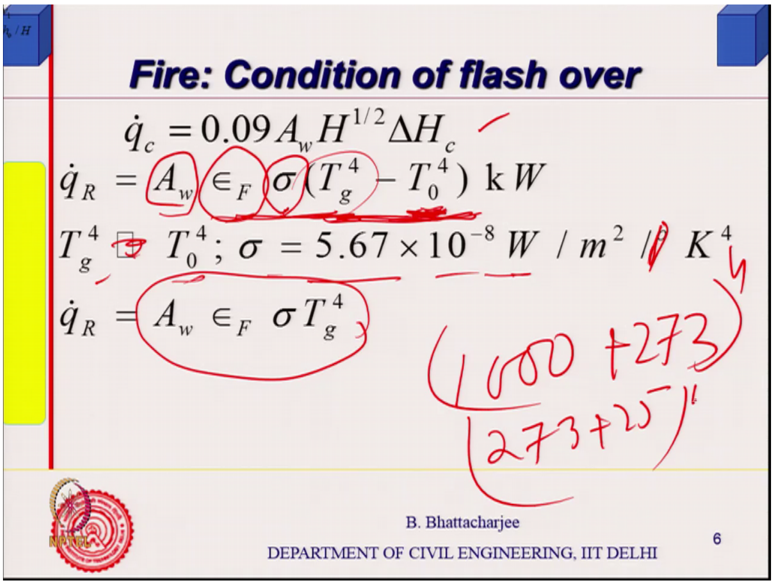

So, q c is this we have already seen multiplied by delta H c radiation heat transfer is a little bit of problem. Here, it is T gas to the power 4 minus you know it is governed by Stefan Boltzmann law.

So, radiation law if would have done it in school or otherwise or if you do not remember, let me tell you. The radiation is proportional to radiation heat exchange between bodies is proportional to T to the power 4 minus T 0 is outside multiplied by Stefan Boltzmann constant 5.7 into 10 to power minus whatever it is. You know, 6 7 into 10 to power minus 8 watt per meter square per this is not degree. Kelvin to the power 4 because, there is an absolute temperature 273 plus and this is called equivalent emissivity. Because, a perfect black body radiates everything absorbs everything equivalent emissivity equivalent emissivity, alright.

So, equivalent emissivity of the window area flame and air that one can find out and A w is a area of the window, because this is rate of radiation heat transfer is proportional to this temperature difference and this is Stefan's Boltzmann constant. This is the equivalent emissivity this is per unit area multiplied by area of the window because radiation is taking place from area of the window.

Now, this is this you know T g, T g and T to power 4 minus T to the power 4 is this very much there and this is anyway, this is ambient temperature. This is a gas temperature. So, one can simply simplify this a little bit, but because you know one can simply simplify this a little bit by taking this value as nearly you know, if I am interested in rise over ambient. So, I might take this data point as T 0 itself and you know this one can one can in fact, do some I mean one can write in terms of the amount of heat going in is proportional to because, this will be small compared to this will be 100 plus 273, let us say.

This will be how much? 273 plus 25 take to the power 4 take to the power 4. Now, this value would be very large very large. So, one can approximate it. In this manner, one can approximate it in this manner. So, radiation heat transfer, but the problem comes you can see that this is non-linear.

So, you just cannot just like that you cannot solve it is T to the T g to the power four and T g is my unknown. So, you cannot solve it, because just like that it is more complicated than this solved by trial and error method.

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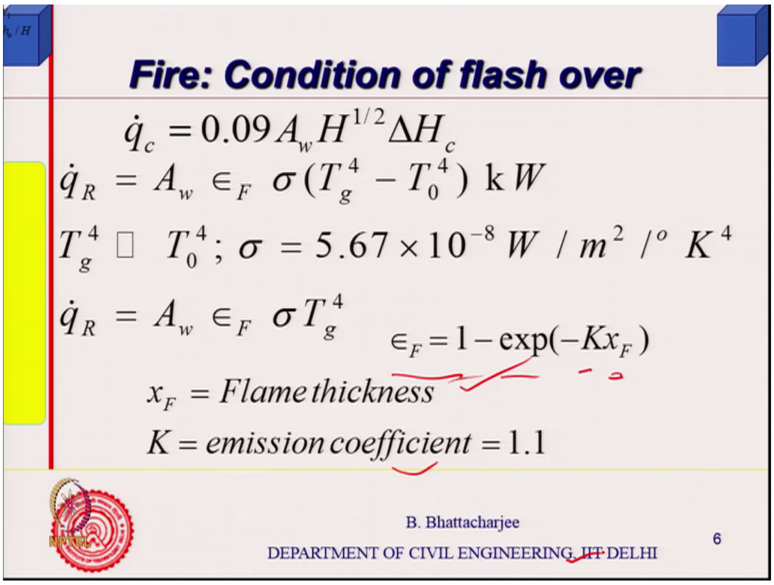

And e F is given by 1 minus e to the power some constant x F. So, this is flame thickness emission coefficient 1.1 roughly, these are the values. Again, I am not interested in interested that you calculate this, because that would take my 90 percent of my course. If I actually you know or at least 20 30 percent of the fire part of you know at the same time as this. So, I am not interested, but I want you to understand what factors go on that is important. So, flame thickness is this.

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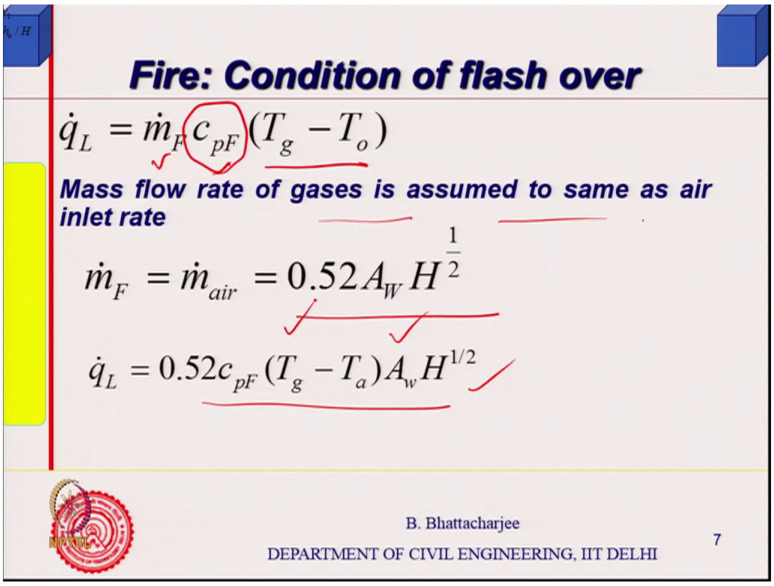

And this is you know this is the mass flow rate of gas q L.

Mass of the mass flow rate of the hot gases going out specific heat of the hot gases multiplied by the temperature difference because cool air comes at room temperature same amount of mass goes out hot gases. So, specific heat of the hot gas multiplied by the mass rate flow rate that is, the heat it takes out, and then you know this is known to us actually there amount of air coming in. So, this I can I can put in here and we you know we can get an expression of this form in terms of A w H to the power half T g is my unknown. So, far T a is the ambient temperature.

Here I cannot neglect T a ambient temperature because, the temperature will be 100 minus 25. So, something of that kind would be there. I can you know it you can assume more or less not very large.

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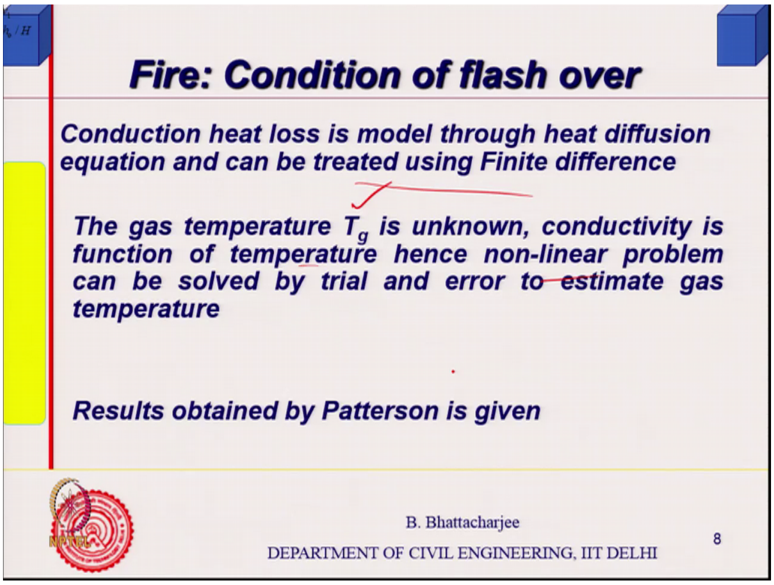

So, conduction heat losses from the wall that that has to be done using Fourier's bias heat transfer law heat transfer equation T g is unknown and conductivity is a function of temperature. So, it is a non-linear equation non-linear problem and you can only solve this by trial and error. Now, what is this equation? Ok.

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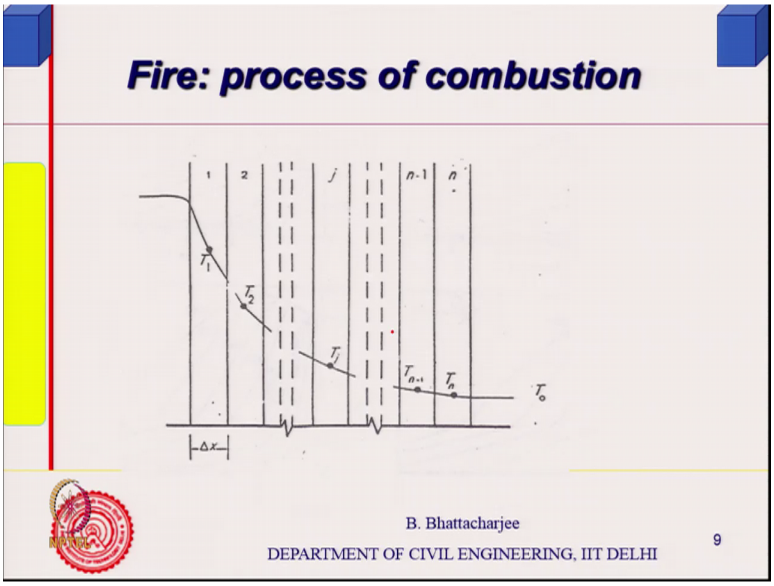

The equation I hope I have given the heat conduction equation let me see if I have given it right, no I have not given it because I assume that people would be knowing the heat conduction equation.

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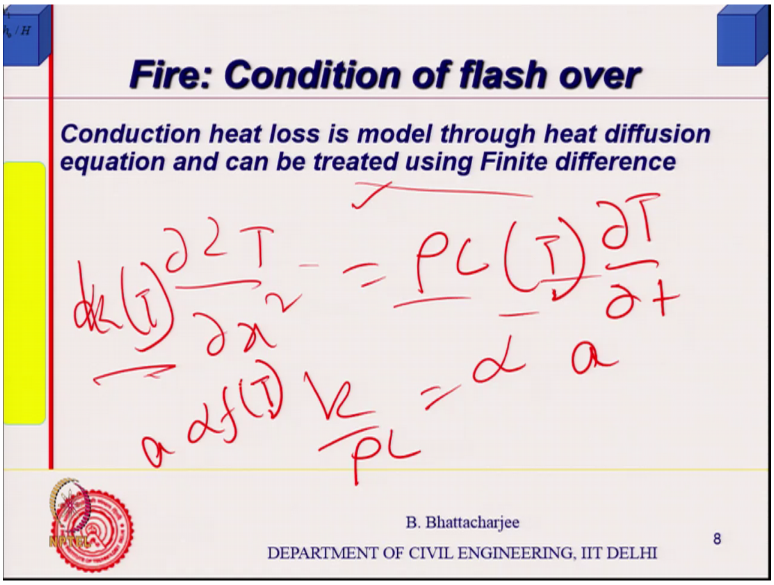

Basically what you have to solve is del square T del x square right you know and alpha or k which is a function of temperature equals to rho C which is also function of temperature into del T del T. So, this is a transfer equation.

So, this parabolic non-linear because k is a function of temperature rho C is a function of temperature and we write k by rho C we call it thermal diffusivity written by sometimes denoted by alpha some people denote it by a and in my case in this case is a function of temperature. So, this is you know every step you do not know the temperature to start with. So, you do not know that conductivity you cannot solve it easily it is a non-linear equation. So, it is solved by trial and error procedure by assuming a value and I treating it and finding out we are not interested in this.

But I wanted to give you this equation and give you the understanding what it is boundary condition is unknown T g is known. So, it makes it is life even more complicated if I want to solve.

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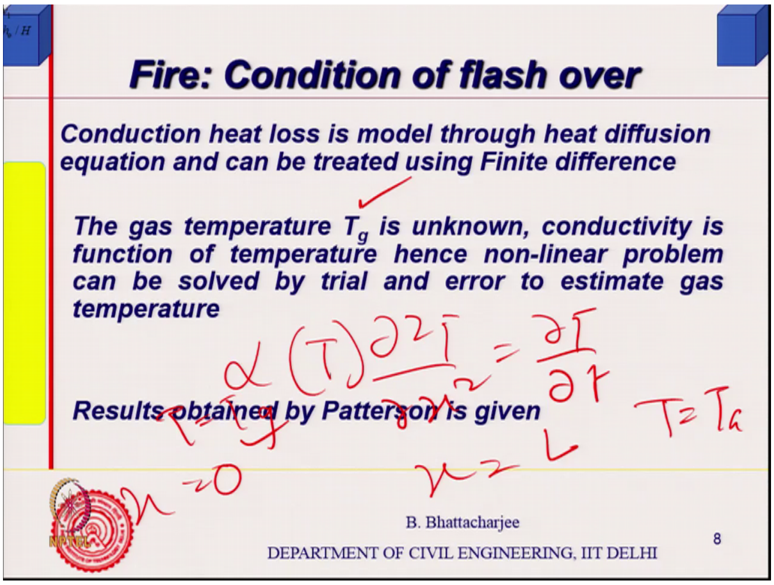

This differential equation that I showed you alpha as a function of T del square T del x square is equals to del T del T. If I want to solve this equation you know; then if I need 2 boundary conditions; outside condition at x equals to l T is equals to T I can say outside boundary and at x equals to 0 T g T equals to T g which is unknown.

Initial conditions, I can assume that everything at ambient. So, you see boundary condition is unknown, you got 2 for unknown boundary conditions in inverse kind of a problem it becomes problematic. So, it one can solve this by trial and error procedure one can solve this by trial and error procedure, right. And people have actually done this. Patterson has obtained some of them. I am not interested in again solving it for you, but some people have solved using let us say, a finite difference scheme.

So, you divide this wall into separate you know several layers write the equations for everywhere time steps at every time step do iterations it will have you have lot of computational today of course, it is very easy. So, many C F D model does it or do solve it by finite element or finite difference numerically you can solve them ok. By solving this, people have derived this kind of curve post flashover time temperature curve time versus temperature curve.

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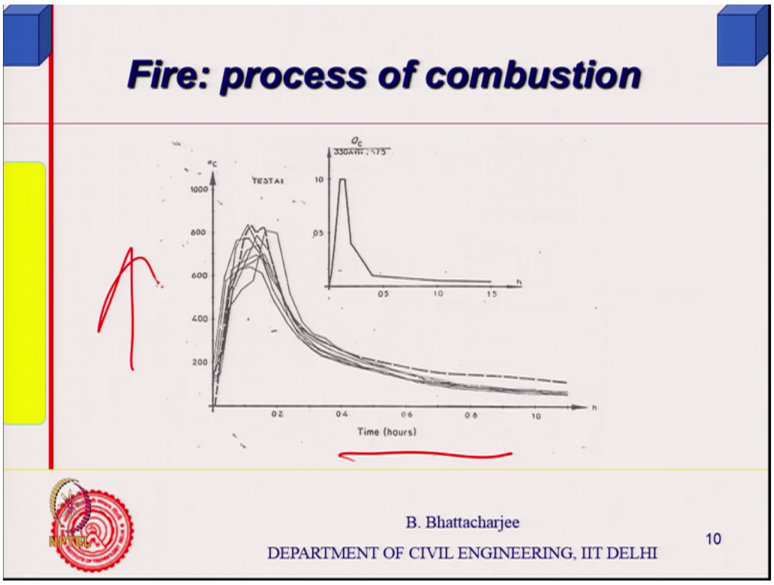

For various fire load and ventilation condition various fire load and ventilation condition, it is given in tabular form. Also you want to approximately find out for a room you can find out, but you want to really do it model find out you know simulate in a model. Then you have to use more than this C F D models which will give you, right.

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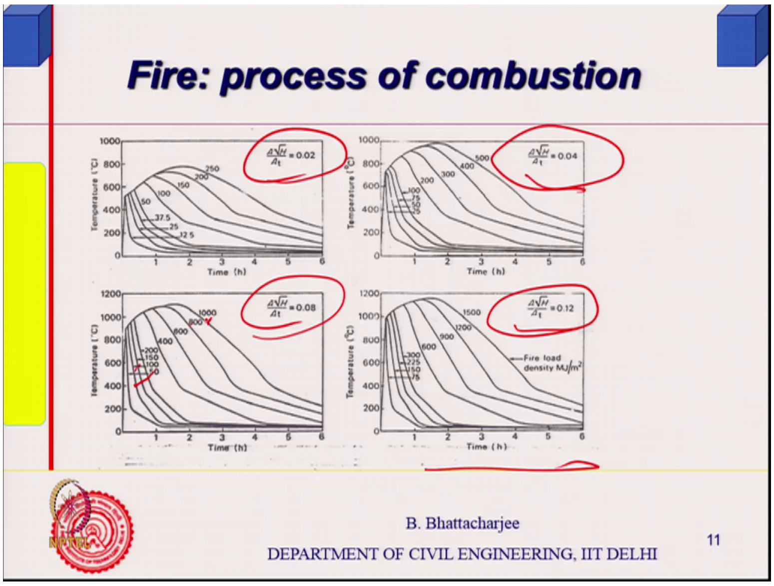

So, typically this is a function of you know the fire load and whatever fire load as well as the ventilation condition. These are the kind of curves that you to have time various ventilation opening factor values various opening factor values various opening factor values and these are the fire loads. So, low fire load to high fire; that is it.

So, theoretically it is possible to simulate them. They all at least pattern wise they match accept value. There may not match the real fire, but if somebody is trying to do fire design structural fire design, this has to be coupled with the structural design part of it and people say abacus or (Refer Time: 18:07). Some of the softwares, they do it actually they combine this and complete fire design of the building can be done. And this is a new area of research. There are a lot of actually activity going on this line in the world over last about like you know 9 11.

After 9 11 lot of thirst has been given to fire design the failure was because of the explosion you know this the aircraft trending it exploded the there was a fire and this fire led to collapse of one of the floor which fell on another I (Refer Time: 18:44) that structural failure. So, huge research for example, Michigan state university, they do huge fire lab. There is a old hangar. I do not remember the university, I forgot about the name the gentleman, there is an Indian, but (Refer Time: 19:02) was written a book from where I have collected most of this info, you know this knowledge base of fire dynamics. They have they have huge hangar Second World War hunger left it is not being used anymore. So, they use it as a file laboratory.

So, make a full structure sort of full beam full size beam column and test them we use costly research actually, but there are lot of fire research thirst England has been doing UK. They have been doing a lot of it most of the ideas actually develop the nuclear earlier in Canada, the Canadian you know the national research council of Canada, whatever it is, they have been doing US, they are doing. Now, lot of design structural fire design is a even Hong Kong, I find people are doing structural fire research.

So, structural fires structure trying to design the structure. So, that if is extreme fire goes in structure will remain intact, but safety of people does not depend only on the structure much before that we have planning and things like that which you will look into. So, our idea is fire protection not structural fire design, but if somebody of you are into in structural fire design, then you have to get into this fire dynamics as well right. So, I just try to give you an experience right.

For our purpose, this table (Refer Time: 20:22) are you available and get some rough ideas? That is fine. So, that is related to structural fire design. That is related to structural fire design or fire you know fire dynamics not. Fire design fire design I will I will just cover, right. Now, I will just cover right. Now, fire design part of it simple ones very simple because, design for a given fire resistance, that is what we will do.

But before that, we got to understand the material behavior we got to understand the material behavior how does material behave. Because, you want to find out do structural design one thing is finding out the temperature heat transfer part of it, but then this heat affects the material. Material properties changes with temperature and then properties, there are several affect; one is that, I will be interested in the thermal property change why because, in heat transfer calculation I would need them.

I will be also interested in their strength how strength reduces with temperature elastic modulus right and similar sort of properties. So, we look into now properties of material properties of material how fire affects the material properties. For example, most commonly used construction material is concrete. So, let us look at concrete. Now, you know concrete main it is basically made of inert aggregate system bonded by cement hydrates, right.

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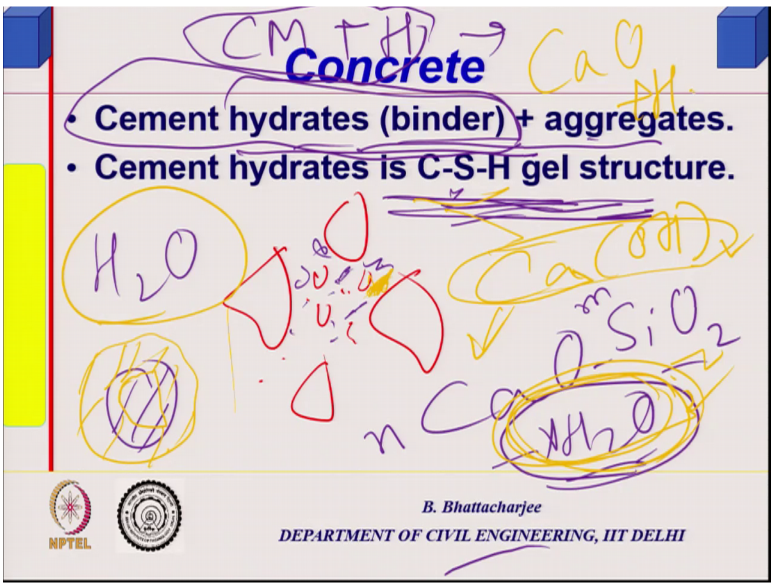

Cement hydrates bond them. It is a particulates and basically you have something like this. You have you have you know you have you have particles of finer size different sizes. Particles of finer sizes finer sizes finer sizes right. And, inside there will be hydrated paste hydrated paste, right cement hydrates well.

You can have something called epoxy concrete. Now, in epoxy concrete this binder is epoxy. Actually epoxy a glue hardener which solidifies. So, basic one understanding of concrete is simple understanding is you have inert particulate system and the void space in between them. They have to be put together right. The void space between them is minimized and you filling in the void space in material which material which can hold them together by largely mechanical bond bonding because, inert material do not react.

So, aggregates do not react. They are inert material by mechanical bonding or at best in some cases, maybe and they are also kind of bond in between you know, some kind of some chemical bond could be there once in a while, but the binder itself must be well bonded with itself. So, semen hydrates should bond well with itself. It should not break and the bond between the aggregates and cement hydrate. That is also an important. So, that that is basically concrete.

Now therefore, this is most important aggregates are natural material. Many of them would have come from the volcanic source. So, actually formed at very high temperature and then over the years they are there in the nature. So, they are inert and may not get affected till you go to the temperature of their formation. If you go to temperature of their formation they might start disintegrating ok. Some aggregates can disintegrate. Earlier, we will see that the vulnerable one is this because, this is man made at ordinary temperature through the reaction of cement right, through this is the vulnerable portion right.

So, this is this is. So, what we call calcium silicate hydrate gelatinous structure. So, we call it C H S gel what is calcium oxide some of you have forgotten your Si O 2 stands for S. Now, this can have some n, you know some value n M right and H is nothing, but water; so x water. So, this is the kind of structures I have chemistry chemical structure, I will have which is the main product of hydration cement hydration ordinary cement or all the modern kinds of cement. They are there which are lime based cement. They are one of the products of hydration with this.

And this is vulnerable to hit aggregates are not aggregates are not. So, vulnerable some aggregates are vulnerable sand quartz from over the years. They are natural material they are not so vulnerable. So, this is vulnerable see you know this honorable. So, what happens this has got this H 2 O first where you start heating them up there will be free H 2 O you know, there because, this system is C H S this system is capillary porous. This system is capillary porous.

Now, why it is capillary porous because, the reaction process of cement and water the product occupies less volume then cement and water combined you know, first you have cement. Let me call it C M plus water H. Now, the volume occupied by this 2 and volume occupied by this product which is formed right. Product which is formed, they you know they if they this was product is more, it will require it would have expanded.

If the product is less, then some volume will be left. Now, normally what happens is, generally you have cement something like particulate system. Let us say, it will hydrate it will hydrate. It will hydrate and some of it will get consumed and hydration product will come here and there is additional water we add to make it throw able. Otherwise, I can compact it. So, this additional water which does not react it will evaporate out leaving what is called capillary porous.

So, this system is you know cement hydrate binder system is capillary porous. So, you I will have some water in the beginning in the capillary pores themselves as I heat this, water will simply evaporate out I have no problem till that point of time. So, up to hundred degree centigrade. I do not mind some water will evaporate time. There will be some amount of shrinkage some you know shrinkage would occur because, as water goes out, there are it would it would some you know some loosely bound water in this system. Also, tends to go out structure changes a little bit like you know clays wells you take water out of clay. I do not want to go into the complete technology part of it science part of it in this class.

Now, given analogy clay, if you add water, it swells. If you withdraw the water, it shrinks and might crack also. So, such kind of thing will occur up to 100 degree centigrade. Beyond 100 degree centigrade, 110 degree centigrade 200 degree centigrade, this water is actually chemically bound water of crystallization. They start actually getting disintegrated. They go out from the C H S system they go out from the C H S system right the disintegrating themselves.

So, they go out from the C H S system, all right. And once they go out from the C H S system, it starts actually losing. It is you know it is own binding property; that means, this material the layer which is actually binding the paste you know the hydrated paste which is actually binding the aggregates. Now, paste itself it is own bond gets this term. So, it terms tends to become powdery rather than a bonded single solid.

When this bond does not exist it is almost like a pack of sand and aggregate and find some fine particle loose particles. So, beyond 200 degree centigrade, this water starts going out up to 400 degree centigrade. Most of this water will go out resulting in resulting in loss of bond and strength. So, gradually there is a loss of strength and bond up to 400 degree centigrade, but beyond that, one of the product of this hydration cement hydration is calcium hydroxide.

You see cement is produced from calcium carbonate by bonding calcium carbonate you produce calcium oxide right carbon dioxide goes out. Now in the in this, calcium oxide cannot be stable because it is not a natural material. So, in presence of water, it becomes calcium hydroxide and in the long run, it takes carbon dioxide from the atmosphere and for million years, if you leave concrete for million years in atmosphere, it will go back to it is stable state of calcium carbonate again from where you have got from the nature. It will go, I mean, in an ideal condition.

So, anyway, here the point I am trying to make is, calcium hydroxide that is there in the cement system. This starts this starts disintegrating this starts disintegrating and I will have now calcium oxide and water again going out this occurs around 600 to 700 degree centigrade and after that, if you 800 degree centigrade you touch the concrete you will find ashes white ash only.

So, in a post fire building, if you want concrete structure, if it has reached 800 degree centigrade, you scratch it everything will simply come on. So, that is the behavior of concrete, concrete under fire. That is how it behaves, right. So, that is how it behaves. So, that is the thing.

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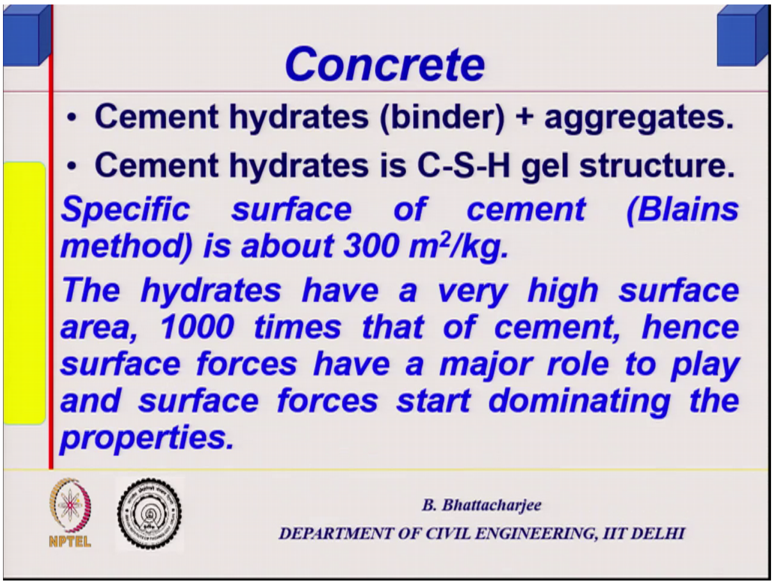

So, we look into it. We will just quickly look into this in the, after I respond to some of your question. So, a little bit of concrete, we look into right.

So, that is what I said. So, just putting them in words, cement has got a specific surface that is surface area per unit mass by 300. The hydrates have got very high specific surface and you know more than 1000 times of the cement some of this cement concrete science issues. Hence, it has got very large surface the surface forces dominant and they bond each other cement hydrate bond with each other and you know that is properties of concrete is governed by that.

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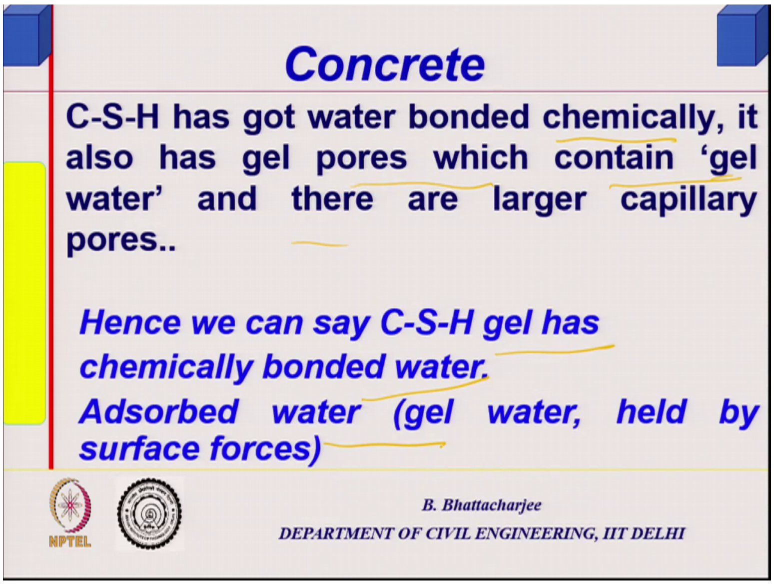

So, water bonded chemically I mentioned C H S it also has gel pores which contain gel water which is actually absorbed water like clay water adsorbed you know adsorbed water is electrostatically bound water and there are capillary pores as I mentioned and you have capillary water. So, C H S gel has chemically bonded water adsorbed water and then you have capillary water.

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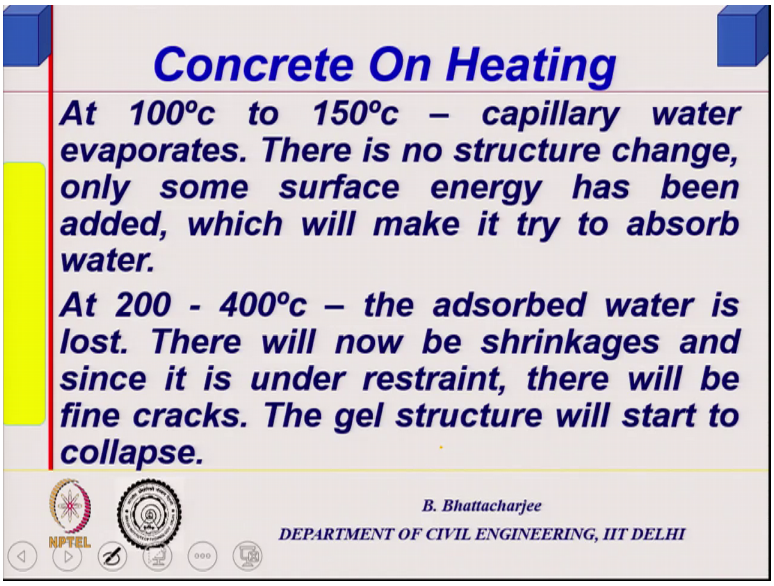

So, up 250-degree capillary water evaporates. There no change in the structure only some surface energy has been added which will make it try to absorb water, if right and again it will absorb. So, it is almost not exactly reversible, but nearly reversible process up to this.

200 to 400 degree centigrade the absorbed water is lost adsorbed. Water is lost there will now be shrinkage and since it is under restraint, there can be cracks also large cracks in 200 to 400 degrees the gel structure starts to collapse. That is what I just mentioned.

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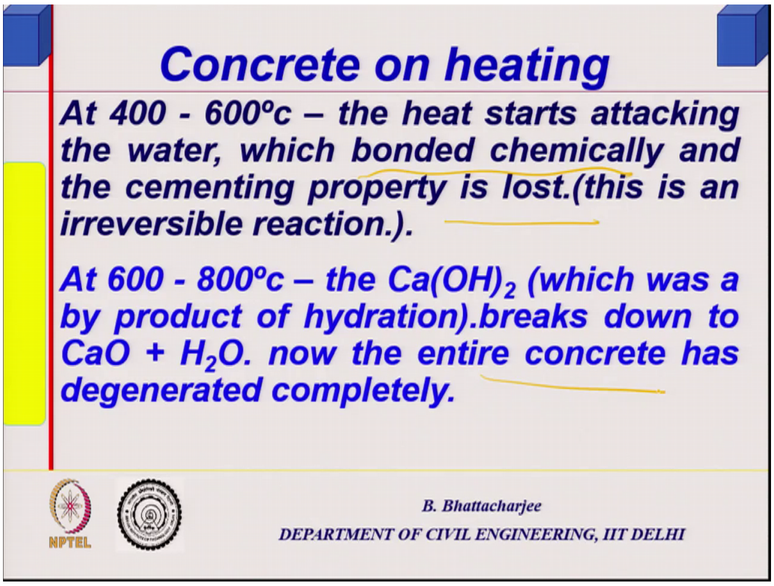

The heat starts attacking the water which is bonded chemically and the cementing property is lost completely.

So, 400 to 600 degree centigrade beyond that calcium hydroxide will break down. And entire concrete has degenerated completely. So, properties change accordingly 100 250 degree centigrade not much of an effect strength would not reduce 200 to 400-degree centigrade shrinkage cracks etcetera, you will find large as you go towards the higher temperature strength starts reducing beyond 200 400 to 600 chemically combined water is gone. Strength is practically you know almost all strength is gone. And 400 to 600 and above calcium hydroxide also break down. In fact, it is almost like ash it is simply ash. So, that is the concrete behavior on heating.

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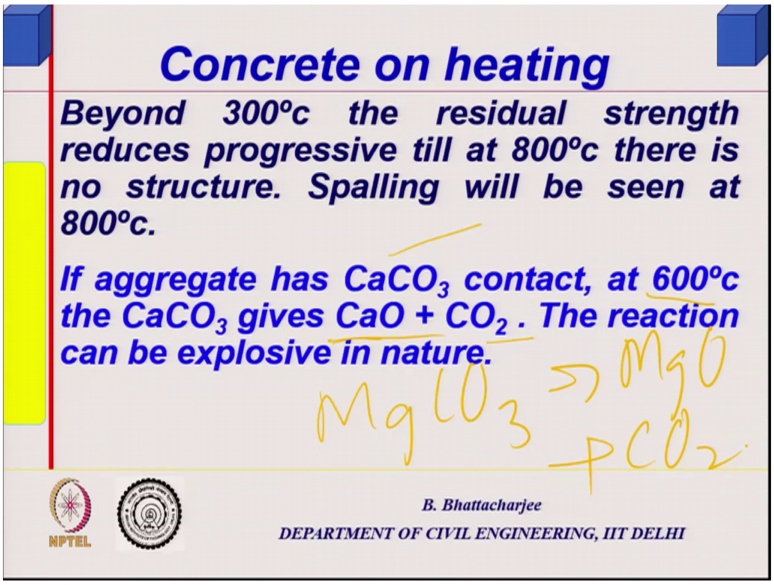

Residual strength reduces progressively up to 800 degrees centigrade, there are no structures and you will find spalling of concrete will actually start occurring. Chunk of concrete will come down, if you subject it to 800.

So, if you have gone to a post fire a structure where there is fire has occurred let us say even a bridge who had the concrete you know or P S C or R C bridge and you find that chunks of concrete has come out. In certain portion, you can rest assured that they are 800 degree centigrade or near 800 degree centigrade would have reached you will find reinforcements exposed and almost as like concrete.

Some aggregates like calcium you know limestone aggregate, they actually break down at 600 degree centigrade, you know to calcium oxide to calcium carbon dioxide 600 and above. Now, what will happen? If I have such an aggregate inside, suddenly it will bust out. So, you have explosives spalling, if you have limestone or magnesium carbonate (Refer Time: 34:44) you know all carbonate aggregates, they break down. Like this kind of chemical changes or magnesium carbonate will also break down into magnesium oxide and carbon dioxide these are explosive in nature.

So, they just simply spall out the causes spalling of concrete right, spalling of concrete.

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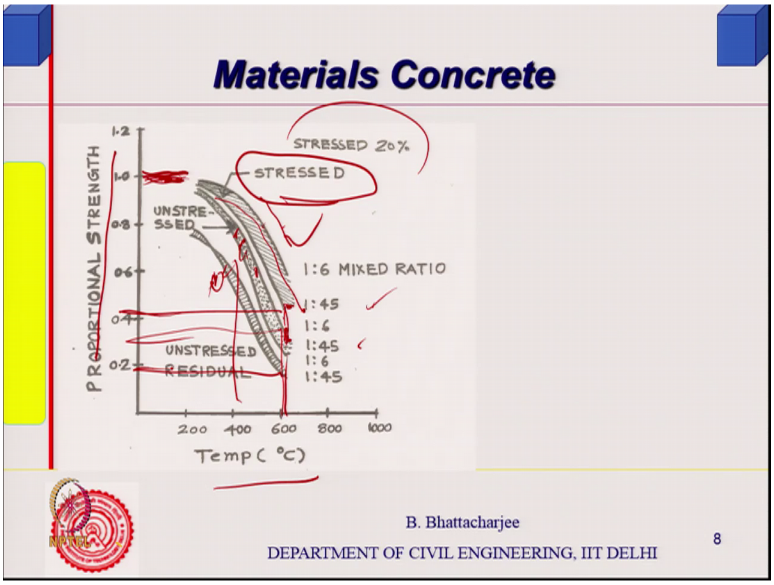

So, people have actually done experiment to find out the properties of properties of you know properties of aggregates, I am in concrete with temperature. So, this is what they have found Here is proportional strength versus temperature. Now, there is complicates in measurement. In fact, at IIT Delhi we have some facility been established by doctor (Refer Time: 35:29) Sagar; little bit he has done, I suppose, Roorkee they have you know as I said Karnataka, there is an I ministry of engineering they have.

So, some in C V R A, of course, they have some places there is a physical disease now too. If you want to test the material, how do they behave at high temperature? What you can do? You can raise the temperature, keep it constant and then measure the strength, compressive strength for concrete ok. This is one of the ways. Otherwise, I load it increase the temperature. Then also, it will fail for a follicular load.

So, this could be stressed already this could be stressed already. This could be already stressed. And this could be unstressed and this could be subjected to temperature say 400 degree centigrade and cool it and stress it I mean test it. So, this is called residual unstressed residual. This is unstressed raise the temperature. then say 400 degree centigrade raise the temperature of the specimen, the compression testing machine is capable of containing a specimen at 400 degree centigrade.

So, it will first raise the temperature hold it there. Then the compressor will be done. You know such systems the specimen will be heated up and then the corporation load will be applied. This is unstressed stressed means; I just stress it to 20 percent, Because, structure will be stressed. So, stress it and 20 percent stress of the failure. If I know the F c k value or strength value cube strength expected, they stress it to 20's 20 percent. Then, raise the temperature to 400 centigrade, then failure or 600 degree centigrade then failure.

But at ambient temperature is stress to 200 degree centigrade. So, when there are different mixes, they did you know the people have done such experiment. So, you find that with temperature strength reduces uniaxial compressive strength reduces proportional strength is 1. If I take proportional strength is 1, which is unstressed that ambient temperature that is I am calling as you know relative strength.

I am finding out divide every strength by the normal strength test that you do, then you get this is proportional strength. You find that strength comes to if it is 20 percent strength at 600 degree centigrade you will be left with only 40 percent strength.

So, if you concrete was showing 35 mpa cube strength was there at ambient condition at ambient condition. If your subjected to 20 percent stress and then, raise the temperature to 600 degree centigrade and then again stress test. It you will find only 0.4 into 0.35; that means, around you know 14 m p a or so; 14 m p a or so, right. And if it is unstressed, then you find it, still you know unstressed still or you will find it around 600 degree centigrade something like 25 percent or 30 percent.

And if you heat it up to 600, cool it and then test you find still less 20 percent. So, you will find about 7.5 only. So, post fire structure strength is much lower, but it is a function of temperature people have actually fitted some equation simple equations. We will look into and then fix.

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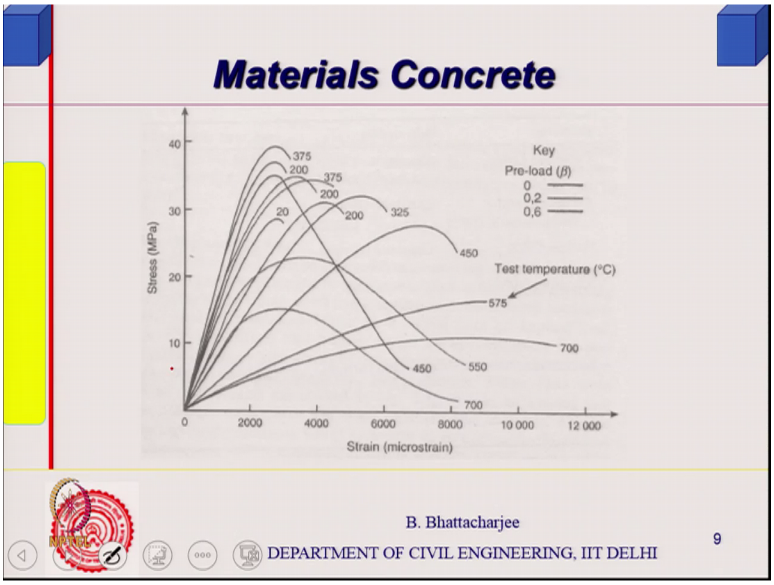

So, this is the kind of behavior of stress strain behavior stress strain behavior of concrete. This is the kind of stress strain behavior of concrete, all right. Stress strain behavior of concrete. So, this is stress strain behavior of concrete and you find that this is this is you know this is the at 375 degree centigrade this is the kind of scenario.

At 700 it is like this at 575 it is like this. So, what happens it is normally concrete is brittle 200 degree centigrade 375 you find slight increase in strength. I will discuss this sometime later on. As your strength increases, as your strength increases as your temperature increases, it tends to show a lot of deformation capability, but strength is much lower; that means, it will have lot of cracks develop lot of cracks develop the 700 degree centigrade. You are doing this stressing it already cracks have developed and it will go on developing more cracks and more cracks. So, it can show a lot of deformation capability where here the failure is quickly and brittle.

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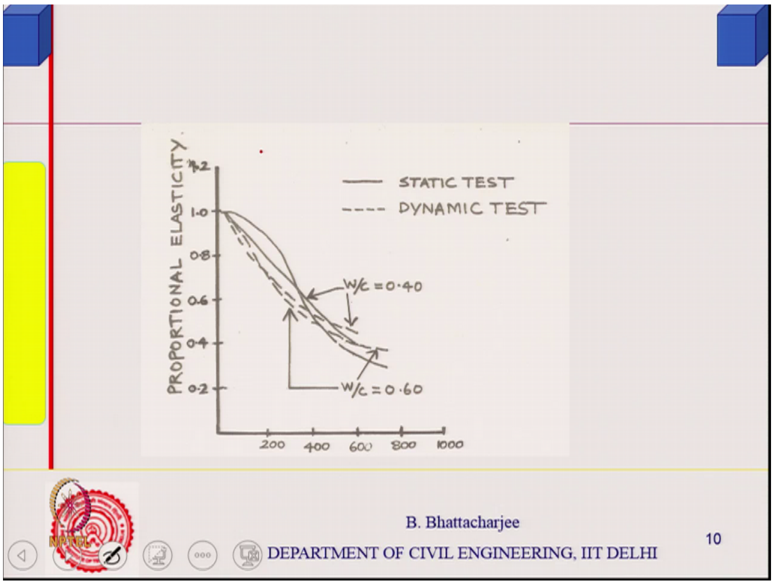

So, this is a stress strain behavior of concrete and I thing will repeat this. This is the elastic modulus of concrete which also reduces this temperature and then, we look into steel in the next class.

So, I think we will stop here.