Fire Protection, Services and Maintenance Management of Building
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Lecture – 03
Fire Resistance

So, continuing with Fire Resistance, where we stopped in the last class you know if you recollect just to remember what you did fire resistance is defined in time unit.

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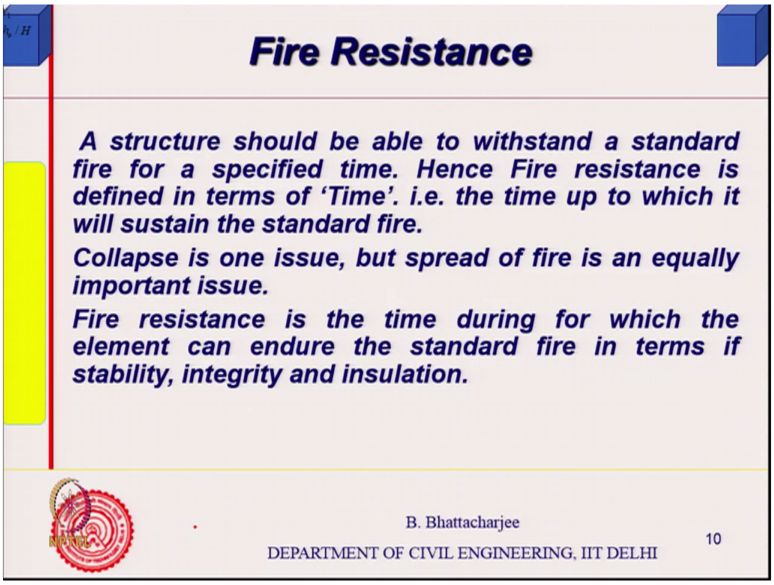

So, it is the time for which an element is able to withstand or perform adequately against standard fire right. So, it should sustain the standard fire during that period of time. Now, three issues we discussed one was collapse that is you know structural inadequacy or structural stability issue, other is a time, during which it can it does not transmit the fire to the next room, that is by virtue of its insulation quality and also maintaining and integrity. So, that is how we define fire resistance right.

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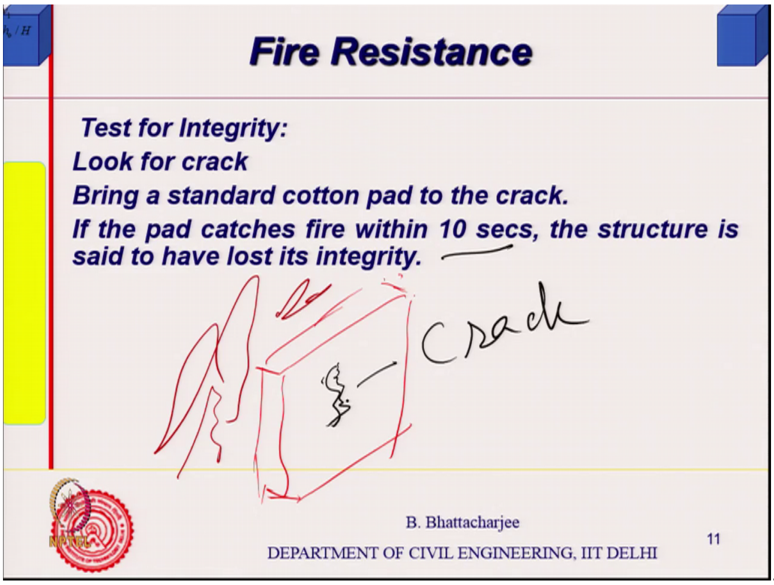

So, test for integrity look for a crack on the, which side? On the ambient temperature side furnish side the heat would be there look for a crack on to the, you know room temperature side and bring a standard cotton pad in front of the crack right. And if the pad catches fire within 10 seconds, then the structure is said to have lost his integrity. For example, it could be it could be something like this you know say let us say this is my structure, this is my structure right this is my element wall element let us say I am talking of wall element wall and there would be tested as there supposed to be in the structure.

For example, a slab element will be kept horizontal in the furnace, heated from the bottom and you will see the top, because usually fire you know effect is from the bottom because hot gases tend to go up and accumulate. So, normally floor will be least effective as we shall see. So, if something like this you know if this is your element and on this side you have let us say on this side you have the fire, on this side you have the fire this side you have the it is engulfed in fire. So, you look for a crack, you look for a crack on this side some sort of crack formation some sort of crack formation on this side. So, this is the crack; bring the standard cotton pad in front of the crack and if it catches fire within 10 seconds then you say that the element has lost its.

Student: Integrity.

Integrity, elements is lost its integrity all right. So, that is what is its lost its integrity fine. So, that is what it is.

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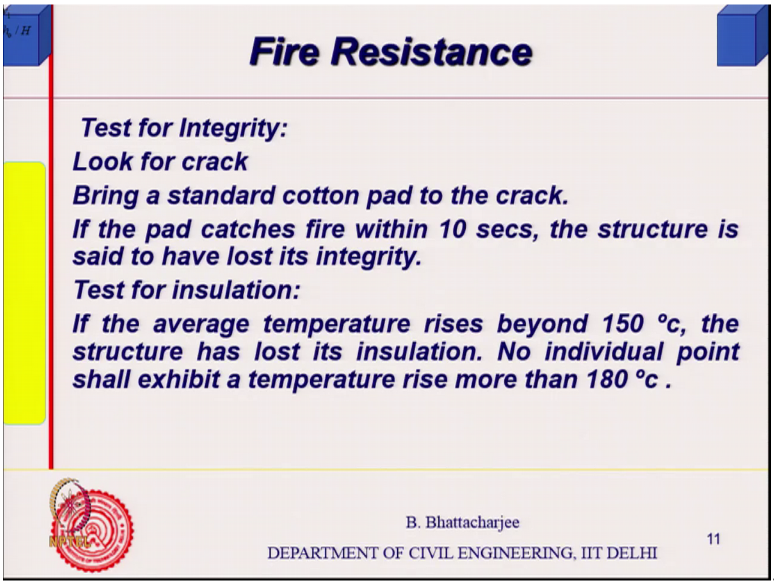

So, that is how we test for integrity, test for insulation we look for temperature rise on the other side. So, here we are now looking average temperature if it goes beyond 150 degree centigrade, then the structure is lost his insulation quality. And no individual point shall exhibit a temperature rise more than 180 degree centigrade.

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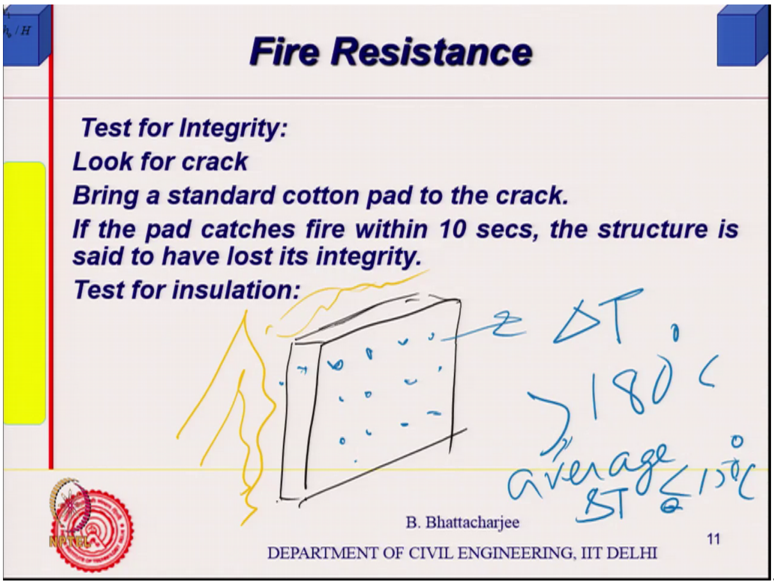

Just let me explain again to you, supposing this is my structural element again let us say its again the same wall element I am talking of right. So, what I will do is, I will instrument it the furnace side is furnace side is this is the furnace side, this is the furnace side, this is the furnace side right. So, the fire is on this side. So, what I will do? I will have some sort of you know some sort of thermocouples all over the places, thermocouple all over the places right temperature measuring devices and so, will be the cases there also inside also.

So, if the temperature rises here if the delta T here is more than 180 degree at any point if it is greater than 180 degree centigrade at any point delta T, then I say that it has lost his insulation quality. Not only that average delta T for all these points you can measure and the average delta T should be less than 150 degree centigrade you know less than 150 degree centigrade. So, as long as this condition is maintained that is less than 180 at any point less than 150 on an average, its fine we say that it is this you know it can still withstand the fire. And, it has you know the moment it losses this is a moment it in you know goes beyond this we say that fire resistance is the is the time at which you know the time corresponding to that we call it as a fire resistance.

So, if the average temperature rises beyond 150 degree centigrade, the structure has lost is insulation, no individual point shall exhibit a temperature rise more than 180 degree centigrade. So, that is a idea so, that is how we define.

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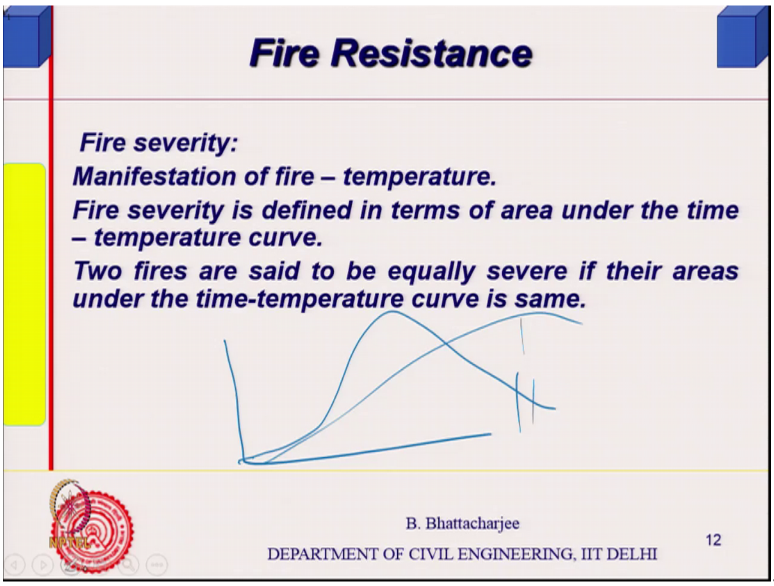

So, you got to have a you know furnace large furnace; now other day you know a (Refer Time: 05:10) was there that how do I handle it for structures? As I said that standard fire we have device because fire from space to space will vary. So, therefore, we have to device standard fire and define, and they are all relative measures. So, an element performs well and another element does not perform so, well that we can talk about, but its quantified in terms of the time.

So, to in order to actually how much fire resistance do I require for a given space, let us say this room the room you are sitting how much fire resistance do you need for the for this room. So, if you if you if you want to find out, because this room will have fire which will be different than the standard fire, which will be different than the standard fire. So, we talk in terms of a concept called fire severity.

Now, as I said to effect why fire severity, how do we define actually let us say, what is a you know logically what how should I define? Well one thing is a temperature; you know how much peak temperature it is attained because as I said either human body or materials they sustain the temperature if the subject is a very high temperature, it would get damaged instantaneously. So, one is that temperature other is a time of exposure. So, both these aspects are taken into account. So, it is talk and if I want to take it over a small delta t delta t small delta t period of time summit of the effect then I should be integrating so, any under the time temperature curve is what is defined as fire.

Student: Severity.

Severity so, two fires are said to be equally severe if there areas under the time temperature curve is.

Student: Same.

Same right now real fires will vary that is what we have seen that we saw that it was something like this maybe it will go like this, and standard fire goes something like this. So, area under these two as long as if they are same so, now, if this is the area or let me have my own diagram, which is already there existing here right.

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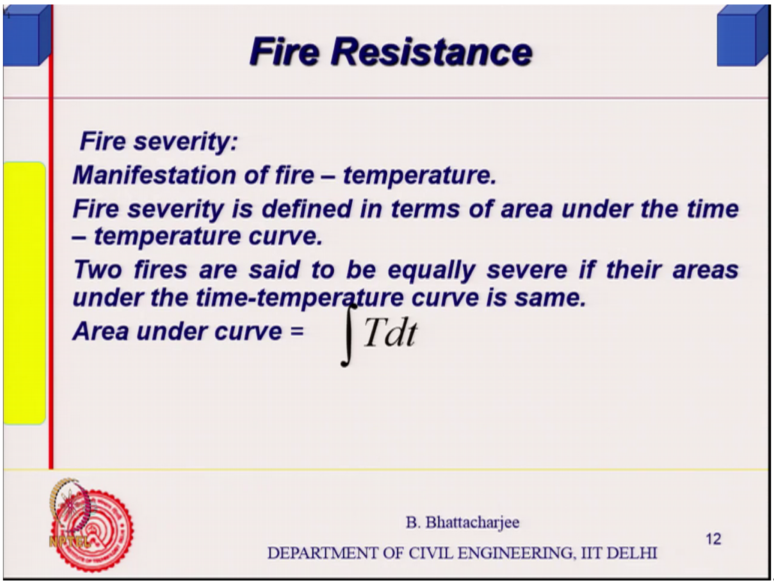

So, the area under the curve has to be same. So, area under curve will be integral capital T is temperature dt is the time small t is the time. So, integral T dt should be same right integral T is T dt will be same.

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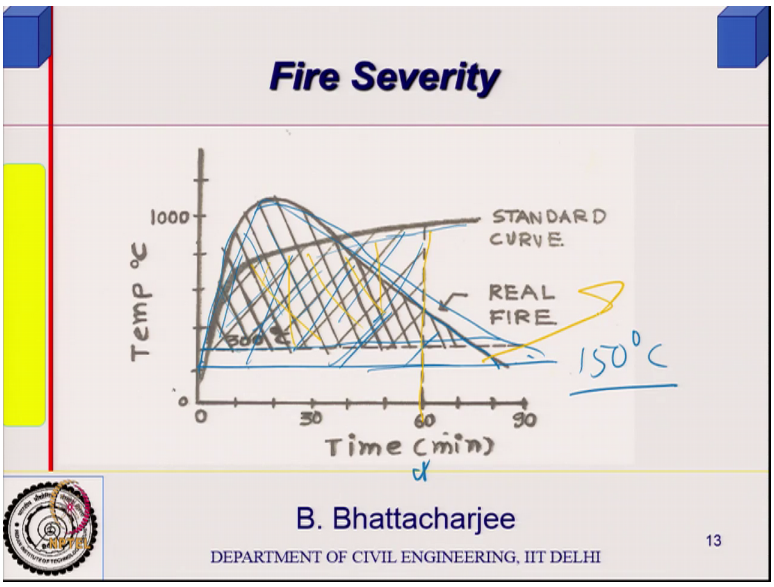

In other words say this is my real fire, this is my real fire this is my real fire right if real fire varies like this and this is my standard fire this is my standard fire this is my standard fire right this is my standard fire. And, the area under this curve area under you know what I do is the standard fire I go on finding out the area right area under this curve, and also find out the area from under this curve. And when these two are same; that means, 60 minutes is the equivalent fire resistance of this fire. Now there is one thing this we have taken it above 300 degree.

See generally either it is material, 300 or 150, some datum level we take we do not take ambient because generally as we shall see materials their effect you know there are let us say concrete it does not does not nothing happens to it till say about 200 300 degree centigrade. Steel nothing happens to it till 200 300 degree centigrade right, 200 degree centigrade would be a good statement. Human being of course, exposed to 250 degree centigrade for a very short period is very dangerous, but even then it can lead to fatality, but then human being we expect they will escape out they will go out of the space you know.

So, anyway some datum level you take, and above this day which could be 150 degrees somewhere you will find 150 degree, somewhere it is 300 degree centigrade and then we start finding out the area under you know the area under this curve actual fire. Now actual fire how will you estimate there are models available, will see that as empirical at least empirical model we can look into, but that will look later on. So, if I know the area under this curve, now go on finding out the area under the under the.

Student: Standard.

Standard curve you know. So, that is this is the area and let us say at 60 minute this becomes equal, then require fire resistance for this real fire would be.

Student: 60.

60 minutes 60 minutes that is what it is you know. So, what we are say is. So, therefore, you the material that you put in the walls columns slab and beam etcetera in this that particular room should have a fire resistance minimum 60 minutes. So, we can actually you know using this fire severity concept, we can estimate out what is the requirement of fire resistance in a room or elements exposed to given room. So, walls floor roof etcetera etcetera beam columns all structural you know nonstructural elements we can talk in terms of this, but this is fire resistance.

You know fire resistance is essentially related to more realistic related to elements such as such as you know structural elements like beam column and also other elements like walls partition wall, you know which are structural element plus the elements which is enclosing the room. Now, if you come to even you can talk in terms of the fire resistance of let us say furniture's that is fine, but there are certain additional things also one has to look into. For example, issues like flame spread flame spread I will talk about that sometime later on because spread of flame can be very fast in certain finishing paints etcetera etcetera.

So, when you have finishing this these are the other issues not exactly fire resistance is for, building elements which are relatively larger not the thin coating or something of that right, but as an integral element we would be looking into. So, that is what the concept of fire severity right.

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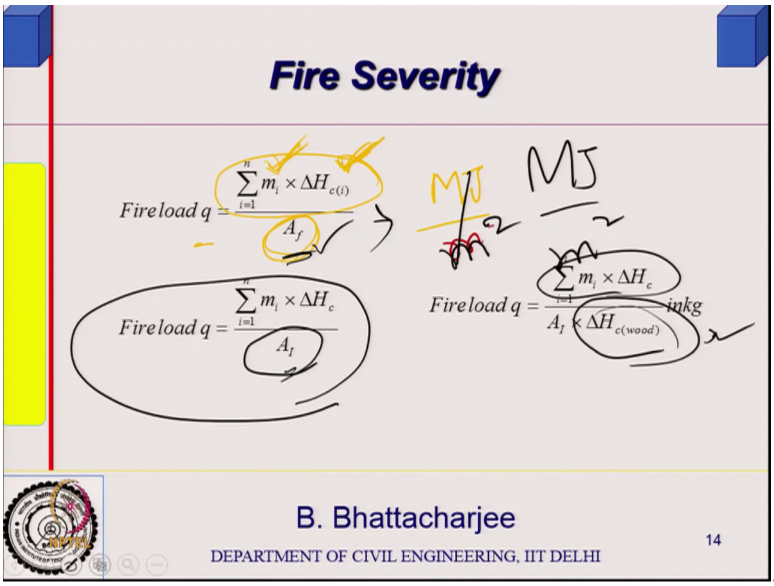

So, therefore, now fire load I have just defined now fire load if I know because fire severity will depend upon or time temperature curve for a real fire will depend upon fire load. And last class I was just mentioning some time earlier I was mentioning fire load we define in terms of with some time denoted by q, but I think is you know it can be because books defined q, but heat flux also sometimes we are defining by q. So, please do not get confused. So, this is fire load q is the heat of as I said combustion of ith material, multiplied by mass of ith material that is present in the room full room divided by the either the floor area, you talk in terms of floor area or sometimes the total internal area is also talked about right. So, fire load is defined in this manner.

Now, this is in you know it will be in kilo joules or mega joules, this will be in mega joules per unit mass if you multiply per kg mega joules per or kilo joules per kg multiplied by the mass. So, this is in terms of kilo joules or mega joules for all the materials in the room generally mega joules so, mega joules per meter square is a unit. So, usually it will be mega joules per meter square mega joules per meter square you know I am not happy with the colour let us let us use the black mega joules per meter square. So, mega joules you know mega joules per meter square.

Now, I have also mentioned. So, this is a unit, but I also mentioned that I might express it in terms of equivalent kg of wood, because most of the experiment is done in terms of equivalent kg of wood. So, fire load in kg would be kg of wood would be something like this, now this is this is you know this is for wood if I know the delta H c of wood, then this is mega joules divided by mega joules per kg this will give you in kg.

Now sometime I also denote it by all internal area that is why this difference is A f floor area, some people have tried to define it with all internal surface area. This the reason is in whichever way you do the idea is that this spread is important spread is important right and if you are looking at the whole internal surface area, internal surface area is the one through which heat gets dissipated. So, some people earlier days people also use A I, but commonly it is A f floor wise right.

And then you A I or A f whatever it is, if you divide by the heat of combustion of wood then you get in equivalent kg. So, you simply write kg of wood right simply you write kg of wood. So, that is how we define fire load, that is how we define fire load equivalent kg of wood and people have done.

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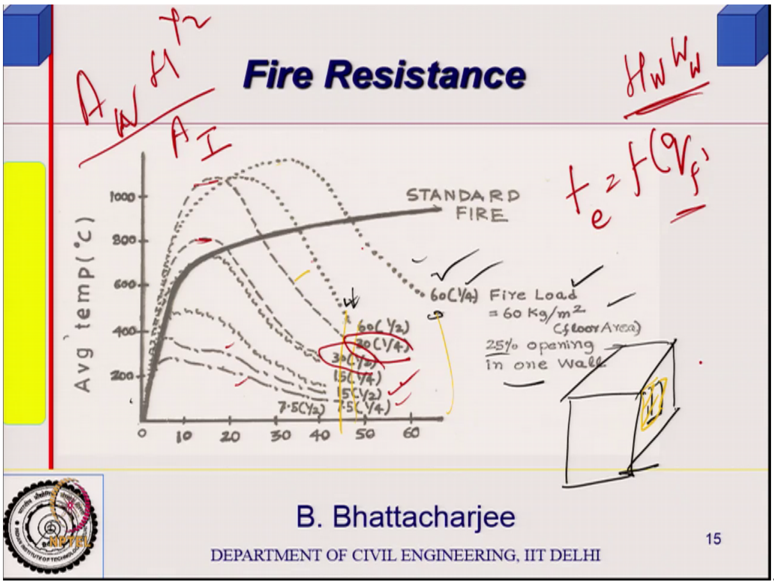

Some experiments in wood old days you know they have done some experiments in wood old days in furnaces and what they have done? They have varied the fire load like 60 kg per meter square of floor area right and then ventilation. So, considering something like a compartment a single room compartment, something of this kind having one window somewhere one window which is occupying 25 percent area of the wall.

So, if this is the wall its 25 percent then that is what the did experiments they did; and then 60 kg per (Refer Time: 15:22) meter square and per unit floor area you know in terms of floor area and 25 percent (Refer Time: 15:28) one wall. So, this is the case. So, what they saw was this is the typical time temperature curve. Now when you vary this ventilation is increased to half the wall area; that means, this has now become instead of instead of.

Student: (Refer Time: 15:44).

Yeah, instead of 50 percent 50 percent this is become half now slightly bigger you find that it lasts for lot loss lesser period of time the fire actually finishes off here right and temperature is nearly similar temperature is nearly similar.

Now, we can understand this how we can understand this how we can understand this physically, because we said oxygen availability. If the oxygen availability sufficient it would actually quickly consume all the fuel all the fuel will be consumed quickly. So, oxygen rate of burning is a function of the oxygen availability also. So, it will consume the fuel quickly therefore, it finishes of lesser time, while this took longer time. And now if I reduce down the fire load if I reduce down the fire load, if I reduce on the fire load let us say I make it 30 kg 30 kg right temperature does not go like one forth is here, but if ventilation is half it really comes down temperature is reduced because now fire load itself is reduced. And if still I have 15 and one forth and so, these are the experimental empirical evidence is 7.5 kg per meter square.

So, basically it depends upon opening, area of opening and also depends upon the fire load also depends upon the fire load also depends upon the fire load. So, as fire load increases temperature increases may be severity will increase, as ventilation condition is lower up to certain level severity may be more, beyond certain point severity may be lowered because it will burn out faster time will be less. So, these are the kind of empirical experiment done on furnaces, experimental work done on furnaces right and then somebody would have fitted an empirical equation to this. So, I will come back to this I will come back to this empirical equation right this is a equivalent fire resistance actually they worked out.

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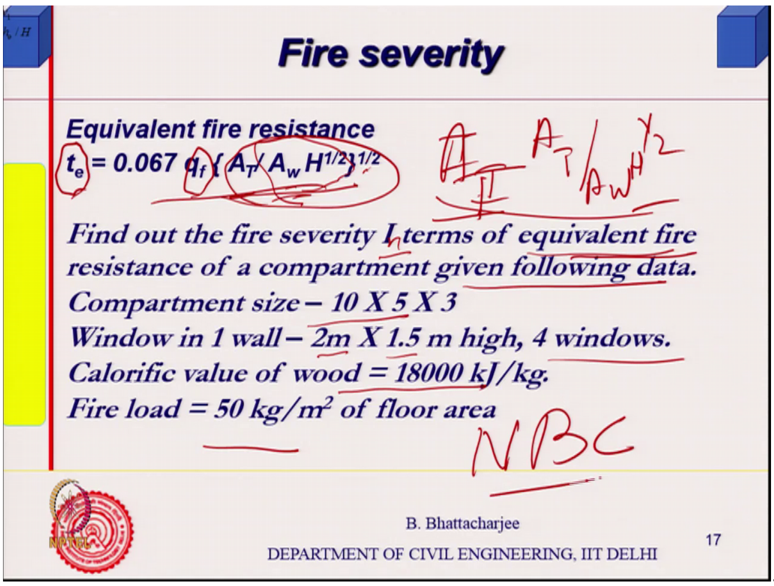

Now, what was done is, you see this they defined a factor called just a minute maybe I have this is a calculation, but maybe I will just tell you this formula first. What they have done is, they have fitted an expression to this they fitted an expression to all this. So that means, my fire resistance required equivalent fire resistance required t equivalent is a function of fire load, and its also function of ventilation area now what is ventilation area? Height of the window multiplied by height of the window multiplied by width of the.

Student: Width of the window.

Yes width of the window. So, there is a ventilation area right, but people did something more because this is related to per unit area floor area or if in this in this empirical equation actually they used all internal area. So, area is already taken care of this, but here I got to take care of that area also, because it will be a function of the area as we have seen function of the area how much is the area corresponding to that wall. So, this that they call it something is called an opening factor ventilation factor and opening factor.

Now, it is been found that area of the window multiplied by H to the power half right will derive this actually will derive this actually. So, that we have better physical understanding; H to the power half is what is called ventilation factor it is called ventilation factor. And if I divide this by total area A I, I call it opening factor at the moment at the moment I will I will go more details into it because it might appear to that suddenly it is coming from where, but will derive this the we will give the physical basis.

area of the window we have found out that is important and per unit total proportion of the area compared to total area this is important this we have already seen why h to the power half? Because top half through top half hot gases go out through the bottom half air comes in if it is a single window situation that I talked about. So, last class I was just mentioning the top half hot air will go out and bottom half fresh air will fresh oxygen will enter. So, there is something to this age right and it is actually related not straightaway half which were something not linearly, but to the power square root of that will see that actually will just see that.

So, but the equation that was found out equation that was found out was something like this, this is the equation this is the equation that was found out is t equivalent fire resistance they actually then equated that now equated to what the estimated?

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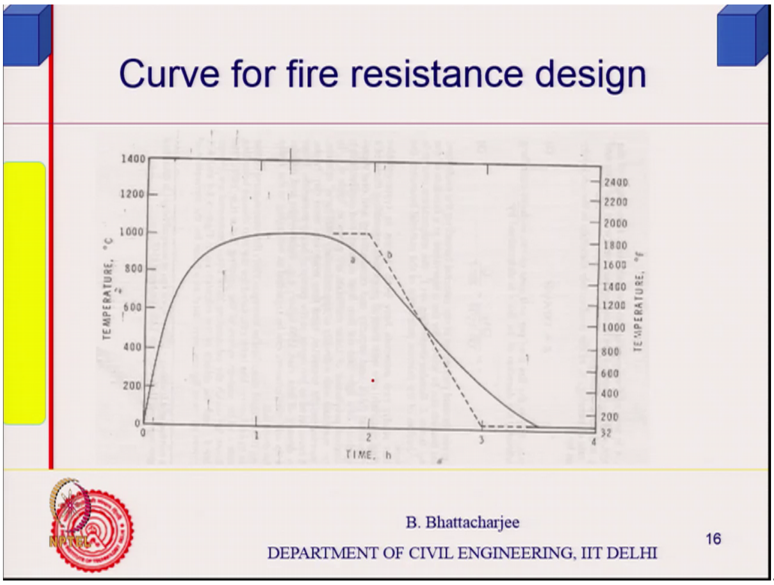

Estimated fire you could find out right either theoretically here earlier it was empirical experimental found out or theoretically you can find out will see the, you know how people find out theoretically. Then find out the area under this curve and the area under the standard fire curve, which is equal to the area under this curve. That means, find out the equally severe standard fire up to particular time, because 10 standard fire is perpetual it goes on increasing, it is it does not you know it does not extinguish it is a continuously increasing with temperature curve.

So, therefore, standard fire since it is continuously perpetually increasing type of curve, somewhere at some time you got to fix it and find out the area under that curve. And when this area matches with the area under real curve that is we are calling as equivalent fire resistance. So, they empirically not only done this empirically you know experiment, and also try to find out the equivalent time or equivalent fire severity you know equivalent fires I means the cv equally severe fire in terms of the time. So, that is how this expression came into being; that means, this time t e stands for t e stands for t e stands for oh again [FL] t e stands for equivalent time for standard fire right.

Since they found that is proportional to fire load and proportional to total area divided by A w. So, it is a total, total means all internal area all internal area this A T is been used by those people who derived I earlier use A I internal area, A total area; that means, floors ceiling everything divided by what is called ventilation factor. This term is called opening factor not half this term A T by A w H 2 the power half is called opening factor its basis will look into this because that involves a little bit of fluid mechanics issues will come to that right. So, that is it.

Now, just as an example suppose you want to find out the fire severity in terms of in terms of equivalent fire resistance of a compartment given the following data. This compartment size is 10 by 5 by 3 window in one wall of size 2 meter by 1.5 meter right and 4 windows let us say 4 such windows.

Student: (Refer Time: 23:43).

In the in the in the in the you know 4 such windows actually calorific value of wood is given as 18000 kilo joules per kg and fire load is 50 kg per meter square typical 4 of its things like that the values I think I might be having somewhere typical values for fire loads people have actually found out for various types of occupancies right. Also national building code does not give the, such values really. Because it does not look into modeling national building code part 3 which will discuss in terms of planning NBC National Building Code now 2005, then there is a now all modifications even resent also.

So, national building code of India it give its deals with it has got a section 4 I think part 4 which deals with fire protection, but 4 deals with fire protection I think part 3 is administration, part 4 deals with fire protection right. So, this part 4 gives you what are the fire protection need for every types of occupancy, including planning number of escape you should have. So, that will discuss later on, but it does not give you the fire load in all. Because it does not really address the question of design for fire resistance design for fire resistance, whether it is a partition or a structural element it does not discuss it. But IS 456 if you remember Indian standard 4 50 six gives you now in one table the minimum cover thickness required for particular fire resistances. So, cover thickness is also decided based on fire resistances.

So, that you know. So, all the codes they have in some somewhere other they looked into steel code for example, takes care of this because for steel it is relatively very important to look into the fire issue. So, some empirical formula is being used we will look into the simple simpler case and find out. So, 18000 kg and this 50 kg per meter square is typically for a office and let us do a small calculation before we go to the next one.

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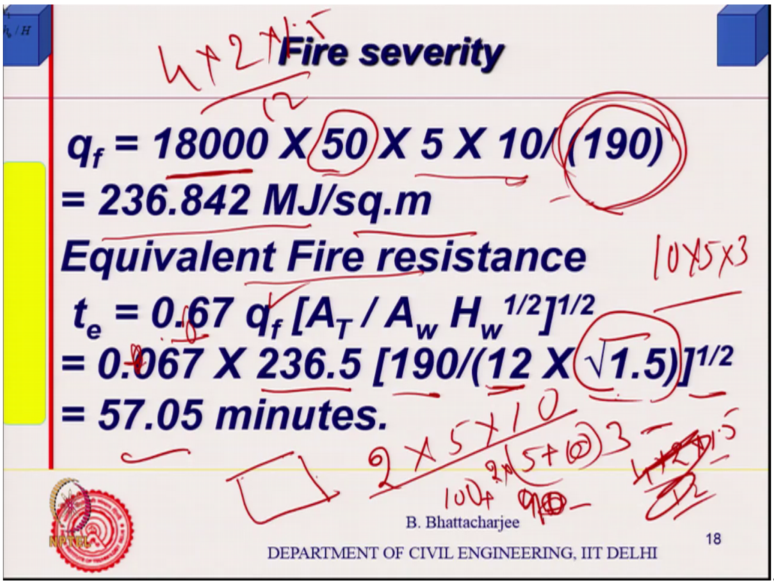

So, if it is 18000 kg per meter square per unit floor area, 50 kg per meter square of floor area and 5 into 10 is a because room size is 10 by 5 by 3 we said make it a simple case. So, this is the floor area. Now, this q f in this empirical formula is divided by total internal surface area. So, what is the total internal surface area? 5 into 10, 2 into 5 into 10 that is ceiling and the floor right and how much is the wall? Wall is basically 5 plus 10 into 3 minus the window area because, 4 windows are there 4 into how much we said? 2 into 4 into you know 4 into 2 into 2 into 1.5 into 4. So, 2 into 1.5 into 4 2 into 1.5 into 4 so, this will make it how much this is actually 100 plus 15 45 minus 45 is it 45 or.

Student: (Refer Time: 27:10).

5 into 2 also because perimeter I am taking no perimeter I will I am taking so, 5 into 10, 15 into 2 30 into 3 90 right. So, how does it come 190 there are something some mistake still I am doing 50 into 100 is very much there and 4 into 2 into 1.5 is 12. Now 190 is the internal area I just it is based on the total internal area is respect to the window not solid area its total sorry. So, this is not required there is no summation minus is not required. So, this is 190 is the area of the wall. So, this here is total flow area not the window area subtracted. So, divided by 190 and you get mega joules per square meter to be using that empirical formula; to be used in that empirical formula because this is not done if you see from fundamentals this may not be necessary floor area itself is good enough.

So, equivalent fire resistance is given as 0.67 not 670.67 there is 0.67 that is what we said 0.067 there is a 0.067. So, if you multiplied by 0.067 multiplied by point this is 236.5 a total area is 190 divided by area of the window and height is 1.5. So, area of the window is 4 into 2 into 4 into 2 into 1.5 that makes it 12 right, that makes it 12. So, this is 12 and H to the power half is point square root of 1.5 to the power half, half it comes out to be 57.05 minutes. That means, about a 1 hour fire resistance you would require for that all the elements in that compartment, all the elements in the compartment right all the elements in there.

So, that is how one can find out how much is the fire resistance required in given space. For example, you know if I know this space classroom approximately I can find out the fire load as well, because total wood or materials known to me plastics there delta H c would be known right and I can find out the total fire load the area internal area is known. So, I can find out the q f to use in this kind of an empirical formula. So, all the concrete element here should have a fire resistance or all the structural element here should have a fire resistance calculate you know corresponding to this all more. So, I think we can break, take quick questions and then again start.