Fire Protection, Services and Maintenance Management of Building

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Lecture - 02
Basic concepts of Fire Protection-II

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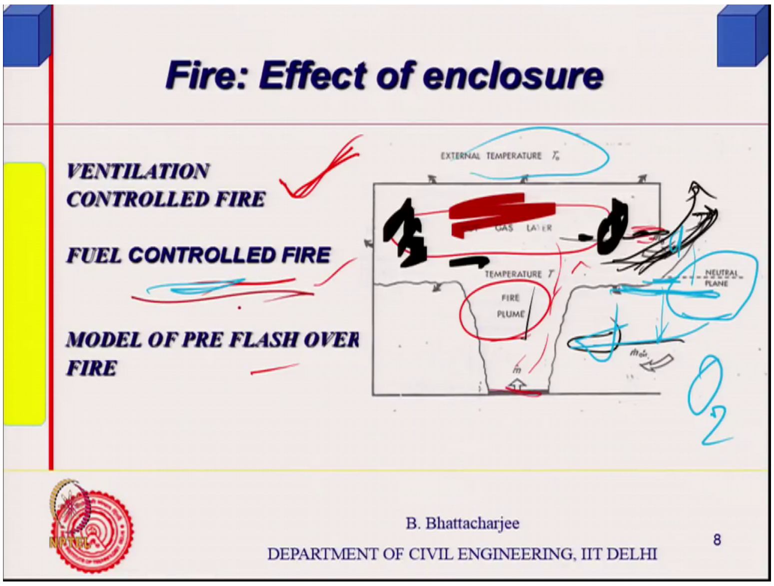

So, as we said that we have you know we can have situations where I will have ventilation control fire that is oxygen is availability is not in abundance. Well, fuel control fire is where oxygen is available in plenty, but fuel is getting depleted. So, this is a situation. So, we can also do some modeling a little bit, but let us see lets understand first physically. Model is not important I am not going to solve the model here, but give you the physical understanding of this.

So, let us say this is my combustible material. And fire has started. The plume that is burning gases hot gases flame etcetera put together. They actually rise and hot gases filled in these place hot gases will fill in this place, hot gases will filled in this place. You know hot gases will generally it will fill in this places hot gases will fill in this series. So, the hot gas layer it accumulates up to this line; it will accumulate up to this line first, you know there is only one opening left here, just for our simple understanding. So, it will accumulate up to this point.

And then what will do? Once this is accumulated up to this point, it will now start going out, because hot gases there density is less, there density is less you know temperature high is a will model it also do not worry a little bit equations will like it put it.

So, hot gases goes out through the top, but what happens is to sustain the fire and there is a volume you know like the gases are going out something must come and fill in this space. The volume is conserved, volume is same volume is the room volume is same. So, if something is going out, something must come and occupy that space. Hot gases tend to occupied, but to generate hot gases I need oxygen to come from the bottom.

So, oxygen comes from the bottom, oxygen comes from the bottom oxygen, oxygen or air comes from bottom, supply sustains the fire condition and then gases accumulate. And when it becomes more you know it tend to accumulate over half of the opening area or some portion of the top half of the opening, and oxygen comes from the bottom half usually bottom half or nearby half or something like this.

Plane where this below which oxygen comes and above which the hot gases go out we call it neutral plane, neutral plane because nothing is going out nothing is coming in there the pressure must be 0, so that is a neutral plane pressure inside and outside must be 0 that is a neutral plane. So, that is actually that is actually you know behavior of the fire. So, external temperature is T and then internal temperature goes on increasing internal temperature goes on increasing right, so that is it.

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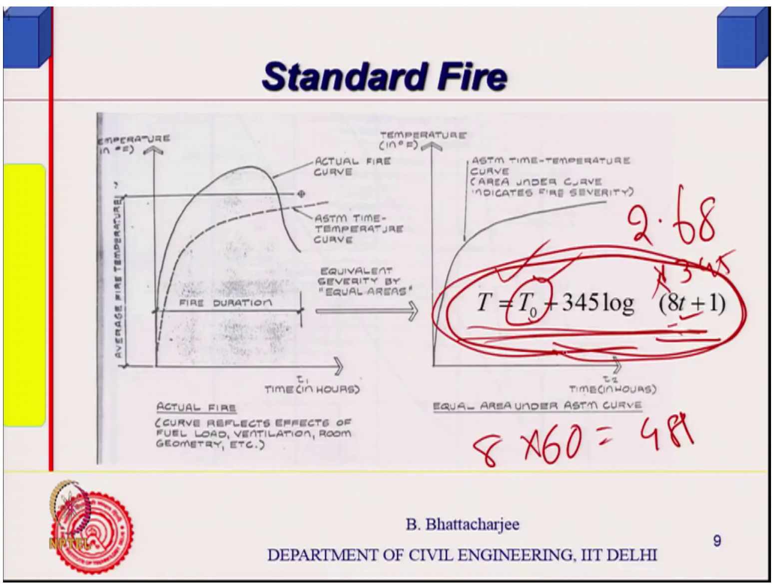

Now, let me define a few thing before I go to standard fire. So, this is the behavior of fire in a room, this is the behavior of fire in a room. I have not defined I think something so oxygen I have talked about, but related to the fuel I have not told you something. How do I quantify the fuel content in a space, how do I quantify the fuel content in a space you know fuel control in a space room or something like this. Well, we define in terms of what is called fire load.

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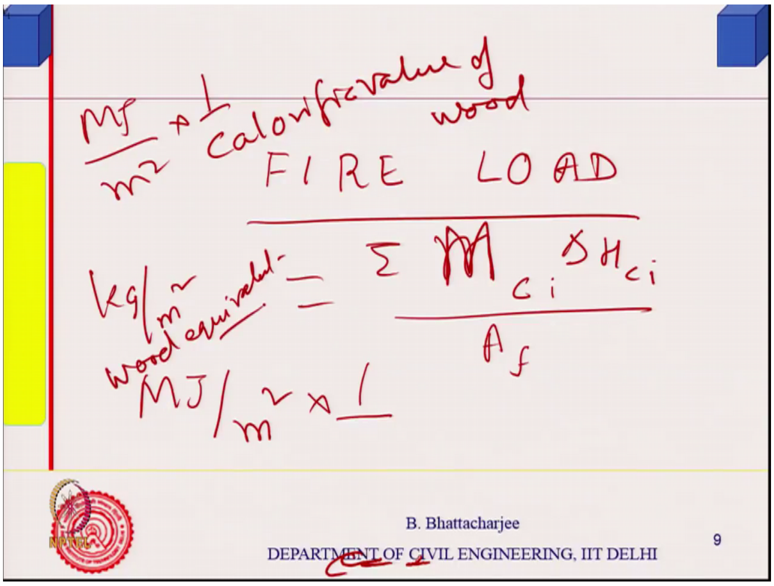

We define in terms of fire load. Now, what is fire load? Fire load is you can identify total quantity of combustible material in the room, total quantity of combustible material in the room divided by the area floor area or internal surface area you know people use both this, but generally it is floor area right. So, fire load is nothing but sum total of all combustible material multiplied by their delta h c. So, it would be actually mass, mass right mass of the combustible material.

So, let me put it as shall I use capital M or small m, I do not remember what do, small m we have used for burning rate. So, let use capital M, mass of all combustible material M c i let me call is ith material into delta H c i of that material right or heat of combustion of that material or fuel value or whatever it is divided by floor area. So, fire load I might talk in terms of mega joule per meter square, mega joules per meter square. Fire load I might talk in terms of mega joules per meter square.

But something interesting is there; interesting in the sense that earlier all experiments that is done to understand the fire in furnaces they used wood, small wood pieces. Therefore, there is another way of expressing this fire load in terms of equivalent kg of wood. So, the mega joule per meter square if you divide it by the calorific value of wood calorific value of wood actually, oh, so you know the mega joules per, so this is actually calorific value of all the fuel mega joule per meter square multiplied by calorific value of wood which will be again in mega joule stamps per kg.

So, you will get kg per meter square wood equivalent, kg per meter square wood equivalent. So, kg per meter square wood equivalent, wood equivalent, wood equivalent right, wood equivalent, kg per meter square wood equivalent. So, you get kg per meter square wood so that is how fire load can be defined that can be that is a fire load can be defined. So, fire load is one.

Now, it depends upon occupancy class; it depends upon occupancy class; it depends upon occupancy class. For example, in residential building type of fire load, you will have is different; then in an office right. And in office again you can have two types of scenario one all papers are today of course things are quite different, but good old days you will have lot of papers some offices; just some other offices you might have all of papers locked up in a steel almira.

So, those ones are will have less. So, you know fire load is based on that. However, you know no occupancy class you can in the occupancy class residential etcetera, etcetera which will talk about sometime later on occupancy classes. So, fire load can be related to the occupancy class itself. Like you do for even gravity load gravity load is based on occupancy class today so that is what it is. So, fire load is defined in this manner.

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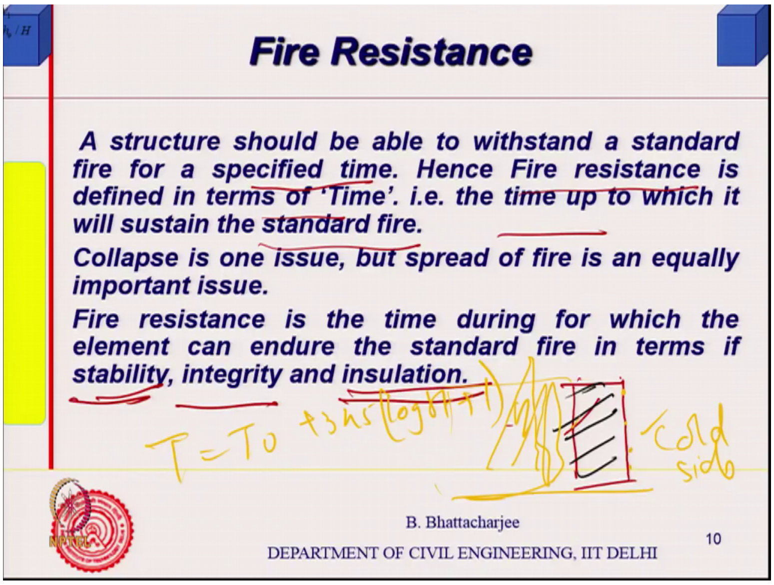

Now, let me see if I have defined this fire load somewhere.

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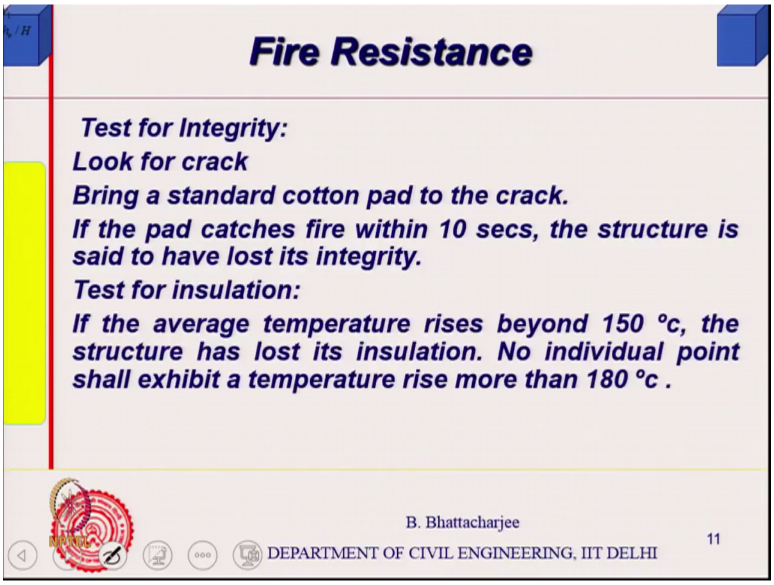

Fire load not really here I have not defined I will see.

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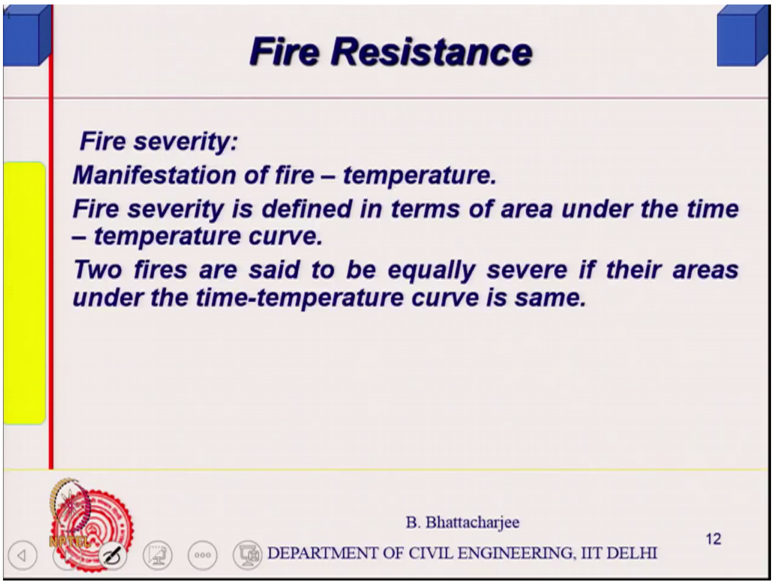

If I have defined them somewhere ok. So, fire load is that is how we define fire load. Now, I if I have to compare a building element, you have to compare a building element for its performance against fire, I must have some way to quantify this performance right and from this point of the point of view what it would be for example, if it is a wall or a you know roof or ceiling floor slab or the floor system floor system a floor, then I must be able to quantify their fire performance.

Now, how do I quantify their fire performance? Well, issues are I mentioned earlier the first thing is that it should remain as it is means should not really fail structurally. If it fails structurally that is a disaster altogether. So, it should not fail structurally, but I also said that it should not transmit the fire to the next room.

Now, how can I transmit the fire to the next room? Either the flame may go away or the heat can get transferred. Supposing heat transferred through this is very large, lot of heat can pass through it conduction heat transfer and that heats up the next room combustible material. Supposing 1000 degree in one room, and next to my have got you know the conduction is. So, high that next room it goes to 200, 300, 400 exist there then there is a problem. So, that is the one issue is related to the structural performance; the other issue is related to the performance related to conduction of heat.

But other there is a third aspect also the flame. Now, when can flame pass who can pass through, supposing it develops a large crack because of differential expansion etcetera

etcetera or material you know degrades at higher temperature generates cracks right drying or similar sort of thing whatever it is. So, if the cracks become too large, even hot gases and flame will pass to the next room. So, the performance against fire is just by these type of three conditions. One is the structural I will have again this in the slide, one is the structural performance; other is a insulation quality and third is the integrity it should remain integral I mean standing all right structurally still safe, it will not collapse, but if it is not integral, there is some gap hole has come into it, it will actually transmit the heat. So, this is the performance how we define against performance.

But performance against what fire, performance against what fire? Because the fire that will be there in a given room will depend upon the fuel condition of that room, ventilation condition of that room right. So, it is space dependent, it is space dependent; it is not independent of the space. You cannot you cannot say that if I have residential building, all residential building will have similar kind of fire. Now, how do we define fire, we said by temperature versus.

Student: Time.

Time, time-temperature curve. So, time-temperature curve of all the spaces are unlikely to be same. Therefore, how do I judge these materials or elements? Structural elements beam column or slab or wall or whatever it is. Well we have to have a standard fire, I have to have a standard fire, so that is the concept of I need a standard fire that is the concept of standard fire right concept of standard fire.

Now, this actually standard fire this concept started developing somewhere around 1920s people started doing experiments in furnace. And largely they found the typical most of the typical fire would go around 100, I mean 1000 degree, 11, 1200 degree centigrade in about an hour and one and a half hours time. And then try to come out with a standard fire which will cover almost all fire you know effect of all fire, cover almost effect of all fire.

So, if you see actual fire should look something like this, because we said that you know if I look at the post flashover situation particularly because before that it is in some corner I am not so much worried. It will built up be a steady position then it depletes. And temperature would be somewhere there. Now, the other fires also I have some more diagram of fires I will see that we will see that how the behave. Generally, you will find it something like this. So, they deplete after certain period of time during ambient fire duration of fire.

Now, standard fire was basically arrived at by consensus of people like you have you know loads. If you look at the loads of loads that you take in buildings, because the bridges things could be different, because they are more or less you know the vehicle, bridges or depend many other industrial structures specific you know, but then you have impact factor etcetera you can estimate specific cases industrial it becomes complex, but bridges for example, class a loading.

Etcetera, etcetera, there are other kind of loading class a loading a loading etcetera, tank in you know whatever it is. They are relatively it is more or less the load is somewhat known the extremities of the load, but when it comes to building, you have characteristic loads which has been arrived at by consensus.

Because this is very difficult to measure the load of all the furnitures, which are quasi static load actually dead load is continuous, it is a steady load it will there all the time, but imposed load is actually quasi static, I mean supposing somebody wants to change the furniture of a classroom tomorrow and it becomes lightweight the load actually changes or it becomes heavy because you have put in some kind of teaching equipments let us say it changes you know the culture.

So, they are quasi static usually number of people come in and go. So, the well is very difficult to come out from a measurements of 5 person load that will be exceeded only 5 percent of the time you know that characteristic load is exceeded only 5 percent. So, people have arrived at that by consensus, experts consider all over the world. Some measurements were also done somewhere.

Similarly, in case of fire the standard fire was arrived at by kind of a consensus of experts ASTM Standard Fire or Indian Standard Fire you know there this is basically adopted from appropriate international code and that fire is something like this, something like this ASTM time temperature curve.

So, what they do is this monotonically increases it does not stop, it does not stop. So, as the time passes, the temperature is higher than the real fire. The concept is like this the severity of the effect on a fire. If you see on human being fatality, you can sustain 30-40 degree centigrade for very long time. If puts somebody in a chamber 100 degree centigrade, the time would get reduced; 250 degree centigrade could be very fatal in a very short time some tissues will simply will damaged. So, there are you know, so the time is important I mean why I mention this point is temperature and time is important. If you see the materials, materials also since the material is not very you know in a you know for example, I talking about that wood thing. If you cut pieces of wood spread that is important that is why per unit area fire load per unit area is important density.

See, if you have pieces of wood that would burn faster that would catch fire at various surface area is large. While I have a log, it does not burn in the same. So, if you see the effect of fire depends upon the fuel density or load density right. So, the area is important area or you know distribution of this is actually important.

Now, what I was I just mentioning is that time and temperature issues actually. So, basically if I take the material, any material, if I expose it for a longer period of time at the same temperature, now point that I was why the wood thing came actually if I have a thick log, heat as to pass from outside periphery to inside. So, it will take longer time for heat to pass it now, if you see our structural elements, they are not thin elements, they could be thicker elements.

So, if you have longer time then even inside material will get affected. Why, surface might get affected initially. So, time is also an important factor. This is not only the temperature supposing somewhere the temperature goes high up, but then we quickly comes down, the heat will not be able to pass into the structural elements inside or for that matter any other thing inside it will not be able to pass.

So, time is an important. So, effect of the structure because most raw material would degrade when exposed to higher temperature, whether steel, concrete, plastics of course is much faster; if it is a thermoplastic, glass transition softening point glass transition temperature could be 70-80 degree centigrade. Now, therefore, time metal for which it is exposed that is also an important issue. So, what has been taught is two things time as well as?

Student: Temperature.

Temperature.

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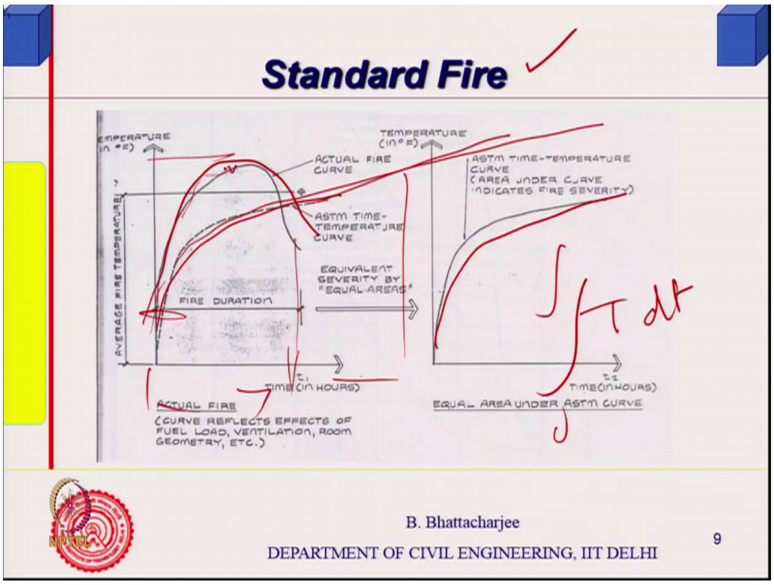

Now, how do you take care of this? That would be one of the simple way would be integrate area under this curve that takes care you know like it is it you know area under this curve would be supposing I consider temperature T and small time dt. I would not take effect of both so the you know just integrate it over the time 0 to whatever time you like. So, basically the area under the curve is important because where I have larger area under the curve that is slightly smaller temperature for longer period of time right slightly smaller temperature, but for longer period of time that would be equivalent to slightly higher temperature for.

Student: (Refer Time: 18:48).

Absolutely, so that is why what was done is tendered fire is monotonically increasing. Actually this fire is above many of the actual fire could be above; not necessarily all would be above, but many of them could be above. But even then by consensus people who write back this kind of thing. So, this is ASTM time-temperature curve right this diagram showing, but if you see the Indian, I superimpose over it this is given Indian or British or many other actually internationallym it is also ASTM same curve.

T is equals to temperature the standard time temperature curve which I need. Why, do I need because I have to judge the performance of element against a standard fire, fire from room to room varies, but if I have to say this wall is better than that wall then I need a standardization of the load or fire to which I should subjected to, so that is why I need a standard fire. So, standard fire was arrived at by people from initial experiments and then consciousness of experts.

And one of them which is used for this kind of fire not fire associated with let us say petrol pump inflammable liquid, where the temperature will go up very fast. So, forget that, but these occupancies of the kind of residential officer etcetera, etcetera, standard time temperature curve for fire would be given by this expression.

Where this stands for ambient temperature at 0 time before fire plus t is in minutes, t is in minutes. So, 8 t plus 1, log 8 t plus 1 obviously, I have to have one otherwise log zero is not defined right. So, supposing it is one hour how much will be this temperature, this will be sixty minutes. So, 8 into 60 is 480, 481 this value is 481, one really does not make any difference. So, take log of 481 right, log of 481 will be two point two point something two point.

Student: 2.68.

2.68 multiplied by 345 multiplied by 345.

Student: 925.

925 plus 25 degree or 30 degree centigrade ambient temperature. So, let us say so it is it will come to around 1000, close to 1000, 900 and something. So, you see this is this is this a standard time temperature curve. Now, this is used to define fire resistance, this is used to define fire resistance, this is used to. So, if you if you it is it is you know normally in fact, in you know the we were surveying just to again deviate from this a little bit. We are surveying one of my one of our student was working on I am still working on failures of bridges.

Look at failures of bridges you know he surveyed whatever is available in net and things like that. And one of the causes he found that and never bridges collapse because of fire. Then he found that out of six, seven causes fire was also one of the cause causes for some failure of some of those bridges. So, but in any case the point that I am trying because they are from transportation engineering if somebody is from transportation engineering this issues are relevant they are also, maybe you do not look at the fire resistance exactly in the same manner you do for building because bridges are in open. So, this, but this is fire resistance will define with respect to standard fire.

So, let us see how do we define further right. So, a structure should be able to withstand standard fire that is how we define for a specified time. Hence fire resistance is defined in terms of time. So, unit of fire resistance is seconds, minutes or hours, generally hours. So, people will talk in terms of 1 hour fire resistance wall or 3 hours fire resistance wall or 4 hours fire resistance wall and things like that you know. So, fire resistance is talked in terms of its unit is time up to which it will sustain the standard fire standard fire right.

Now, how will you sustained performance collapse is one issue as I said, but spread of fire is an equally important issue. So, fire resistance in time during which the element can endure the standard fire in terms of stability, integrity and insulation; stability integrity and insulation all three and, it is not or it must be able to sustain; that means, failure is or; that means, failure is it fails by this or that whichever fails early whichever fail fails early. So, if the insulation is broken down earlier then the still the fire resistance will be that much time or integrity is lost by that much you know, so it will be related to that right ok.

Now, how do I judge stability that is very easy because for civil engineers to understand how do I judge stability it is very easy for civil engineers to understand that because failure is in terms of either collapse or excessive deflection. Excessive deflection here you know one of the major serviceability limit excessive deflection. So, if the deflection becomes high that would actually lead to you know imminent collapse later on.

I mean if the material has got lot of deformation capability, then ductility it has got lot of it the system it can deform before failure, then it will give indication, but anyway after beyond a point it is not acceptable, it might go to the plastic zone. So, therefore, stability is defined as normally done for a slab for example, it is related to the span or a beam. It is maximum deflection is related to the span or the you know span yeah span depth etcetera. So, it is related to that. So, therefore, it is it is related to that criteria the deflection or collapse.

Insulation is different dependent defined in terms of temperature rise on the cold side. Now, what you do is the actually you have furnaces where you subject such elements whatever the elements is. If it is a linear element like beam or column linear element put it in the same manner as you expect the load supporting system as well, because behavior will depend upon the you know structural behavior depends upon the fixity at the end and things like that. Now, some wall etcetera wall or floors or ceiling roof whatever it is those kind of horizontal system two-dimensional system to you know to to 2D elements actually linear elements or 2 d elements.

So, 2D elements the subject for example, if it is a wall they will heat up this portion if it is a wall you know supposing this is a wall, oh, the colour is not changing this is a wall. So, subject this specimen to heating on this side, heating on this side, maintaining the temperature I mean this will not be like this actually it would be through heating element maintaining a temperature say total temperature control right. And this is the cold side; this is the cold side. So, you have to have lot of temperature measuring devices that is thermocouples on the cold size and temperature rise you have to monitor.

So, in India we have facility in CBRI. There are maybe one or two more maybe one or two defense laboratories they have, but the best facility of course is available in CBRI there are couple of institutions, which are trying a little bit one I think is the some facility something structural fire testing a little bit of facility in Mysore National Institute National Engineering Institute of Engineering NIE, they have a small facility, they have set up. Some other places also they are trying to set up similar sort of facility, but CBRI has got a full best facility.

And this temperature here on the furnace side is totally controlled you have a control room computer control system. So, you have to see that it maintains the same time temperature you know t equals to t 0, t equals to t equals to t 0 plus 345 log 8 t plus plus 1. So, this you need a controller you know control system. So, temperature cold side you measure; p hot side obviously, will have thermocouples. And gas temperature you will be continuously measuring gas temperature because that is how it is defined it is in terms of gas temperature not the surface temperature. Surface temperature is also measured.

And then you will have strain gauges or any kind of you know modern days there are cameras digital you can measure them through various kind of other kind of advanced techniques of deformation measurement. So, you have to have deformation may not be strained, but at least deformation measurements some sort of deflection and because deflection criteria is important, strain may not be, but deflection deformation criteria. So, deformation measurement devices has to be there.

And then the third thing is integrity. Now, how do you measure integrity? Integrity is measured by very you know innovative way they actually proposed by the experts right the proposed very innovative way. It is like this. If there is a cracks in here you continuously observed on this side on the cold side is there a crap. Now, if you find a crack has developed, then you put a standard cotton pad in front of the crack. Now, if it catches fire within a specified period of time, if this cotton pad catches fire, you know you bring a cotton pad and if it catches fire within specified period of time, you say integrity is lost.

So, three measures, one deformation, collapse anyway you can see, but before that you will be seeing deformation; other thing is measuring the temperature; third thing is measuring the integrity through this cotton pad measurements. And whichever fail first we stop the experiment that is the fire resistance that is the fire resistance right that is the fire resistance ok. So, that is how fire resistance will define more of it. (Refer Time: 29:35) some question I will like to answer that.