Building Services
Lecture 8

Principles of fire Behaviour

Let us look at Principles of Fire Behaviour first. The underlying science of fire protection engineering rests on the following principles. For a fire to happen, you need three components; one is an oxidizing agent, second is a combustible material which is going to burn and an ignition source maybe a fire or an electrical spark are essential for combustion. An oxidizing agent, a combustible material and an ignition source are essential for combustion. The combustible material must be heated to its piloted ignition temperature before it can be ignited or support flame spread. Subsequent burning of a combustible material is governed by the heat feedback from the flames to the pyrolyzing or vaping combustible material. This is how fire happens. This is called a 'fire triangle' which depicts the 3 major components for a fire to happen and how it works. One is oxygen. There is an oxidising agent and then the fuel for the fire to happen and then the energy.

The burning will continue until one of the following happens; the combustible material is totally consumed, then the burning will stop. Or if the oxidizing agent concentration is lowered to below the concentration necessary to support combustion. Sufficient heat is removed or prevented from reaching the combustible material, thus preventing further fuel pyrolysis, the fire will be put off. The flames are chemically inhibited or sufficiently cooled to prevent further reaction. If you do one of the above, the fire will stop or the burning will stop. By way of graphics, let us look at how a fire starts in a room for example and what are the different stages that happen after that until the entire room is filled with the fire and smoke.

First, when a small object, say for example A which is a source of fire, starts burning along with the oxygen present in the room, the flame begins to grow further and further and the smoke begins to rise and fill the entire room. At first, it reaches the space immediately above the source of fire. Reaches upto the ceiling. This initial effect. You will start seeing a very thin layer of smoke which is being spread on the ceiling or where the fire or smoke goes and hits. Once the top layer of the ceiling of the room is filled with smoke, it slowly begins to move to other spaces. It starts to travel to other spaces. Once it goes outside, it takes a big angle, it goes to the other room's ceiling area. This happens because there is a pressure difference between the space where the fire is happening and the other spaces. Say this is within the compartment and that is outside the compartment. Finally, this is called a Flashover where the fire is spread totally to the other room also. There is a thick or dense layer that covers the entire room. Once the entire smoke apartment and the other room is completely filled, that's when we say this

material gets burnt and we call it a fire accident, this is how it happens. Now, let us look at the leading causes of fire.

One is the cooking equipment as we already know. Or the heating equipment, or the incendiary or suspicious causes. It could be the electrical distribution system, appliances or the tools we use at home. It could be because of smoking materials, child play or exposure to other hostile fire or heat source and finally because of natural causes.

Now let us look at the Fire Safety Design Principles. Here it is divided into two parts; objectives - what we aim at and the strategies to achieve the objectives. The objective 1 will be Life safety; 2. Property protection, 3. Continuity of operations, 4. Environmental protection, 5. Heritage conservation. How to achieve these objectives? First, you can prevent the fire ignition or after it has happened, you can control the combustion process. You can also control the fire by means of construction, by means of using non-combustible material for construction. Fourthly, you can detect the fire and provide notifications, so that act fast to save the lives and materials or you can automatically suppress fire with the help of sprinklers. You can manually suppress fire by throwing water or fire hosiery, etc and finally manage the exposed.

When we talk about fire protection or fire safety, there are two ways of approaching it. We call it passive and active fire protection. What is passive? Passive fire protection is an integral component of structural fire protection and fire safety in a building. PFP attempts to contain fires or reduce the spread, through use of fire-resistant walls, floors and doors. Basically, the construction materials we use to build a building. If we can wisely choose the ones that fire resistant, that will take care of 50% of the job, meaning you can prevent or control the fire. Secondly, once it has happened and it starts to burn a lot after the accident has happened, it has to started to burn a lot and the accident has happened. Then you have to opt for active fire production where you require some amount of motion and response in order for it to work. This is where all the different extinguishers, sprinklers, fire hydrants come into picture, this active fire production. In this lecture we will look into passive fire protection measures.

NBC Planning

Let us look at how does NBC help us in this. This is basically the contents page of NBC, where we have highlighted only Part 4 which talks about Fire and Life safety. Inside that, they talk about fire prevention, then they talk about life safety and then fire protection.

NBC classifies buildings according to their category and typology into various groups and they give some guidelines and suggestions on the approach we should follow for every group of building. There is a clause, in part 3 which talks about Urban control rules where they state,

Buildings shall be so planned, designed and constructed as to ensure fire safety and this shall be done as per Part 4. Part 4 is the major chapter which talks about fire safety in NBC. These are the various groupings or classifications of buildings as far as NBC is concerned. Group A talks about residential buildings, Group B is educational, Group C is institutional. Group D has all these assembly buildings, your theatres, your banquet halls and clubs, Group E talks about Business, buildings that come under business typology like offices, banks. Group F talks about all the shopping stores, the departmental stores. Group G is Industrial. Group H is storage or in other words warehouse, cold storage, freight depots, truck & marine terminals. Group J is Hazardous buildings.

We will move on to Non-combustible materials. Non-combustible materials are materials that produce a negligible amount of heat when exposed to a thermal environment, representative of a flash or fire. These materials are referred to as non-combustible. Basically the materials that produce a negligible amount of heat. When they are exposed to a fire environment. The materials we know and use predominantly in today's construction are steel and concrete, they are non-combustible.

How do you rate a product based on its non-combustibility? It is based on three aspects, one is the ignition aspect, the other is the surface Surface flame spirit and the third is the heat, smoke, release rate. All these things determine how a product reacts to a thermal conditions that are representative of a pre flashover fire. These characteristics collectively describe the reaction-to-fire of the product. Building codes restricts interior finishes pertaining to its reaction to fire. That is, wall and ceiling linings and floor coverings. Which are the metals considered ideal? Those that have a flame spread index that is lesser than 25 and those that have a smoke development index that's lesser than 450.

Even in this non combustible material, we can further classify them into three categories. One is called fire resistant materials, one is call retardant material and the third one is called flame retardant and flame resistant material. What is a fire resistant material? Fire resistant material signifies the ability of a structure, material, or assembly to resist the effects of a large-scale severe fire exposure. For example if you take a door or a wall for that matter, if a fire accident happens in a particular room and the wall is built with brick or concrete, how long can the wall withstand the fire before it gets damaged, collapses and lets the fire affect the surrounding neighbouring areas. Fire retardant signifies a lesser degree of protection than fire resistant. It should be used in reference to chemicals, treatments or coatings to reduce the combustibility of building materials and other such treated materials. The third type is Flame retardant and flame resistant; once again here also they do a treatment due to chemical treatment or inherent properties. So, these materials do not ignite readily or propagate flaming under small-

to-moderate fire exposure. As far as interior finishes concerned, what are the aspects we should consider before choosing the right finish in a fire prone area?

Interior finishes affect fire hazards in four ways. One is, they affect the rate of fire buildup to flashover conditions. Secondly they contribute to fire extension by flames spread over its surface. Thirdly, they add to the intensity by contributing additional fuel to the burning fire and fourthly they produce a lot of smoke and toxic gases that can contribute to the life hazard and property damage. How do I choose? Which is the right material? From a life safety standpoint, the most desirable interior finish is made from relatively dense and non-combustible material, good conductor of heat, does not speed up flashover, does not add fuel to the fire, provides no paths for surface flames to enter, produces little or no smoke toxic gases. If you can find such a metal, that is an ideal metal for an interior finish.

Egress System

Now we move on to the Egress systems or exit access and the distance between exits. When we see the definition, Egress refers to the continuous and unobstructed way of travel from any point in a building or structure to a place of comparative safety. What are the various means of Egress or how do you define them? Most of the building codes describe the term 'means of egress' as a continuous path from any point inside the building to a public way, outside at open air at ground level, where you will be really safe. Egress consists of three separate and distinct parts. One is the Exit access itself, referring to the door or the corridor through which you escape from a fire accident. This is the key point in the floor to the entrance of an exit i.e through a door or a corridor, that is called the exit access. Then the exit, the exit is nothing but the portion of a means of egress that provides the protected path to the exterior of the building. Say for instance, you are in the deep interior of a hospital and you have to escape the fire that has happened and you have to escape to the exterior of the building. Naturally you have to walk through a corridor or a staircase if you are on a different floor. These are called the exits and the exit discharge. This can be called a portion of means of variation because of the termination of exit and the public road. In between if there is a huge building, before you reach the exterior itself, you can rest for sometime, people can get collected in a holding area, that's called an exit discharge. Naturally various courtyards act as exit discharges. This is a scheme or a graphic depicting the various exits, exit access and exit discharge. This is the travel distance, how long does it take for people to escape from their rooms. From here if you have to escape, you have to go through the door, run through the corridor, if it's the upper floor, you have to take the protected staircase. Similarly, for other rooms. This diagram shows how people escape from remote corners of a space. All these form the part of exit access and exit discharges.

What are the other things we have to consider when we talk about means of egress? We have to keep in mind these things, an exit may also include a horizontal exit leading to an adjoining building at the same level. Lifts/Escalators are not considered as Exits. You might have seen in buildings, warning signs about not using the lifts during fire, please use the staircase instead. This is because the lift shaft also contributes or adds to the transfer of smoke and fire to other places. All exits shall provide continuous means of egress to the exterior of a building or to an exterior open space leading to a street. Exits shall be so arranged that they may be reached without passing through another occupied unit. Every building meant for human occupancy shall be provided with exits sufficient to permit safe escape of occupants in case of fire or other emergency.

Now, we will look at another aspect of fire safety, talking about the exterior corridor and maximum travel distance. One has to travel before reaching the exit. Here, we have to first define certain aspects like unit width, before we move on to any other aspect further. The unit of exit width shall be minimum 500mm & 250mm as half-width for additional occupants. We will go to the next slide where we can see how this unit width helps with the definition. The exit doorway width shall be minimum 1000mm or 1 m except in assembly buildings where minimum door width shall be 2000mm. Doorways shall be not less than 2000 mm in height. The following is the minimum width of staircases to be provided for occupancy classes. As you can see for residential buildings its 1m, for hotel buildings it is 1.5m, for Assembly buildings like auditorium 2.0m, for theatres and cinemas 2m. For educational buildings upto 30m height is 1.5, for educational buildings higher than 30m height is 2m and all other buildings 1.5m width.

Here, this is a tabular column extracted from the NBC where it talks about the occupants per unit width. The table on the left shows the occupancy and against it they show how many people i.e the number of occupants can be accommodated within one single unit width. Say for example you have a residential building on a particular floor, you have 25 people, you can calculate the door width for one unit width or 500 mm. Of course 500mm doesn't make sense, naturally it is 1m which is more than required. If it is for 50 people, it has to be calculated accordingly. For every 25 occupants i.e 1 unit width. This is how they calculate the door width, the ramp width or the staircase width. The second table 22 talks about the travel distance for occupancies and types of constructions.

What is the maximum travel distance? One has to or should travel from any remote corner of the building to a safe place or a protected enclosure or an exterior space, this is the maximum travel distance is calculated. If your building has fire sprinklers, then you can go in for lesser travel distances or more travel distance on the contrary. If it is not fire sprinkler protected, you have to have lesser travel distances.

Window Egress

Next we will move on to Window Egress and Accessibility for the disabled and also talk about corridors. The exit corridors and passageways shall be of width not less than aggregate required width of exit doorways leading from them in the direction of travel to the exterior. For example if you have multiple doorways, one is 1m, the other is 1.5m and all those things. The exit corridors and passageway width should be accumulative or an aggregate width required of the exit door. In the case of buildings where there is a central corridor, the doors of rooms shall open inwards to permit Smooth flow of traffic in the corridor. Where stairways discharge through corridors and passageways, the height of corridors and passageways shall not be less than 2.4m. That is the minimum width you have to maintain in corridors and passageways. All required exits that serve as egress from hospital or infirmary sections shall not be lesser than 2m in clear width including patient bedroom doors to permit transportation of patients on beds, litters or mattresses. The minimum width of corridors serving patients' bedrooms in buildings shall be 2400mm. The clear width for hospital buildings, for all the patient rooms especially is 2m and the minimum corridor width in hospitals is 4m. Next, we will talk about window egress. Can windows be used as a way of exit when a fire accident has happened. The first point is windows are not exits. They may be used as access to fire escapes in existing buildings if they meet certain criteria concerning the size of the window opening and the height of the sill from the floor. Windows may be considered as a means of escape from certain residential occupancies, eg; schools - one - two family dwelling etc. Windows are required in school rooms subject to student occupancy, unless the building is equipped with a standard automatic sprinkler system and in bedrooms in one- and two-family dwellings that do not have two separate means of escape. Basically, what is being said is, you should have windows for fire safety reasons. These windows that we use for egress, these windows are for rescue and ventilation and must meet the criteria for size of opening, method of operation and height from the floor, meaning the sill height from the finished floor. NBC clause 1.7 states that openable windows on external walls shall be fitted with such locks that can be opened by a fireman's axe. This is the graphic or the picture that shows the fireman's access panel. Basically in high rise buildings if you see, they should provide some openable windows on the facade for the fire brigade or the fire personnel to evacuate people because if the shafts are all fired and people are running down when people are stuck there, this is the only way the fire brigade can help people evacuate.

How do you make considerations for handicapped people? What should we do when a fire accident happens in a building. Handicapped people have a variety of limitations like sensory problems, we can't define or cap or say this is what is handicapped, everyone has their own problems. It can be sensory problems, deafness, blindness, mobility problems, intellectual

problem or mental retardation. Buildings where the use of elevators is not allowed in a fire, adequate areas of refuge must be provided for handicapped, sick and elderly occupants. These people cannot move as fast as the normal people can. We should provide several areas of refuge called holding areas where they can wait until some help arrives. In general, households with handicapped or elderly occupants need a higher level of protection to provide additional escape time. Some handicapped/elderly persons need continuous assistance, provisions should be made for them to provide help.

Additionally, you can have an audio-visual alarm, bed vibrator to be used by hearing impaired persons. Ramps for non-movable personas to facilitate evacuation using wheelchairs. For high rise buildings, assembly occupancies etc, providing wheelchair at the area of refuges where people can move and wait there. You should try to provide a lot of horizontal exits.

Next, moving on to fire doors. What is a fire door? Fire doors are necessary to prevent a fire from spreading from one fire to another. Fire doors should be properly rated and close automatically in the event of a fire. If you refer to NBC for each and every area, depending on the type of construction, depending on the classification of the building a particular fire rating for the doors have been mentioned, we have to use that kind of door. Here, what I mean by fire rating is, its classified in terms of time , one hour fire rated, two hour fire rated. What they mean by this one hour, two hours is; until one hour or two hours, the door will contain the fire which is happening on the other side. For instance, we are staying outside the room where the fire has happened, inside the room the fire has taken place, this door will not deteriorate, collapse or break until the fire rating time i.e one hour or two hour. So people can evacuate the building in that time period, in turn saving people's lives. Usually we provide these fire doors at protected stair cases and horizontal exits. We might have seen this kind of a fire door with a panic bar to push open the door and run. this is a double door and a single door. These are usually metal doors with some insulation inside. These are different ways or layouts to provide fire doors in the minimum width and the angle and such.

Next moving on to Lift lobbies, stairways and Ramp design. The general guidelines for egress systems with respect to lift lobbies, stairways and ramps are as follows; all the fire lobbies should be provided with fire doors of minimum two hour fire resistance. Suitable arrangements should be provided like providing a slope in the floor of lift lobby shall be made to provide water to be used during the fire fighting etc, from entering the lift shaft. For buildings 15m in height or above, non-combustible materials should be used for construction of lift shaft and staircase enclosure. In other words it is advisable to build a concrete lift core. This should be made of brick work or reinforced concrete or any other material having a minimum of 2h fire rating. Here, even a 9 inch brick wall can contain fire for 2 hours, that is also considered a good

non-combustible material. A staircase shall not be arranged round a lift shaft. No gas piping or electrical panels shall be allowed in the stairway. Ducting in stairway may be permitted if it is of 1 hour fire resistance rating. For building 15m in height or more, access to main staircase shall be through a fire/smoke check door of a minimum 2 hour fire resistance rating or as required by local fire department. No living space, store or other fire risk shall open directly into the staircase or lift lobby. External exit door of staircase enclosure at ground level shall open directly to the open spaces or through a large lobby if necessary.