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Estimation of Fire Loads for an Educational Building - A Case Study

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Abstract: ***Fire is one of the major hazards which may occur due to natural or man-made causes. In general, fires may be classified into five categories depending on the fuel that is burning. In recent times, there is an increase in incidences of fires in urban population due to very densely populated areas. The losses associated due to fires can be classified as loss to the life of structure, loss of human life and loss to property. It was observed that many options are available which help in early detection of fire and minimizing the losses. Smoke detectors and fire fighting equipments were studied for a public building i.e. an educational institution. Analysis of fire loads of different compartments and providing sufficient number of fire fighting equipments can help in reducing the severity of fires. The fire loads and fire densities were analyzed at some locations to determine the requirements of fire fighting equipments. The paper includes study of various types of fire detection, alarm and fire fighting systems and systematic analysis of fire loads and densities for an educational building.***

Keywords: fire, Ionization, calorimetry

I. INTRODUCTION

Hazards can be classified as natural or man-made. Fire is one of the hazards which can have either of the two as its origin. Losses due to fires are not only limited to loss of human life, but also include loss in the life and strength of the structure and loss to property. In recent times, there is an increase in the incidence of fires in urban areas due to very dense population. As the population density increases, the number of people affected by even a small fire also increases. Calculation of fire loads and densities gives us an idea of how severe a fire can get, if it occurs and what measures should be adopted to arrest it so as to have minimum damage. Three methods can be used to estimate the combustible energy content of a particular compartment. These are direct measurement of mass (conversion based on the net heat of combustion); direct measurement of volume (with conversion based on density and net heat of combustion); and energy release measurement by calorimetry of an item sufficiently similar to the fuel package. The first two methods are generally followed. The survey conducted in this study considers the use of volume [1].

In most of the natural disasters, it is possible to have a prior warning making evacuation of persons from the affected area possible, thus reducing the extent of damage. Such a warning is not possible in case of fires. Fire is a major hazard because it gives only limited time to address the issue. Installation of smoke detectors and sprinklers can attend to the fire in the early stages. Sometimes, the fire spreads at such a fast rate that controlling it by means of only sprinklers may not be possible necessitating the use of fire-extinguishers. The spread of fire depends mainly on the availability of oxygen and fuel for the fire. Since, both are present in abundance in any building, it is of prime importance to control the fire as soon as possible in order to minimize the resulting losses to life and property. Based on the fuel that is burning, fires can be classified into five different categories as shown in table1.

Fire fighting systems can be either internal or external. External systems are external to the structure or building such as fire hydrants provided by the local authorities to fight fires. Internal systems are those provided within the building or structure to control fires such as smoke detectors, alarms and sprinklers.

Table 1 : Classification of Fires

Class of fire	Symbol	Description	Example
A		Common combustibles	Wood, paper, cloth
B		Flammable liquids and gases	Gasoline, propane, solvents
C		Live electrical equipments	Computer, fax machines
D		Flammable metals	Magnesium, lithium, titanium
K		Cooking media	Cooking oils and fats

A. Smoke detectors

The two most commonly recognized smoke detection technologies are ionization smoke detection and photoelectric smoke detection.

- **Ionization smoke detectors**: They are more responsive to flaming fires. They have a small amount of radioactive material between two electrically charged plates, which ionizes the air and causes current to flow between the plates. When smoke enters the chamber, it disrupts the flow of ions, thus reducing the flow of current and activating the alarm.
- **Photoelectric smoke detection:** It is more responsive to fires that begin with a long period of smoldering. These alarms aim a light source into a sensing chamber at an angle away from the sensor. When smoke enters the chamber, it

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reflects light onto the light sensor; thus triggering the alarm.[5]

B. Sprinkler systems

Sprinkler systems are the oldest and most widely used type of automatic fire extinguishing systems. When a fire starts, these systems immediately and automatically generate a fire alarm and extinguish the fire. Depending on the presence of water, these are classified into five types.

- **Wet sprinkler system:** In this case, the pipes are kept filled with pressurized water which sprays out water as soon as the sprinkler heads open. This is of great advantage as the fire is attacked in the initial stage itself leading to lesser losses.
- **Dry sprinkler system:** In very cold regions, water in the pipes may freeze leading to a situation of no water when a fire actually breaks out. Hence, dry sprinkler system is adopted. Here, water flow detection unit is filled with pressurized water up to the primary side and the secondary side piping is filled with pressurized air (or nitrogen). When the air pressure in the secondary side drops due to sprinkler head opening up, the dry system water flow detection unit opens to release the water.
- **Pre-operation Sprinkler System:** The primary side of the water flow detector unit is filled with pressurized water and the secondary side piping is filled with compressed air. When a fire occurs, the fire detector uses the fire signal it has caught to first open the pre-operation water flow detector unit to cause the primary side pressurized water to flow to the secondary side. This pressurized water operates the pressure switch, which generates a fire alarm, and the decrease in pressure in the primary side piping causes the pump to operate and begin spraying water when a sprinkler head is opened by a heat sensor. Water will not be sprayed unless both the fire detector and a sprinkler head operate. This prevents water from accidentally being sprayed and cause damage when there is no fire.
- **Open Sprinkler System:** Open sprinkler heads have no heat sensor disassembly unit hence water is sprayed from each and every sprinkler heads of the set when manually operated. This type of system is used when the ceilings are high; because in this case there is a possibility that the flow of hot air might open even those sprinkler heads which are not directly over the fire source leading to damage to other property.
- **Foam water Sprinkler System:** It is a special system connected to a source of foam concentrate and to a water supply. The piping system is connected to the water supply through a control valve that is actuated by operation of detection equipment. When this valve opens, water flows into the piping system, foam concentrate is injected into the water, and the resulting foam solution is discharged.

C. Alarm systems

These can be either manual or automatic. Manual alarms are those activated after a person detects a fire. Automatic alarms are those linked to smoke detectors which operate if the smoke level increases beyond a certain level. Sometimes, fixed heat alarm systems are used which react to heat (generally over 58^0C) instead of smoke so are less likely to give false alarms. Addressable alarm systems are used for large structures where it helps in knowing the exact location of fire when the alarm sounds, as precious time would be lost in locating the fire otherwise.

Detailed guidelines for selection, installation, system design and maintenance for fire detection and alarm systems for buildings, selection of fire detectors etc. are given in relevant national/international Standards like IS: 2189 : 1999; BS : 5839 : Part-1 : 1988 and NFPA-72 : 2002.[4]

II. Methodology

Fire load density is the heat energy released per square meter of floor area, by the complete combustion of all the material present in a compartment. Fire load is an important parameter in determining the growth and severity of fires. Other important parameters are ventilation, arrangement of combustibles and room geometry [7]. For this survey, the inventory method was used for the calculation of fire loads. The volume of different types of material are calculated (in m^3) and multiplied by its density to get its mass (in kg). This value is then multiplied by its calorific value (in MJ/kg) to get the fire load. This value divided by the floor area gives the fire load density of a compartment as shown in the equation (1).

$$q_c = \frac{\Sigma m_v H_v}{A_f} \qquad (1)$$

where q_c = fire load density (in MJ/m^2); A_f = floor area (in m^2) ; m_v = total mass of v^{th} combustible material (in kg) and H_v = calorific value of the v^{th} combustible material (in MJ/kg). [2]The calorific values of some common combustible materials are shown in table 2.

TABLE 2
CALORIFIC VALUES OF COMMON COMBUSTIBLE MATERIALS

Materials	Clothes (avg.)	Leather	Paper	Plastic	Wood
Calorific value in MJ/kg	18.8	18.6	16.3	22.1	18.6

Fire loads were calculated for some rooms within the public building taken as a case study. The building chosen was Sardar Patel College of Engineering, Andheri which is located in an urban area. In order to calculate the fire loads, rooms in the building were categorized on the basis of their usage. Library entrance, student section, internet section, classroom and administrative office were considered. The materials present were considered under the following heads: wood, steel, glass, plastics, cotton and paper. A major portion of fire load consists of wood [6] .The volume of paper stored in cupboards and shelves were approximated by eye observation depending on the percentage fill. No derating factor was considered for enclosed combustibles such as papers in filing cabinets due to the possibility of the drawers being open in case of a fire.

III. Results and Discussions

An area of approximately 1700 m^2 was surveyed. A summary of the fire load densities obtained is shown in table 3.

TABLE 3
SUMMARY OF FIRE LOAD CALCULATIONS

Sr. No.	Area under consideration	Fire Load in MJ	Floor Area in m^2	Load Density in MJ/m^2
1	Internet section	21188.58	36	588.57
2	Ladies common room	25551.7	62.32	410.01
3	Mechanics laboratory	24923.11	65.36	381.32
4	Classroom	33852.305	69.16	489.48
5	Transportation laboratory	41710.29	69.16	603.10
6	Survey laboratory	56607.87	69.16	818.51
7	Geology laboratory	57792.424	69.16	835.63
8	Elect. Engineering dept.	68270.54	91.2	748.58
9	Physics laboratory	71147.58	91.2	780.13
10	Library entrance	35938.03	94.5	380.30
11	Seminar room 121	85323.54	106.72	799.51
12	Hydraulics laboratory	84645.72	162	522.50
13	Drawing hall	153785.9	198	776.70
14	Administrative office	161735.2	216	748.77
15	Library student section	181079.6	288	628.75

The values of fire loads were found to be varying depending on the usage of the compartment and the nature and amount of the material stored. The average value of the fire load density was found to be 634.12 MJ/m^2 as shown in the graph depicting variation of fire load densities for various rooms. The maximum value was 835.63 MJ/m^2 for the geology laboratory and the minimum value of 380.30 MJ/m^2 was for the library entrance section. This is expected as the geology laboratory has a large number of wooden models stored which adds to the fire load. Also, the laboratory is crowded as it has just been relocated and a large amount of unwanted material is still stored. The library entrance section does not have much storage and has more glass than wood. Glass contributes very little to the fire load and hence a smaller value is obtained for the entrance section.

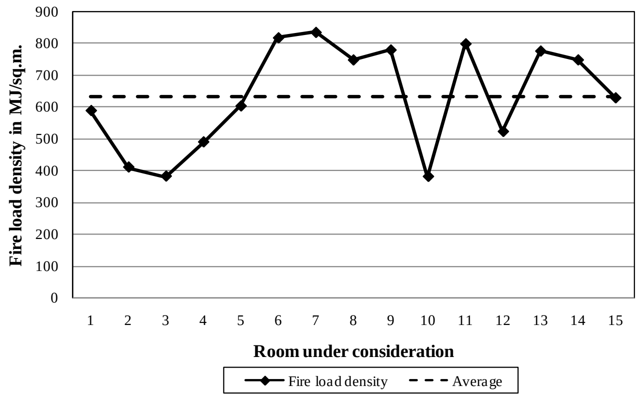

Fig. 1 Variation of fire load density for various rooms.

The results obtained were compared with those obtained by Sunil Kumar and C.S.Kameshwar Rao [2]. The maximum load was obtained as 1860 MJ/m^2 which is very high as compared to 835.63 MJ/m^2 that is obtained presently. A possible reason could be that now large amounts of data are stored in soft format thus reducing the amount of stored materials. The average fire load density is presently found to be 634.12 MJ/m^2 which is higher than the value obtained then (348 MJ/m^2).

The fire load density obtained was also compared by those obtained by George Hadjisophocleus and Zhengrong Chen [3]. The mean fire load for a classroom was 426.3 MJ/m^2 which is well comparable with the value of 489.5 MJ/m^2 obtained for a classroom in present study.

For an institutional and educational buildings (type B and C), the fire load density given in the NBC part 4 is 25 kg wood equivalent in kilograms per square meter [8]. This converts to 450MJ/ m^2 which is lesser than the value 634.12MJ/m^2 obtained.

IV. Conclusions

Analysis of fire load density in an educational institution is done and the study gives following concluding remarks:

- The fire load densities obtained for Sardar Patel College of Engineering ranges from 835.63 MJ/m^2 to 380.3 MJ/m^2. The average value obtained was 634.12 MJ/m^2. For other educational buildings, it may differ based on their variation in functional activities.
- As per earlier reported studies [2], the maximum load obtained was around 1860 MJ/m^2 which is very high as compared to 835.63 MJ/m^2 obtained in the present analysis.
- In present scenario, a large amount of data is stored in soft format. This leads to reduction in combustible material like papers. This may be one of the reasons for reduction in fire load density.

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