Comparison of Fire Risk Evaluation in a Ground Floor of a Modern House with Conventional House

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Abstract - Composition of a typical household drawing room has changed drastically in recent past with the advent of several petroleum products based newer materials in the furniture and punishment industry. In this background it is proposed to examine the nature of fire risks and its escalation in modern drawing rooms with specific attention to the contribution of increased composition and nature of flammable substances. A qualitative study will be conducted to understand the impact of material properties on the fire behavior. Existing national building code will be studied and the prescribed fire protection techniques for materials will be understood. Quantify the contribution of newer materials to fire risk increase (in terms of increase in fire load and/or smoke production rate) compared to older punishment materials. Understand the fire protection techniques like fire retardant coatings etc., being employed in the furnishing industry. There is an increase of 15% more concrete work in Modern Building compared to Conventional Building as it uses clay tiles. It is observed that fire load due to Plastic and Wood is relatively more compared to other items. The emergency exit plan has been inserted or executed. Developed a technique to assess the fire risk and suggested possible options to bring down the enhanced fire risks due to newer materials used in residential enclosures. Emergency Fire escape routes are also suggested for both type of house.

Keywords: Fire Load, Fire Safety, Calorific value, fire growth, heat release, combustion.

1. INTRODUCTION

India is a land of many diversities and the second largest populated country in the whole world. The demand for safe house construction is on rise. Use of Energy efficient materials instead of natural resources is encouraged. Type of building considered (as per bureau of Indian standards: residential building): "Group A". Fire resistant houses need to be designed for safety of people. Project calculates fire load of a building based on fire load density and wood equivalent. Comparison of fire load between old and new building is done highlighting the area of improvement (exit plan, critical locations) .The fire risk in modern buildings is relatively more compared to an old buildings of same size. The main reason is usage of high flammable materials in furniture's, gasoline and electronic gadgets.

The fire load of material is dependent on a number of material properties such as:

- Density (ρ)
- Specific heat at constant pressure (C_p);
- Ambient Temperature (T_∞);
- Thermal Conductivity (k);
- Ignition Temperature (T_{ig})

1.1 Development of fire:

- **Incipient stage:** Invisible products of combustion are given off, no visible smoke, flame or heat is still not present.

- **Smoldering stage:** The burning process is referred to as smoldering if it is sluggish and flameless. Smoke, the byproduct of combustion, is now apparent. There is still no flame or heat.

- **Flame stage:** Today, there is fire. There isn't much heat, but it falls off fairly immediately.

- **Uncontrolled stage: (Heat stage)**
  Large volumes of heat and smoke are now created. Uncontrolled heat is present, and the fire is moving across space very quickly.

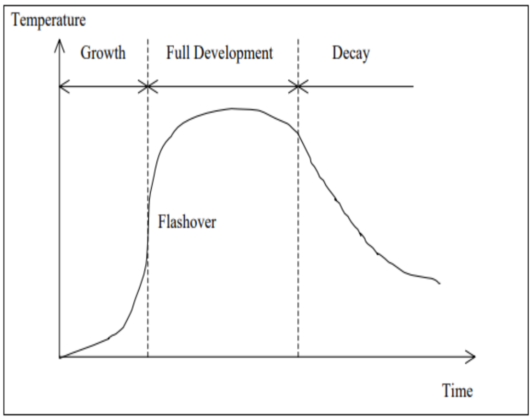

Fig 1: Growth of Fire

During the development stage, when the combustible surfaces are exposed to more heat, the intensity of the fire increases. At this point the type of fuel surfaces burning often controls the rate of combustion. After the electric flash, the fire enters the full growth phase, commonly referred to as "full-chamber engagement," when the temperature of the upper layer reaches approximately 600 °C (Fig.1). At this point, all flammable materials in the room start burning strongly and the temperature rises rapidly. Although the available ventilation controls the rate of combustion at this point, the surface area of the fuel can sometimes have an effect.

1.2 Initiation of Fire Process

Heat, fuel, and oxygen are the three things a fire requires. These three factors combine to help a fire begin and spread (Fig 2). A fire will, however, go out and cease to be a hazard if one of the three components is taken away.

1. Enough heat to raise the material to its ignition temperature
2. Enough oxygen to sustain combustion
3. The chemical, exothermic reaction that is fir
4. Some sort of fuel or combustible material.

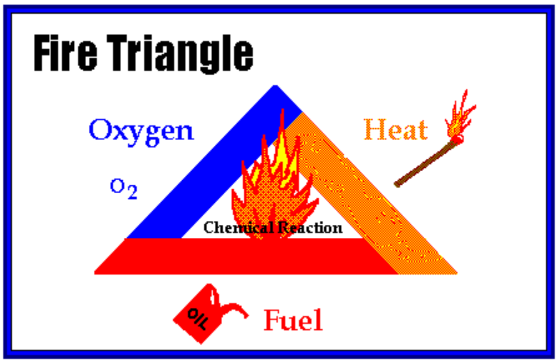

Fig 2: Fire Traingle

1. METHODOLOGY

To analyse the fire in a building we need to identify, characterise and quantity design fire. The burning characters (Heat release, ignition and flame temperature of combustible material in the building need to be quantified for a building). Factors like orientation of building, nearby occupancy and wind flow at the building site also influences the fire load. However these factors are not considered for the present project.

The entire heat energy (MJ) that may be released by a building's full combustion is known as the total fire load. Currently, two buildings with two bedrooms, a living space, a kitchen, and a bathroom are thought to be on a site with almost the same size.

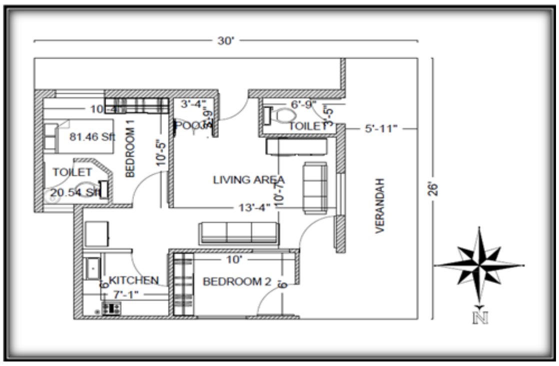

Fig 3: Plan of Modern House

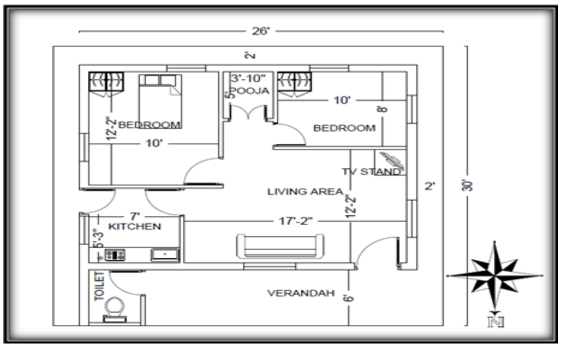

Fig 4: Plan of Conventional House

The objective is to compare fire load for modern House with Conventional House identify critical fire points and suggest energy exit plan. Based on the literature review for fire load calculation we have adopted inventory method.

2.1 Assumptions Made to Estimate the Fire Load

These assumptions are:

1. Consistent distribution of combustibles throughout the structure.
2. Spread of fire in all combustible materials.
3. During a fire, every combustible material in a fire cell is completely burnt.
4. Fire load can be calculated based on the calorific contents of different materials with mass of combustible materials

Fire Load (q_c) is calculated based on Eq (1) below which is based on combination of inventory and weighing method.

$$q_c = M_v \times H_v \text{.......Eq (1)}$$

Where,

q_c = Fire load (MJ/m^2)

M_v=Total mass of the combustible materials (kg) = ρ × Volume

H_v = Calorific value of the combustible materials. (MJ/kg)

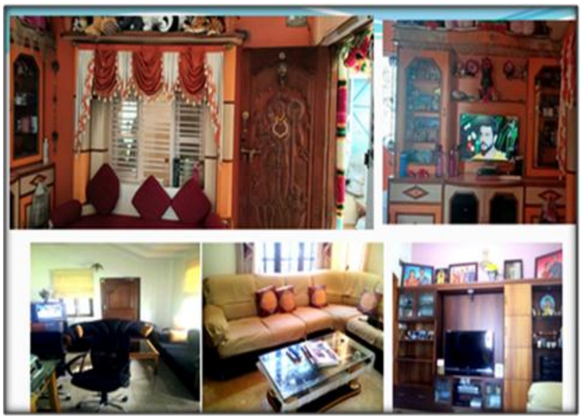

Fig 5: Interior Material for Modern House

Fig 6: Interior Material for Conventional House

Table 1: Comparison of materials used in Old House verses Modern House

Sl. no	Items	Materials used in old furniture's	Materials used in Modern furniture's
1	Sofa	Teak wood or mahogany wood, cotton and cotton fibers	Cedar wood or engineering wood, teak, polyurethane foam, plywood
2	Door	Teak	Teak or engineering wood
3	Window	Single glazed windows	Double glazed windows
4	Cupboards	Mahogany wood	Cedar wood or softwood
5	Teepoy Table	Teak	Engineering wood
6	Central Table	Mahogany wood	Iron
7	Ceiling Height	Avg.ceiling height= 2.4m	Avg.ceiling height= 4.9m
8	Open Space	Very less	More spaces
9	Interior Doors	Solid core	Hallow core
10	Concrete	Cement, sand, Aggregate	Cement, sand, Aggregate, Admixtures

Table 2: Standard Calorific value and Density of different materials

Sl. no	Materials	Calorific Value (MJ/Kg)	Density (Kg/m^3)
1	Teak	20	650
2	Plywood	18.9	941.16
3	Mahogany	19	540
4	Cotton foam	15.49	25.15
5	Plastic	35	1201
6	TV	25	----
7	Book	19	----
8	Paper	20	----
9	Gas Cylinder	46	540
10	Concrete	7.5	25.15
11	Cotton	16.01	1201
12	Leather	20	1000
13	Gunny Bags	20.8	924
14	Clay tiles	2.5	1200

2.2 Enclosure Fire Dynamics

1. To carry out fire modeling understanding the dynamics of fire propagation is essential.
2. Fire Dynamics establishes the relationship between forces and the resulting motion in situations associated with the fire incidents.
3. Enclosure Fire Dynamics is concerned with fire phenomena within the enclosures

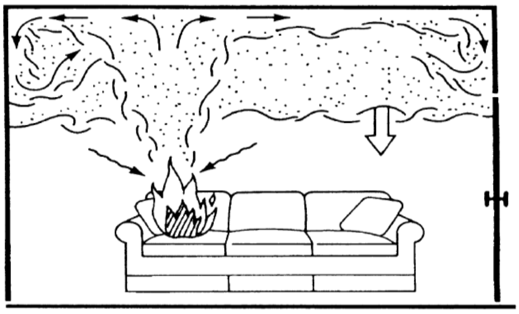

Fig 7: Development and descent of a Hot smoke layer

2.3 Smoke Generation

A curved roof structure shows less smoke deposition, indicating the effect of high mass flow (the area around the base of the flame is smoke-free). Roof construction materials take advantage of the higher temperature of gas exiting at the roof exhaust due to increased drift in case of height increase.

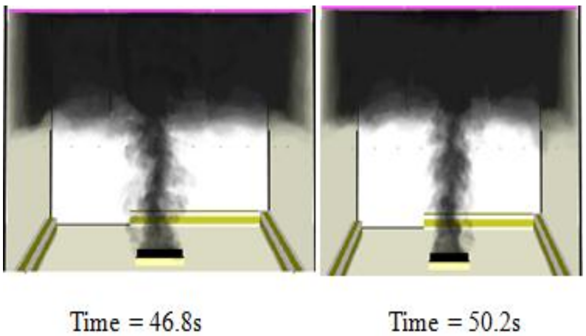

Fig 8: Smoke Generation with different time

3. RESULTS AND DISCUSSION

The data obtained through the methods of calculation was descriptively analyzed. Following the data analyze criteria, the fire risk status of the case study buildings was collectively computed using the matrix for evaluating fire risk level shown in Table 4. Below, the results are presented.

Table 3: List of material with fire load calculation of Modern House

Sl. no	Materials	Calorific Value (MJ/kg)	Density(kg/m³)	Total Volume (m³)	Fire Load (MJ)
1	Ply wood	18.9	650	7.877	140131
2	Teak wood	20	941.16	8.65	112934
3	Leather	20	1000	4.2	8400
					0
4	Cotton foam	15.49	25.15	1.2	467
5	Plastic	35	940	36	1184400
6	Book	19	----	10	190
7	TV	25	----	26	625
8	Paper	20	1201	0.00832	20
9	Gas cylinder	46	1.898	14.94	1304
10	Electric Item	19.6	----	45	882
11	Cotton	16.01	80	35	44828
12	Concrete	7.5	2500	24.84	465750
Total Fire Load of Modern Building				**2,035,532.962 MJ**	

The fire load calculation in modern house clearly shows that Wood, Concrete and Plastic constitutes highest amongst all the material and constitutes around 93% of the total Fire Load.

Table 4: List of material with fire load calculation of Conventional House

Sl. no	Materials	Calorific Value (MJ/kg)	Density(kg/m³)	Total Volume (m³)	Fire Load (MJ)
1	Plywood	18.9	941.16	2.14	38066.15
2	Teak wood	20	650	3.86	50180
3	Gunny bags	20.8	924	4	76876.8
4	Cotton foam	15.49	25.15	0.5	194.78
5	Plastic	35	940	18	592200
6	Book	19	---	10	190
7	TV	25	---	0.20072	5.018
8	Paper	20	1201	0.000832	19.984
9	Gas cylinde	46	1.898	14.94	1304.38

	r(2 no)				
10	Electric Item	19.6	-----	15	294
11	Cotton	16.01	80	10	12808
12	Concrete	7.5	2500	8.6121	1,61,476.8
13	Clay tiles	2.5	1200	78.04	234,120
Total Fire Load of Conventional Building				**1,167,735.82 MJ**	

The fire load calculation in Conventional house clearly shows that Wood, concrete and Plastic constitutes highest amongst all the material and constitutes around 72% of the total Fire Load

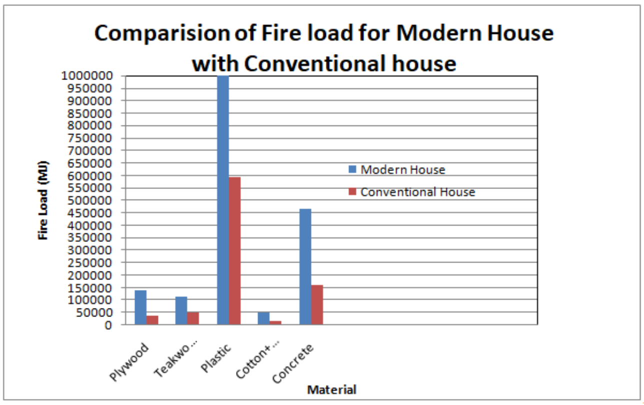

Fig 9: Comparison of Fire Load

(Fig 9) Showing that fire load due to Plastic, Concrete and Wood is relatively more in modern house compared to Conventional house.

3.1 Emergency Fire Exit Plans

Fire plans help to reduce the time needed to escape (TNE) from a fire situation. A reduction of the TNE can increase the safety margin for the occupants and people exposed to a fire.

Suggestions to Improve Fire Safety of Buildings

1. Fire resistant materials
2. Compartmentation
3. Draft control
4. Doors and openings
5. Separation between buildings

3.1.2 Design layout showing Fire-Exit Point

The **red lines** show the path of emergency exit for the modern house in case of emergency. The maximum time needed to escape (TNE) from a fire situation is calculated as 18 sec based on average velocity of escape as 2Km/hr and escaping a maximum distance of 17m

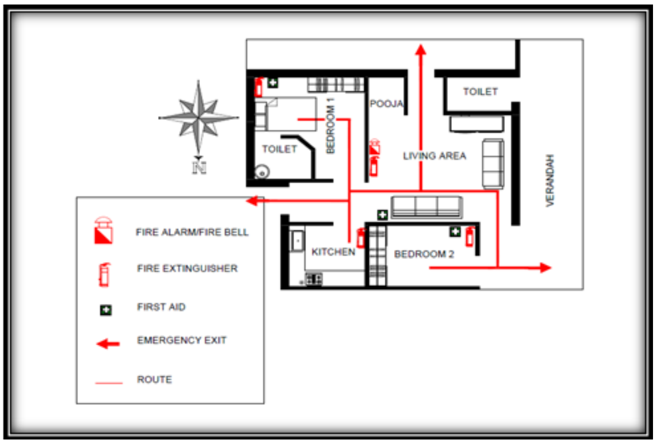

Fig 10: Emergency Exit Plan for Modern House

The **red lines** show the path of emergency exit for the modern house in case of emergency. The maximum time needed to escape (TNE) from a fire situation is calculated as 15 sec based on average velocity of escape as 2Km/hr and escaping a maximum distance of 14m

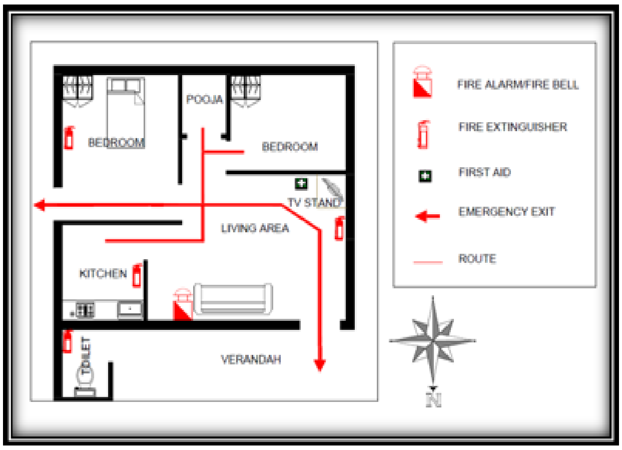

Fig 11: Emergency Exit Plan for Conventional House

Based on the above studies following Fire resistance measures (BS 4422 part 2) for the building are suggested for both conventional and modern house.

- Electrical conductors are needed to be protected thermally.
- Use of flame proof switches and fire alarms at critical locations
- Use of fire resistance glass which is wired- glasses. Wired- glass doesn't breakup and is shatter-proof.
- Use of less concrete and replacing it with fire resistant alternatives like hollow block, tiles (Earth) etc.
- All types of wood products should contain fire resistant paints.

- It is recommended to use fire resistance material with insulation material like Refrasil cloth (silica fiber), glass fiber, Aramid, Kevlar, Proban.

4. CONCLUSTION

1. The main aim of our project is comparison between old residential and new residential drawing rooms.

2. The fire load of a modern residential building is **2,035,532.96 MJ** and for the conventional building is **1,167,735.82MJ.**Comparing the conventional building, Modern residential building having higher fire load than old.

3. There is an increase of **15%** more concrete work in Modern Building compared to Conventional Building as it uses clay tiles.

4. It is observed that fire load due to Plastic, Concrete and Wood is relatively more compared to other items.

5. The critical fire points are 3 in No's in Modern House (Fig 16) and 2 in No's in Conventional House (Fig 18).

6. **Red lines** show the path of emergency exit for the CONVENTIONAL and MODERN house in case of emergency. The maximum time needed to escape (TNE) from a fire situation is calculated as 15sec from conventional house as compared to 18sec in Modern house

7. Fire resistance measures to be adopted are suggested for both conventional and modern building

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