Abstract

Background/Objectives: Fire accidents in buildings is a current thrusting problem in recent past years. Among different type of buildings the assembly buildings and commercial buildings are getting more important in this aspect. Different variables are responsible for fire in buildings but in this article the building construction materials involvement are viewed seriously and few recommendations are given to overcome this problem in buildings. Methods/Statistical Analysis: The statistical data of fire accidents in Tamil Nadu from the years 2000-2013 are analyzed. In this analyze we found that the number of fire accidents, property losses, lives losses are increasing year by year and the total average of values are giving high threatening figures. Two buildings which were subjected under heavy fire and lives losses are considered to case study to find out the fire responsible factors. In these two fired buildings case studies, it is found that, the using of combustible materials in temporary construction is the prime responsible variable for high intensified fire and major lives losses. Applications/Improvements: Application of non combustible materials in construction is recommended due to its high thermal resistance, fire spread resistance and offering of high safety time. These materials application will give solution for fire in buildings.

Keywords:

1. Introduction

Fire is the combustion process of burning. It is a chemical reaction, initiated by the sources of heat energy to join with the combustible fuel substance at a particular temperature and both are combines with the oxygen, which is in the presence of air, starts the process called burning. It is an exothermic chemical reaction process. This process will emit the energy in the form of Heat, Light and Sound. Absence of any one of these element will result in extinguishment of process.

2. Fire in Buildings

The building fire is also needs the basic above said three elements.

2.1 Oxygen

The presence of oxygen is available always in buildings.

2.2 Source of Heat Energy

The sources of applied heat energy availability in buildings are of two types. First one is human error type source of heat energy. They are listed as Children playing with fire substances, Rubbish burning, Smoking and Intentional fire. The Second one is appliances error type source of heat energy. They are listed as Electrical appliances, gas appliances, oil appliances, solid fuel appliance and other sources. As per the survey the human error type source of heat energy fire in buildings is getting prime position in the fire accident list.
2.3 Fuel Combustible Substance
The combustible fuel substances are available in buildings are in the form of furniture, other utensils items and other loads. The quantity and materials type may be vary from building to building based on its occupancy features, but the usage of combustible materials is unavoidable in practice because all activities are material based one now a days.

2.4 Building Fire
When these three basic elements of oxygen, applied heat energy source and the combustible materials in the buildings are meeting at a point in any one of the circumstance the fire will starts.

3. Materials and Methods
The following Table 1 gives the statistical data of number of major, minor fire accidents, property losses and human lives losses in Tamil Nadu from the years 2000 to 2013. The data are collected from (Source) Tamil Nadu Fire cum Rescue Services department.

Table 1. Showing the tabulated statistical data. The minimum, maximum values are marked red in color on the table itself. The total values, average values and lives losses graph are prepared separately

| Year | Number of fire Accidents | Property loss in cores | Human loss |
|------|--------------------------|------------------------|------------|
| 2000 | 16987                    | 13.64(Minimum Value)   | 47 (Minimum Value) |
| 2001 | 17697                    | 15.79                  | 112        |
| 2002 | 18264                    | 14.10                  | 79         |
| 2003 | 16109                    | 24.57                  | 89         |
| 2004 | 16136                    | 13.07                  | 249 (Maximum Value) |
| 2005 | 15093(Minimum Value)     | 14.20                  | 99         |
| 2006 | 17442                    | 27.74                  | 65         |
| 2007 | 21224                    | 28.87                  | 72         |
| 2008 | 17433                    | 53.17                  | 69         |
| 2009 | 21840                    | 53.17                  | 127        |
| 2010 | 18311                    | 24.60                  | 75         |
| 2011 | 22273                    | 27.59                  | 84         |
| 2012 | 32273 (Maximum Value)    | 27.02                  | 87         |
| 2013 | 25109                    | 42.55 (Maximum Value)  | 75         |

3.1 Analysis Results with Discussion
• From the Table 1: The number of fire accidents column the minimum value is 15,093 in the year of 2005. The maximum value is 32,273 in the year 20012. After the year 2010 the values are drastically increased.
• The property losses column the minimum value is 13.64 in the year of 2000. The maximum value is 42.55 in the year of 2013. From the year 2006 onwards the values are increasing from the minimum value.
• The lives losses column showing the minimum value is 47 in the year of 2000. The maximum value is 249 in the year of 2004.

Figure 1. The hierarchy figure showing the total values of the Table 1.

Figure 2. The hierarchy figure showing the average values of the Table 1.

Figure 3. The graph showing the number of lives losses in Tamil Nadu.
• All the analysis values are giving threatening figure.
• From the Graph: The lives losses graph is also indicating the same results. The reason is two major fire accidents occurred in this year which created large number of lives losses.
• These two fire accidents are considered for case study and fire factors are studied.

3.2 Case Studies

Case Study 1, Date: 16 July 2004, Lives losses = 94.
Building type: primary School

The first and the second floors provided with class rooms for the primary students. The class rooms are separated by thatched material. The second floor pitched roof is also covered with thatched material and is continued to cover the kitchen top in the same level height. Ground floor provided with administrative area, stair case and mid day meals kitchen.

3.3.1 Ignition Source and Location

Spark from midday meal kitchen open stove is the ignition source. This kitchen is located in ground floor. Fire traveled from ground floor to second floor roof directly.

3.3.2 Construction Materials

The kitchen area walls and roof is constructed by the thatched combustible materials. The roof is joining with the second floor pitched roof monolithically. Bamboo poles with Coconut coir supported the construction.

3.3.3 Fire Speeded through the Construction Materials

The spark from open stove fell on the thatched material construction and the fire started. The bamboo pole support Coconut coir leads the fire from ground floor kitchen to second floor pitched roof directly. It was a rapid high intensified fire, along with these combustible materials wooden chair table, books and clothes in the class room are made the fire as highly intensified and rapid one.

3.3.4 Reasons for Heavy Lives Losses

The fired partitions and the roof fell upon the primary school students those who were in the second floor class rooms. The heavy smoke, heat, suffocation and consequent scramble blocked the exit routes, arrested their movement and the small children could not make their way out to corridor and the stair case. Within a few minutes the fire and its scrambles engulfing the second floor children.

Case Study 2, Date: 24th January 2004. Lives losses = 57, [Third degree burn injured people 50

3.4 Building Type: Marriage Hall

The building is provided with administrative section and services facilities on the ground floor, Marriage celebration

Figure 4. The building plan explains the different class room positions accommodations, door and stair case location. It explains where the fire started, speeded, the way it was blocked the routes and arrest the movement of the children and caused the lives losses.

Figure 5. Explains the placement of marriage stage, seating arrangement of guests, way out and the location of stair case, fire speeded plastic materials placement and reasons for heavy lives losses are explained in the terrace plan.
place, bride, bride groom room and other facilities are in the first floor Kitchen with dining facilities in the second floors. All floors are vertically connected with single stair case.

At the time of fire accident a temporary thatched materials construction is provided on the terrace. This arrangement is directly above the second floor.

3.5 Ignition source and Location
Short circuit initiated a spark through a video flash gun, which was the ignition source, it happens at the time of wedding celebration. The location is at the terrace floor.

3.6 Construction Materials
Bamboo poles with Coconut coir supported this construction the low height roof and wall of thatched construction is joined with the one meter parapet wall of the terrace. Different types of decorative papers were hanged from the roof.

3.7 Fire Speeded through the Construction Materials
Spark starts from the video flash gun (camera) fell on the lower hanging decorative papers and the fire was started. Fire traveled from hanging paper to roof vertically and horizontally also spread, bamboo poles with Coconut coir helps to spread the fire in all direction. Along with these combustible materials Plastic chairs, clothes, guest’s belongings are made the fire as highly intensified and rapid one.

3.8 Reasons for Heavy Lives Losses
The fired wall and the roof of the thatched materials fell upon the guests. The heavy smoke, heat, plastic toxic gases, other scrambles covered and prevented the exit routes and the stair way. The people could not make their way out.

3.9 Study Inference from the Case Studies and the Data Analysis
From the above said two case studies, the following factors of construction materials, the method of fire spread through the construction materials, falling of fired materials and the reason for heavy lives losses are common in both the case studies. Though many fire safety measures are failed in both the buildings the using of combustible materials in construction and its reaction in fire became the utmost prime factor for heavy lives losses.

4. Seeking Solutions
Building industry using combustible type, fire treated combustible type and non combustible type materials in buildings.

4.1 The combustible materials are having the following three properties when it is subjected under fire:

- The first one is emitting high level heat, thick heavy smoke, fumes and other toxic substances.
- The second one is falling of fired construction materials
- The third one is, the type of fire is the rapid and engulfing type. These three properties are against the lives and property safety, that we have seen in the two fired building case studies.

Therefore the combustible materials are not suitable in fire Environment, totally it is neglected.

4.2 Fire Treated Combustible Materials
Fire proof coated materials and chemically treated materials are having the same properties of combustible materials except the fire ignition time will be high. Therefore fire treated combustible materials are also not suitable in fire environment.

4.3 The non combustible materials are having the following three properties when it is subjected under fire:

- These materials will not produce heat, smoke, fumes other toxic substances up to the temperature of 650°C. Fire or flame will not occur up to this temperature.
- Falling of fired materials are not happens because the structural failure will happens above 550°C.
- The non combustible materials can resist and withstand the temperature above 650°C, high level heat transmission, flame growths are not possible. We cannot distinguish the fire type as rapid, slow, spontaneous and explosive.

Therefore the non combustible materials are suitable in fire environment. Application of these materials in construction will give solution. The suitability justifications are as
5. Behavior of Non Combustible Materials and Structures in Building Fires

5.1 Ignition and Temperature Growth Stage
This stage consists of ignition with initial stage of combustion and a fast reaction of fully developed fire. Very little amount of combustible materials kept inside of the building are consumed in this stage. The temperature of surroundings rises at very high rate. Heat, smoke, fumes and toxic substances are produced in side of the room due to materials burning. At this stage the construction materials are not affected by inside fire and its products.

5.2 Fully Developed Fire Stage
All combustible materials in the building are burning, this stage of fire is knows as fully developed fire. This happens around 500˚C. During this stage full growth of flame, lot of heat at very high level and other scrambles are engulfing the inside area of the building. At this stage also the structure and the materials are affected by inside fire and its products.

Hence here the non combustible materials construction proves its high level thermal resistance above 550˚0C.

6. Non Combustible Materials in Construction having the Following Fire Safety Advantages

6.1 As a Building Compartmentation
The non combustible materials constructions are resist the fire and its products. It is preventing the rapid spread of fire, smoke, heat, fumes and other toxic substance from the origination point to the other part of the building. These materials are having the power to reduce the volume or size of the fire and its products, try to extinguish the fire at the incipient point itself. This is the major advantage in fire environment.

6.2 Standard Fire Tests Answers
The materials are undergoing the following six fire test in all countries answering and satisfying the required criteria. These tests are of two broad categories; the first one is to provide the information on the fire properties of the materials. The second one is to provide the results of thermal behavior of the material, after becoming structural elements or component part of building structures.

6.3 As a Material it is undergoing and Answering
1. Non–Combustibility test for materials. 2. Ignitability test for materials. 3. Surface spread of flame test for materials. 4. Fire resistance test for elements of construction. 5. Fire propagation test for materials. and 6. External fire exposed roof test.

6.4 As a Structural Element it is undergoing and answering
The structural elements are tested under the exact conditions of their utilization in buildings or their position in building, specified conditions of loading, Specified conditions of temperature rise and controlled weather or humidity conditions. The stability, integrity and insulation effect criteria are tested.
Hence here the non combustible materials construction proves its resistance against fire and its products spread in buildings.

7. Recommendation of Construction Thickness

The non combustible material construction thickness is increasing the safety time of the building. This safety time is started from one hour to four hours. As per the code provisions and the expert’s opinion few recommendations are given below. These recommendations are applicable for Assembly, Commercial, high rise, tall, sky scrapers, specials types and other important building. The recommendation of four hours fire safety timing for structural, non structural building elements and door, window assemblies are as follows:

- R.C.C. Column: size 0.54 X 0.54m with 0.04m cover in all four sides.
- R.C.C. Beam: Size 0.42 X 0.42m with 0.07m cover in all sides.
- Brick wall: 0.22m thick with 0.125m thick cement plastering on both sides.
- R.C.C. Roof slab: 0.280m thick with 0.055m cover on both sides
- Outer, Inner Brick wall: 0.22m thick with 0.125m thick cement plastering on both sides.

7.1 Door Assemblies

Glass panels with marble frame, flush door with granite and marble frame, laminated panel door with aluminum frame, flush door with marble frame, glass ventilator with aluminum framing, various boards, steel, timber panels, vermicide boards, are recommended in door components of various floor placement.

Gas seals strips, smoke seals strips, positive latching mechanisms, automatic closing devices, ball bearing hinges are recommended as door’s hard ware.

7.2 Window Assemblies

Wire mesh glass, liquid sodium silicate fills between two window panes, ceramic glasses, borosilicate glass, wired glass typically withstands the fire, sodium silicate liquid application will act as to insulate heat transfer material, due to the endothermic action of this chemical. (Door, window assemblies are to be considered along with brick wall not as separate element in fire safety construction in building.

Hence here the non combustible materials construction proves its fire safety time at the time of emergency.

8. Conclusion

The thermal behavior, slandered fire test results and the properties of non combustible materials construction are counter act the fire and offering maximum safety time to safe guard lives and properties at the time of emergency. Application of these materials in construction should became mandatory in all type of buildings and assure cent percent fire safety in future.

9. References

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