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Structural Fire Safety Measures in Developing Countries: Pakistan - A Case Study

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Abstract: ***In developing countries like Pakistan, provisions of inadequate fire safety measuresresult into occurrence of many fires that cause lot of deaths and economic loss. Here, fire is not taken as a serious threat and fire safety measures are considered as a waste of money. Thus, there is a need to educate building owners and government agencies about the damaging effects of fire and importance of fire safety measures. In this study, three main components of fire safety i.e. prevention, controlling the spread and severity of fire, and structural fire safety have been included. Data on fire incidents was collected from three sample cities of Pakistan (i.e., Islamabad, Rawalpindi and Lahore)to determine the frequency of fires, causes of ignition and relative vulnerability of buildings. 12 multi-story buildings (six each in Lahore and Rawalpindi) were surveyed to check the adequacy of provided fire safety measures. Fire incident of Ghakar Plaza, Rawalpindi has been analyzed to highlight the economic implications of fires.Analysis of fire incidents of these three cities shows that on average there are 3 fires per day, and every 8th fire is severe enough to cause deaths, injuries, property damage and economic losses. Three main causes of fire are short circuiting, gas leakage and cylinder blasts and the most vulnerable buildings are commercial and residential buildings. Most of the common buildings have no fire safety measures at all, and Pakistan does not have any fire safety code to follow. In case of 12 multi-story buildings, the level of compliance with the code requirements is around 60 percent, and, the automatic sprinklers, one of the most effective fire safety measures, have been provided in two buildings only. From the cost analysis of Ghakar Plaza and a model building, it is found that the cost of fire design is around 3% of the overall cost of the building.***

Keywords: Fire safety, Data collection and analysis, causes of fire ignition, Fire safety Measures

I. INTRODUCTION

Fire represents one of the most severe hazards to which a structure may be subjected. Buildings fires not only result into deaths, injuries and property damages but may also cause huge economic losses (e.g. fire incident of Ghakar Plaza in Rawalpindi resulted into 10 deaths, 50 injuries, Rs. 22 billion economic losses, and the business remained closed for 3 years). Fires may also cause environmental damages e.g. fire in a factory of chemicals etc.

Fire is a dangerous event not only because it is not well understood due to its complex behavior but also because it may be a primary or a secondary event caused by many other hazards such as earthquake, blast, impact etc. Thus, fire can create severe life threatening situations and provision of appropriate fire safety measures in building design is of utmost importance. Fire hazards and its damaging effects are well understood across the world, and most of the countries have well developed fire safety codes and design procedures which are strictly followed by building owners, designers and contractors. In developing countries like Pakistan, there is limited awareness about the fire hazards, its life threatening and direct / indirect economic losses. Due to provisions of inadequate fire safety measures, every day, many fires occur in different parts of these countries which not only cause deaths, injuries, property and environmental damages but also result in closure of business and thus huge economic losses. Fire safety is considered an expensive thing and wastage of money in developing countries, and virtually buildings are not designed for fire for the following reasons:

- Limited awareness of stake holders
- Owners think money spent on fire design is a wastage
- Absence of fire design guidelines and procedures
- Non-enforcement of fire design procedures by government

Compared to the life, property, and business losses incurred due to fires in buildings, the cost of fire design is not that much (as shown later in this study). Thus there is a need to educate business owners, designers and contractors about the fire hazards, its damaging effects, fire safety measures and mitigation techniques. In addition, there is a need to develop fire safety codes and fire safety guidelines for Pakistan. Therefore, the aim of this study is to review and analyze fire incidents, their causes and damaging effects and adequacy of fire safety measures with a view to create awareness about the importance of fire design and to provide essential data for developing building fire safety guidelines for Pakistan.

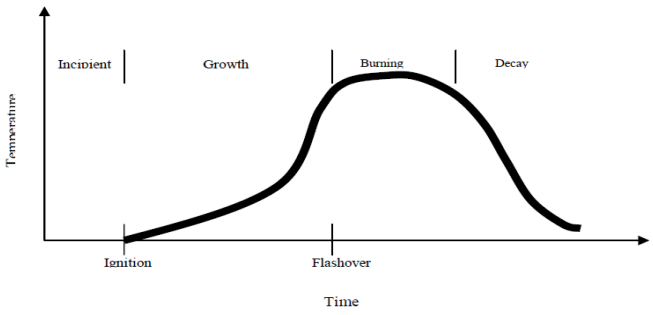

Figure 1: Stages of a typical room

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II. RESEARCH SIGNIFICANCE

The analysis and findings of this study will help educate building and business owners, designers, contractors and government officials about the fire hazards, its damaging effects and fire safety measures, and findings will also help develop fire safety guidelines for Pakistan.

FIRE PROCESS AND FIRE SAFETY MEASURES

Fig. 1 shows four stages of a typical time-temperature curve for a fire in a room, if the fire is not suppressed, but, not every fire will follow this curve (Buchanan [1]). Some fires go out prematurely while some do not reach flashover especially if fuel is not much or if there is not enough air supply. If a room has very large openings, too much heat will flow out of the openings and flashover will never occur. In the incipient stage, heating of potential fuel takes place. Ignition is the start of combustion. In the growth stage, when the temperature of upper layer reaches around 600°C, the burning rate increases and flashover occurs [1].Structural elements are affected in the burning and decay phases of the fire. There are three main components of fire safety i.e. preventive measures - aimed at preventing the causes of ignition, active measures e.g., sprinklers - aimed at controlling thespread and severity of fire and passive measures e.g., application of fire protection materials on beams and columns and using fire rated doors and walls to control the spread of the fire and delay/and prevent the collapse of the buildings. Fire safety objectives (preventing loss of life, property damage, environmental damage and economic loss) are often met with a combination of active and passive fire protection systems and through preventive measures – in this study, these three components of fire safety have been included.

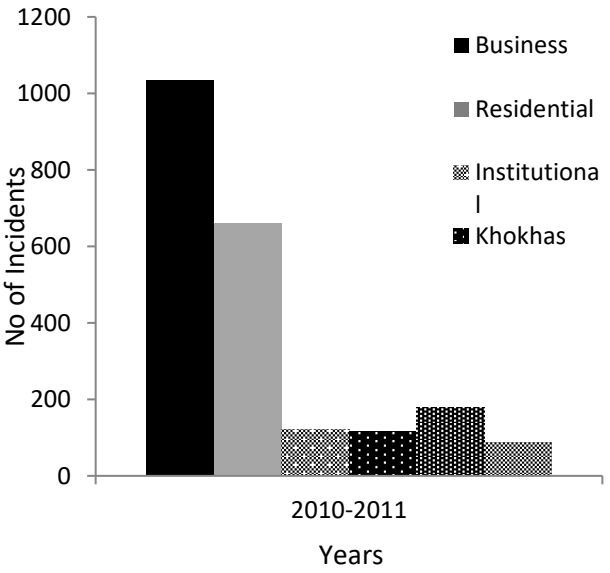

Figure 2: Number of fire incidents in Islamabad in various categories of buildings

III. FREQUENCY OF FIRES, CAUSES OF IGNITION AND VULNERABLE BUILDINGS

The best defense again fire is to prevent ignition, and to know in which categories of buildings fires occur often with a view to provide essential active and passive fire safety measures. For this purpose, data on fire incidents was collected from three sample cities i.e., Islamabad, Rawalpindi and Lahore to determine the frequency of fires, causes of ignition and relative vulnerability of buildings. These cities are considered relatively developed cities of Pakistan and are expected to have relatively better fire safety measures in buildings.

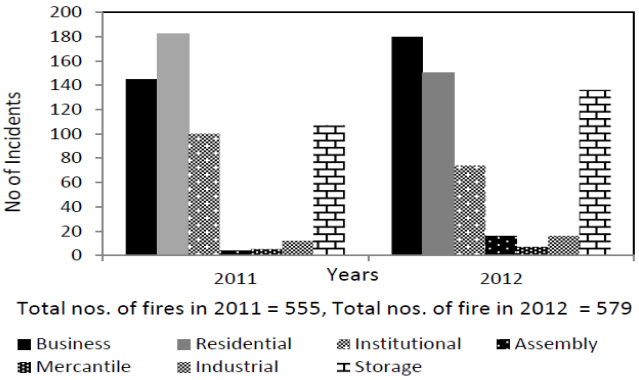

Figure3:Number of fire incidents in Rawalpindi in various categories of buildings

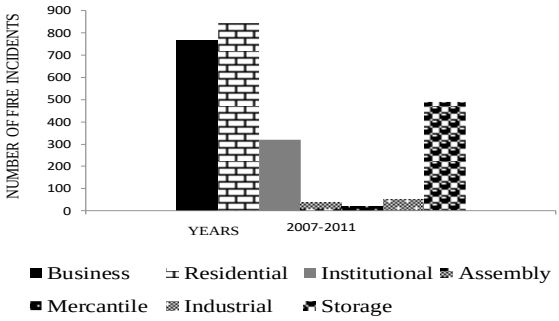

Figure4:Number of fire incidents in Lahore in various categories of buildings

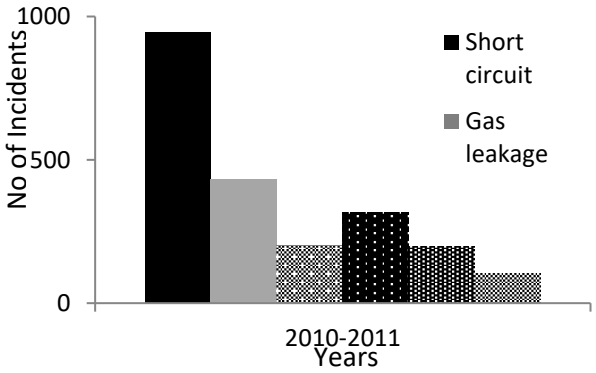

Figure 5: Causes of ignition of fires in Islamabad

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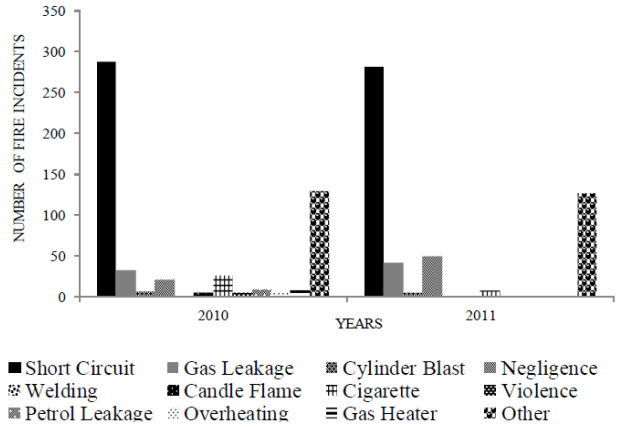

Figure 6: Causes of ignition of fire in Rawalpindi

Data on Fire Incidents from Three Sample Cities

In Islamabad, the agency responsible for fire and rescues operations is Emergency & Disaster Management Directorate of the Capital Development Authority - and in Rawalpindi and Lahore, the emergencies including fire are handled by Punjab Emergency Service (Rescue 1122). Both of these agencies have maintained a complete record of all the fire incidents in their respective cities. In year 2011 and 2012, there were 2202 and 1134 recorded fire incidents in Islamabad and Rawalpindi[2,3] in various categories of buildings as shown in Figs. 2 and 3, respectively. In case of Lahore, the data was maintained for year 2007 to 2011, and it was not possible to segregate the data for each year. From 2007 to 2011, there were 2526 recorded fire incidents in city of Lahore [4] in various categories of buildings as shown in Fig. 4.The causes of ignition in Islamabad, Rawalpindi and Lahore are shown in Figs. 5, 6 and 7, respectively. In Pakistan losses due to fire is in billions per year but it is not possible to quote exact figures due to non-availability of any recording agency.

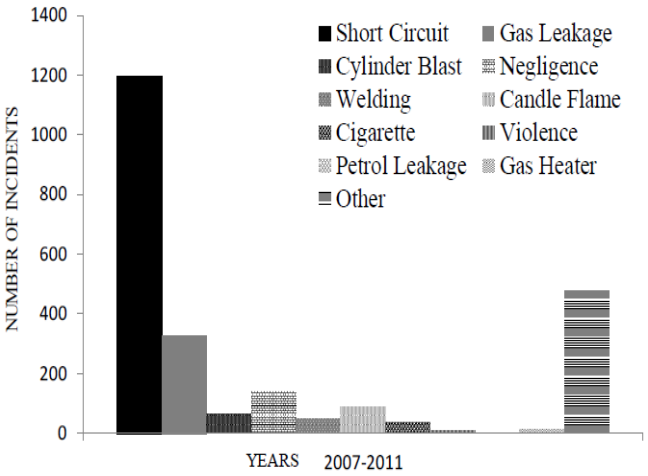

Figure 7: Causes of ignition of fire in Lahore

Evaluation of Data on Fire Incidents

Data on fire incidents obtained from cities of Islamabad, Rawalpindi and Lahore has been evaluated and analyzed to establish the frequency of severe fires, causes of ignition and relative vulnerability of buildings. Main findings are briefly discussed below.

Frequency of Fires

From detailed evaluation of data on fire incidents, it is found that on average there are 3 fires per day in the city of Islamabad, Lahore and Rawalpindi, every 8thfire is severe enough to cause injuries, property damage and economic losses, and every 17thfire is severe enough to cause deaths.Thus fire is a frequently occurring hazard compared to earthquakes and floods, and it can occur anywhere contrary to earthquakes and floods which affect only certain regions of the country.

Common Causes of Fire Ignition

Common causes of ignition of fires are electric short circuiting, gas leakage, cylinder blast, candles, cigarettes, welding and other minor causes as shown in Fig. 8. The "others"category includes (bomb blasts, violent protests, mechanical faults etc.) and "not confirmed" includes the causes of ignition that could not be established. The most common cause of fire, especially in commercial and residential buildings, is electric short circuiting. In the data obtained from three cities, around 50% of fires occurred because of short circuit. In Lahore, out of a total of 2526 fire incidents occurred between August 2007 to December 2011, 1196were due to short circuit which makes it about 47%. In Rawalpindi, a total of 1134 fire incidents have been recorded in 2010 and 2011, out of which 569 (50%) were because of short circuiting.In Islamabad, out of 2202 fires in 2010 and 2011, 147 fires were electrical fires which make only 7%. The proportion of fires due to short circuiting in Islamabad is quite less. This difference is probably because of the fact that construction, and hence wiring, in Islamabad is relatively new as compared to Lahore and Rawalpindi, and also the building laws are followed relatively strictly. The other major causes of ignition are gas leakages and cylinder blasts.

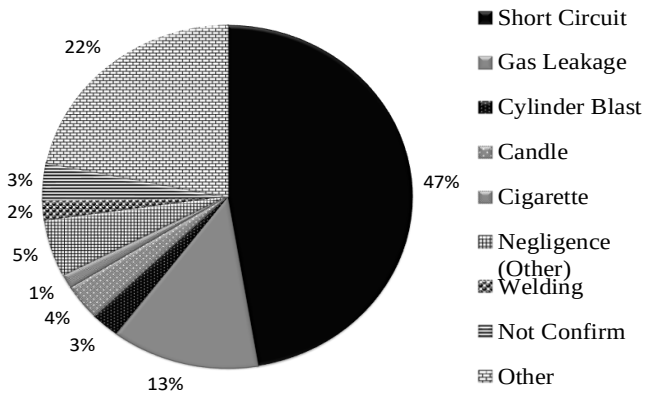

Figure 8: Common causes of ignition of fires

Relative Vulnerability of Buildings

The relative vulnerability of buildings to fire hazard in three samples cities of Pakistan is shown in Fig. 9. It can be seen that occurrence of fire is maximum is residential areas and slightly less in commercial areas. Out of 2526 fire incidents in Lahore, 845 (34%) were in residential areas and 765 (30%) in commercial areas.

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In Rawalpindi, the trend is similar - out of 1134 fire incidents, 335 (29%) were in residential areas while 330 (29%) were in commercial areas. In Islamabad, the trend is quite different - out of 2202 fire incidents, 661 (30%) were in residential areas and 47% in commercial area. Apart from the fires in commercial plazas, fires in "KHOKHAS (a temporary shop having low quality construction)" are separately categorized in the data for Islamabad which are also roughly 4%. The relative less frequency of fires in residential area in Islamabad is probably due to two reasons: (1) good quality of electric and gas lines and fixtures and lesser use of cylinders, and (2) educated residents. This conclusion suggests that number of fire incidents can be reduced if public can be educated.

Although number of fire occurrences in commercial and residential buildings is more compared to other categories of buildings, but, it is important to keep in mind that number of residential and commercial buildings in a city are significantly higher compared to other categories of buildings, and hence the probability of occurrence of fires in these buildings is more as seenin Fig. 9. The occurrence of fire in a commercial or an institutional building or public assembly may have catastrophic effects compared to residential buildings as these buildings house more people and equipment, and hence need more elaborate fire safety measures compared to residential buildings.

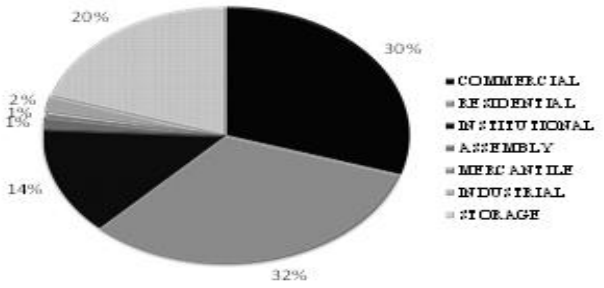

Figure9: Relative vulnerability of buildings to fire hazard

IV. EVALUATION OF ADEQUACY OF FIRE SAFETY MEASURES IN HIGH RISE BUILDINGS

Active and passive fire safety measures are required to ensure safe evacuation of people, control the spread of fire to adjacent rooms or buildings, control the severity of fire, and to delay/and prevent collapse of the building. Active control refers to control of fire by some action taken by a person or an automatic device. The best form of active fire protection is an automatic sprinkler system which sprays water over a local area under the activated sprinkler head. A sprinkler system will extinguish most fires and prevent its growth. Active control of smoke requires the operation of fans or other devices to remove smoke from certain areas or to pressurize stairwells. Occupants can also prevent ignition or extinguish very small fires. Firefighters can actively control or extinguish a fire only if they arrive before the fire gets too large. Time is very critical because it takes time for detection, time for notifying firefighters, time to reach the fire site, and time for locating the fire in the building and setting up water supplies. Firefighters usually have insufficient water to extinguish a large fire after flashover. Then they can provide control by preventing the fire from spreading and extinguishing it during the decay period [1].

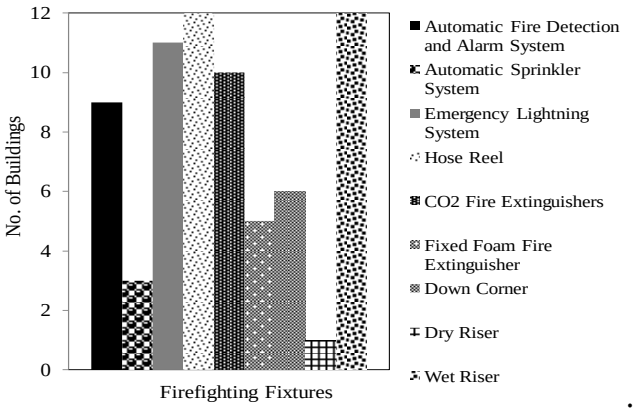

Figure 10: Active fire safety measures in surveyed buildings

Passive control refers to fire control by systems that are built into the structure or material of the building and which don't require any action by people or automatic devices. For fires before flashover passive control includes selection of suitable materials for building contents and interior lining that do not support rapid flame spread in the growth period. In fires after flashover passive control is provided by structures and assemblies which have sufficient fire resistance to prevent damage to structural material and collapse of structure [1].

To evaluate the adequacy of active and passive fire safety measures, several buildings were visited, however, comprehensive survey of following 12 high-rise buildings was done for assessing the adequacy of active and passive fire protection systems.

- **Rawalpindi and Islamabad:** Marriot Hotel Islamabad, Silver Oacks Luxury Apartments, Armed Forces Institute of Cardiology, Quaid-e-Azam International Hospital, Fauji Fertilizer Company and Ghakkhar plaza
- **Lahore:** Pace Lahore, Siddique Trade Center, Ali Tower, Aashiana Tower, Rehman Tower and Sheikh Zaid Hospital

Since Pakistan does not have its own building fire safety code, therefore, National Fire Code of India (NFCI) was followed to evaluate the adequacy of fire safety measures. As per NFCI, there are 20 – 35 (depending on the category of building) different fire safety measures that need to be provided. For detailed information on categories of buildings and explanation of various active and passive measures, readers are referred to National Fire Code of India. Provision of various active and passive fire safety measures in 12 surveyed buildings are shown in Figs. 10-13. The level of compliance with code requirements in these 12 high-rise buildings is shown in Fig. 14.

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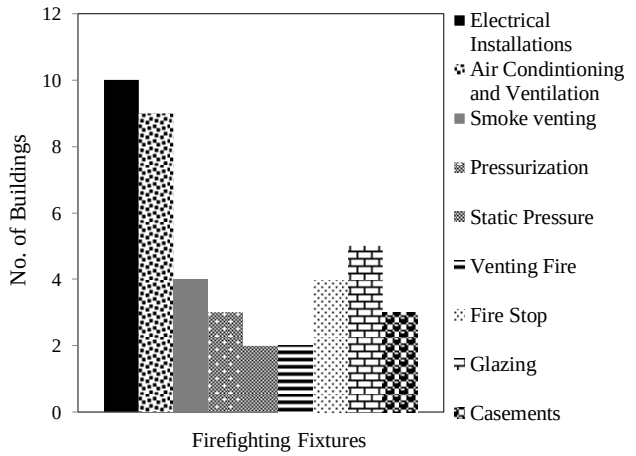
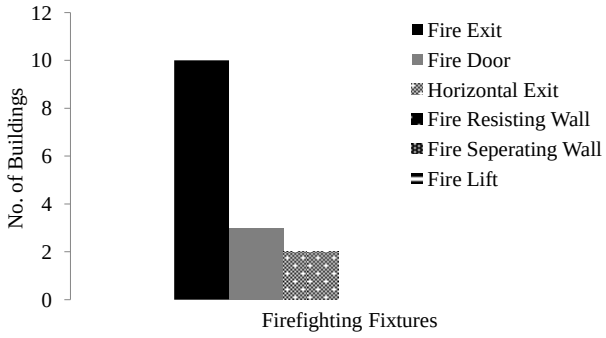


Figure 11: Active fire safety measures in surveyed buildings



Fire Resisting Wall = 0%, Fire Separating Wall = 0%, Fire Lift = 0%

Figure 12: Passive fire safety measures in surveyed buildings

As mentioned earlier to evaluate the provision of fire safety measures several buildings were visited in Islamabad, Rawalpindi and Lahore, then, 12 high-rise buildings designed for fire safety were selected for detailed survey. During the initial visits of buildings in three cities, it was found that most of the common buildings have no fire safety measures at all. In case of 12 multi-story surveyed buildings, the level of compliance with the code requirements for active and passive fire safety measures varies between 5 to 90% (Fig. 14), with average level of compliance being around 60%. Though, level of compliance with code requirements seems reasonably good, but, it may be noted that in the study, all fire safety measures have been given equal weightage or importance (because there are no guidelines to assign importance), which is not true because some of these measures are much more effective in fire design compared to others (e.g., automatic sprinklers versus the interior surface finishes). In these 12 buildings, the automatic sprinklers, one of the most effective fire safety measures in extinguishing or controlling the severity of fire, have been provided in two buildings, only. Similarly, compartmentation and fire separating walls which help in controlling the spread of fire were not provided in about 75% of the buildings surveyed. It is important to mention that in the survey, the focus was whether a particular fire fixture has been provided as per the code requirement, and not much attention was given to the code required specifications (standard and quality) of the fixture.

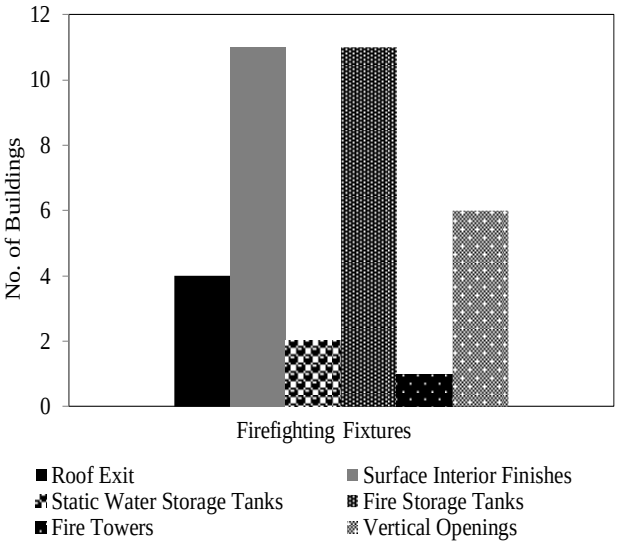


Figure 13: Passive fire safety measures in surveyed buildings

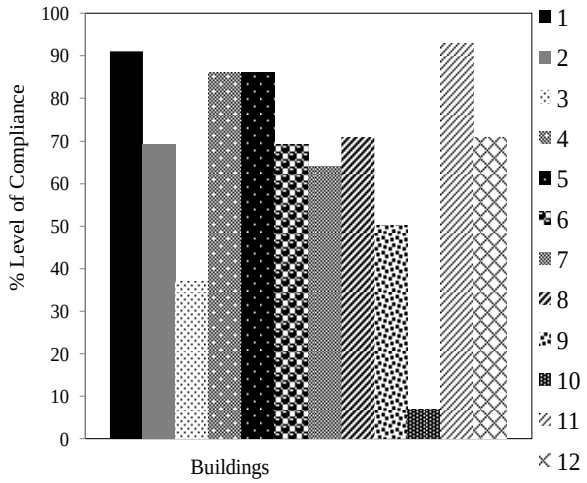


Figure 14: Level of compliance with the code requirements in surveyed buildings

V. FIRE INCIDENT OF GAKHAR PLAZA RAWALPINDI: A CASE STUDY

Gakhar Plaza, a grand six-storey building, was constructed in 1984. The building was situated at Bank Road, Rawalpindi. On December 20, 2008, the building caught fire and was gutted, and all 500 plus shops disappeared as if they never existed (Fig. 15).The fire reportedly started from a small shop on the ground floor and within minutes engulfed the whole building, courtesy of a large quantity of petrol and diesel stored in the shops for generators, as well as cloths and leather wares. Soon after the plaza caught fire, rescue workers from 1122, Civil Defense, City Fire Brigade, Capital Development Authority and Civil Aviation Authority arrived at the site and tried to extinguish the fire, but to no avail, and it collapsed. Following are the main conclusions from the detailed review of investigation report of the incident:-

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Figure15: Ghakar Plaza before and after fire incident

- **Cause of ignition**: Short circuit. Original electric wiring was of standard quality, but, temporary electric connections to share electricity amongst partitions in a single unit and to operate electrical appliances was of poor quality which eventually led to a short circuit and such a fatal incident.
- **Reason of spread of fire**: Petrol and diesel stored for operating generators at different shops led to rapid spread of fire and also increased the severity of fire.
- **Reasons for the severity of fire**: Absence of active measures and poor facilities for fighting fire. The original plan of the building envisaged wide exit routes at the end of each corridor for escape and for the entry of fire fighters. However, the owners cloaked the exit routes to control stock stealing complaints, which made it impossible for fire fighter to enter the building and fight the fire.
- **Reasons for collapse of building**:
  - Building components were not provided fire resistance
  - Inadequate fire fighting force and facilities
- **Financial Effects**
  - Worth of the building: PKR 1.2 Billions
  - Total financial loss: PKR 22 Billions
  - Business remained closed for almost 3 years which resulted into job loss and caused huge indirect economic loss
- **Cost of Fire Safety**
  The building has been reconstructed and has been provided most of the fire safety measures as per the latest fire safety codes.
  - Total cost of reconstruction: About PKR 3 Billions
  - Cost of fire safety: About PKR 78 Millions which is around 2.6 % of the total cost of the building

VI. FIRE SAFETY CODE OF PAKISTAN AND COST OF FIRE SAFETY DESIGN

At present, Pakistan has no fire safety code and designers are generally following NFCI. Few fire regulations are: (1) Capital Development Authority (CDA) Building Standards for Fire Prevention and Life Safety – 2010, and (2) Rescue 1122 Fire Code (Under development). These two fire regulations were compared with International Fire Code (IFC) and International Building Code (IBC) and it was found that these regulations are not elaborate and complete design aids, lot of details are missing e.g., when are sprinkler systems are mandatory, and does not define standards of many fire safety fixtures.

In Pakistan, there is a general perception amongst building owners that fire safety measures cost a lot. What they don't realize is that lack of fire safety measures have led to huge economic and life losses in history (e.g., Ghakar Plaza fire) which were far greater than the cost of fire safety measures. Thus, there is a need to create awareness amongst building owners that the small additional cost can save from huge economic losses later, if a fire occurs. For the purpose, a model building was designed for active and passive fire safety measures according to IFC and IBC. The building selected was "The Pediatric Oncology Department of the Armed Forces Institute of Cardiology, Rawalpindi. It is a 4-story building with a basement, and was constructed in 2012.It is a hospital which is defined as an institutional building in the IFC and categorized as Category-I, Group 1-2 buildings. Since it is a hospital, hence, most of the inhabitants will be patients, many of whom unable to move by themselves. In case of a fire, all the patients will need assisted evacuation. This increases the manpower and time required to safely evacuate all the inhabitants of the building in case of fire. So the building is designed for a 2 hours fire rating in the recommended design. Operation theatres are designed fire resistant to safely complete any ongoing surgical operation because an operation cannot be stopped quickly. All the relevant fire safety clauses were checked in accordance with the IFC and IBC, and implemented in the recommended fire safety design, if not already provided in the initial design of the building. Three main fire safety measures included in the design are:

- Access routes and facilities for fire fighting
- Safe access for evacuation of people
- Active fire safety measures to control and suppress the fire
- Passive fire safety measures to prevent spread of fire and collapse of the building

The cost of the building is as under:

- Original Cost of building is PKR 395 Millions
- Total estimated cost of fire safety measures is PKR11.7 Millions, which is around 2.96% of the total cost of the building.

VII. CONCLUSION

During study, it is found that fire is a frequently occurring hazard in Pakistan, and many fires occur because of the lack of awareness on the part of occupants such as using temporary and low quality electric and gas fixtures/lines, and using poor quality gas cylinders. Many buildings have no fire safety measures at all. In 12 high-rise buildings, a number of small fire safety fixtures have been provided, though not of standard specifications in most of the cases, however, automatic sprinklers have been provided in two buildings only. Compartmentation has not been done in almost all of the buildings.

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Cost of fire safety design is only about 3-4% of the overall cost of the building, but, if this small amount is not invested initially then a fire incident can result into economic loss 17 times as high as the original cost of the building in case of large fire such as Ghakar Plaza fire apart from closure of business for a long time.

RECOMMENDATIONS

A. There is need to have strict regulations on the quality of electric and gas lines and fixtures, especially for commercial and institutional buildings.
B. Shopkeepers may not be allowed individual generators in case of multi-story commercial buildings, instead, owners may be asked to arrange central generator, preferably placed outside the building in a generator room.
C. Building approving authorities should have a mechanism to inspect the adequacy of active fire safety measures before approving it to be fit for use.
D. There should be no relaxation on the provisions of standard fire safety measures for commercial and institutional buildings as these are highly vulnerable to fires and generally house many people at on time.
E. There is an urgent need to develop fire safety guidelines for Pakistan and educate public, building owners, designer and government agencies regarding the damaging effects of fire and importance of including fire safety in the design of important buildings.
F. The present study needs to be extended for other cities of Pakistan.
G. Awareness needs to be spread amongst public, contractors, executives as well as owners to make them understand that spending 3-4% of total building cost can save them from financial loss and save precious lives.

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