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Research Paper

Integrated Approach to Smoke Management System in Healthcare Facilities

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Abstract

Smoke management is a critical aspect of life & fire safety in healthcare facilities due to the unique challenges they present. This research study has focused on various issues about the present status of the Smoke management system in six super-specialities healthcare facilities, which have equal representation from Government healthcare facilities, key national-level healthcare Institutions, and private sector healthcare facilities spread throughout the length and breadth of India. Urban healthcare facilities are at the nexus of safety and sustainability. Incorporating Smoke management is pivotal. These systems control smoke during fires, enabling safe evacuation and reducing toxic gas dispersion. When coupled with passive measures such as fire-resistant materials and clear evacuation routes, they enhance safety by containing and evacuating fire-induced smoke. Advanced protection systems, including fire detection and suppression technologies, further strengthen the safety ecosystem. Their integration with smoke management system limits smoke propagation and expedites evacuations, maximizing the safety. This holistic approach optimizes evacuation procedures, reduce smoke-related health hazards, and maintains secure environments. Collaboration of key stakeholders and supportive legislation is essential to mandate safety protocols and promote implementation, involving government bodies, policy makers, urban planners, fire safety experts and healthcare authorities. In doing so, urban healthcare facilities can exemplify the fusion of safety and sustainability in modern urban development, prioritizing the well-being of all stakeholders. This research article presents an integrated approach to smoke management systems in healthcare facilities, focusing on the efficient and effective combination of passive measures, active fire protection systems, and smoke control strategies. The goal is to provide a comprehensive system that ensures the safety of patients, staff, and visitors during fire incidents and further maintains uninterrupted business operations across the healthcare facility. In this paper, major issues about effective smoke management system and strategies in different super-speciality hospitals were discussed, which have direct or indirect bearing on the life and fire safety of hospital inmates, occupants and other key stakeholders, besides ensuring seamless functioning of hospital operations. This article also highlights the importance of an integrated approach to smoke management systems in healthcare facilities, through case studies across six different Super-specialities large healthcare facilities, identifying the critical gaps and factors affecting the effective functionality of smoke management system and suggested ways and means to mitigate fire & life safety hazards through integrated system approach and technological interventions.

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KEYWORDS: Healthcare facility, smoke management, smoke control, passive measures, protection system, compartmentation, containment, HVAC, Integration of smoke management system, life & fire safety.

1. INTRODUCTION

In present era, large urban healthcare facilities are providing various super-specialities medical/health care besides many allied facilities for patients & caretakers, including large cafeteria, canteens, waiting lounges, pharmacy etc. and often have large open spaces or voids. In the event of fire or life-threatening situations due to smoke logged conditions, healthcare facilities invariably require a properly designed and functional smoke management system to provide tenable conditions for the critical patients, medical & paramedical staff, till the arrival of fire & rescue services personnel, besides, providing safe means of egress for the hospital occupants.

Healthcare facilities, such as hospitals and medical centres, require specialized fire safety measures due to the presence of vulnerable individuals and critical care areas. Smoke management plays a crucial role in maintaining safe evacuation routes, minimizing smoke inhalation risks, and facilitating effective firefighting operations.

Smoke and fire have caused many deaths since the discovery of fire. While fire has been an invaluable resource for humanity, it has also led to significant destruction. Healthcare facilities have not been exempted from this danger, as numerous incidents of fires and life-threatening emergencies have occurred in various healthcare settings worldwide. This was particularly evident during the Covid-19 pandemic when the distressed population believed that only the best and most affordable hospitals could protect them from death. Ironically, Covid care hospitals often became death traps due to frequent fires and smoke-related hazards. These issues arose from overloaded and overstressed electrical circuits due to increased patient load and medical equipment, as well as overloaded low voltage electrical equipment, leading to electrical short circuits. Additionally, the presence of highly flammable mixtures of volatile vapours from sanitizers and oxygen-enriched environments in critical care units caused numerous fires in hospitals. Most of the deaths resulted from asphyxia due to poor and insufficient smoke extraction systems, inadequate planning, and a lack of integration between existing smoke management systems with HVAC systems, building automation systems, air pressurization, and passive and active fire protection measures.

During the recent past and preceding years, numerous fire incidents have been reported across various hospitals, including fire in a private hospital at, Chandigarh (8 April, 2025); a major fire at a Neonatal Intensive Care Unit (NICU) of Maharani Laxmi Bai Medical College, Jhansi, UP (15 Nov, 2024) resulting in the deaths of at least 10 newborns and injuring 16 others, most of which later succumbed to injuries; a major fire in a Newborn Baby Care Hospital in east Delhi's Vivek Vihar, Shahdara (May 26, 2024), wherein at least seven new born babies were died, injuring 05 others and affected residential buildings next to it; a major fire broke out on Metro Hospital and Heart Institute, Noida, UP (7 Feb., 2019), LNJP Hospital, New Delhi (10 April, 2019), SMS Hospital, Jaipur, (10 May, 2019), AIIMS, New Delhi (17 August, 2019), North Bengal Medical College and Hospital, Siliguri, W.B. (27 Sept., 2019), Shine Children Hospital, Hyderabad (22 Oct., 2019), Safdarjung Hospital, New Delhi (13 Sept., 2018), Apollo Hospital, Jubilee Hills, Hyderabad (14 Sept, 2018), ESIC Kamgar Hospital, Mumbai, (20 Dec., 2018), Trauma Center, King George Medical University, Lucknow (16 July, 2017), SUM Hospital, Shiksha 'O' Anusandhan University, Bhubaneswar (18 Oct.,2016), Park Super speciality Hospital, Hyderabad (02 Feb., 2010). The most tragic fire incident occurred at AMRI Hospital, at Dhakuria, Kolkata on December, 9, 2011. 90 people were reported chocked to death (Pal, I. & Ghosh, T., 2014); primarily due to asphyxia from inhaling smoke and toxic fumes. The hazardous smoke could not be removed from the building (Pal, I. & Ghosh, T., 2014) and patients in the wards and Intensive Care Unit were suffocated and died due to lack of smoke control system in place (Nagral, S., 2012).

Therefore, given these illustrations, the role of a smoke management system and its integration with building services has become imperative and potentially as significant as any other critical care medical facilities or super-specialties available in the hospital.

Fig 1: Major Fire incident at Neonatal Intensive Care Unit at Maharani Laxmi Bai Medical College, Jhansi, UP resulted in the deaths of at least 10 newborns and injuring 16 others (**Photo Credit:** AP)

2. LITERATURE REVIEW

Healthcare facilities are where people feel most secure and safe (Sharma R. *et al.*, 2023). This sense of security attracts people to these facilities, but when they become sources of distress, harm, or even death due to fire and smoke, it raises serious concerns and questions about the facility's management. The necessity of an effective smoke management system cannot be overstated, as we often realize its importance only after a tragedy occurs. While healthcare facilities are generally prepared to handle external threats and various biological and environmental calamities, internal threats such as fire and toxic smoke are often overlooked or inadequately planned for, especially when urgent evacuation is required (DeVito *et al.*, 2017; Sharma R. *et al.*, 2014).

Healthcare facilities use many volatile and combustible liquids, gases, and substances, making them particularly vulnerable to fire. Electrical appliance-related fires pose a serious threat, potentially leading to catastrophic outcomes (Sharma R. *et al.*, 2023). In the event of such an accident, many patients are incapable of protecting themselves without assistance and may not even be aware of the danger due to conditions like coma,

unconsciousness, or severe injury. It is therefore the responsibility of hospital staff to be prepared for such emergencies (Sharma *et al.,* 2020). The design and use of buildings must integrate fire safety measures to protect healthcare facilities from fire incidents (Akadiri P.O. *et al.*, 2012). In fire hazards, smoke often causes more severe damage than flames. Smoke inhalation is the leading cause of death in such incidents, as smoke carries harmful gases like cyanide, which is lethal when inhaled (Mydin, M.A., 2014). One study suggests that 75% of fire-related fatalities are due to smoke inhalation (Ebenehi IY, *et al.,* 2017). Smoke inhalation is especially fatal for patients with pulmonary problems and cardiac issues. Due to the heavy patient load, the dependency on various electrical and medical instruments, such as radiological machines, can cause additional stress in the event of a fire. An accidental release of radiation in such incidents can severely impact the entire ecosystem of the area, threatening all forms of life and causing extensive damage to physical structures for an indefinite period (Sharma R. *et al.,* 2023). In the present era, advanced techniques and systems have introduced Building Automation and Management Systems (BAMS), which improve smoke management systems (SMS) and bring various functionalities together, leading to efficient and effective strategies. BAMS can connect and manage heating, ventilation, and air conditioning (HVAC) systems, lighting, security, and more (Himeur Y. *et al.,* 2023). These systems operate through a network of sensors and various monitoring and mechanical operations (Su and Wang, 2020). This article addresses smoke control and management systems, their shortcomings, and the need to overcome these limitations. It discusses various strategies for installing and improving smoke management systems within hospital settings and other related facilities. The primary aim is to prevent fire incidents, and in the event of such incidents, to ensure that life and fire safety norms are well understood and implemented.

3. Rationale of the Study

This research study primarily aims to review and identify the gaps in existing fire and life safety arrangements in healthcare facilities, specifically regarding the availability and effective functioning of smoke management systems. It also seeks to develop strategies for adopting an integrated approach through the interaction of various system components to ensure enhanced life and fire safety goals. Despite the existence of numerous national and international building codes, standards, bye-laws, and fire safety regulations, healthcare facilities continue to experience frequent fire incidents resulting in significant casualties. Hospitals, as critical infrastructure, face unique challenges in ensuring the safety of patients, staff, and visitors during fire incidents. Traditional fire safety measures often focus on active systems, such as fire detection and suppression, but fail to adequately integrate passive measures, protection systems, and smoke management strategies. The primary goal of this research study is to propose and evaluate a systems approach that seamlessly integrates smoke management strategies with passive fire safety measures and protection systems within hospital facilities, thereby optimizing life and fire safety.

4. Smoke Management System and Its Importance in Healthcare Facilities

Smoke is the primary killer in the case of fire. The first step in such an emergency is to evacuate the building, but this can be challenging in large-volume buildings, where panic and havoc can ensue. Additionally, some patients may be critically ill or severely dependent on others for movement and survival, necessitating special care during evacuation. Smoke management systems (SMS) include physical measures such as smoke-resistive construction within the building. Equipment like fans, ductwork, dampers, operable windows, and smoke detectors provide additional protection. Compartmentation, which contains smoke passively within the source area, can also restrict smoke movement (Magdanz C.E. and Klote, 2002). Containment, prevent smoke migration into egress routes, aiding in protecting life and reducing property damage. Fire dampers are often needed for duct penetrations of fire barriers, but combined fire/smoke dampers can seal against smoke leakage, ensuring smoke resistance. Smoke management system or smoke control system are mechanical systems designed to prevent smoke movement during a fire. While smoke control system manage smoke to increase egress time and facilitate safe evacuation, smoke management systems are used post-fire to remove smoke or restrict its entry into specific areas, such as common egress pathways, aiding fire and rescue personnel in locating the fire, trapped victims, and increasing visibility.

Building codes and design layouts enable hospitals to contain smoke and fire, protecting lives and resources. These codes include active features like smoke ventilation fans, automatic sprinklers, and mechanical ventilation systems, as well as passive features like fire and smoke dampers and physical barriers (Kramer S.W. *et al.,* 2018). Generally, hospitals are equipped with infrastructure to handle fire mishaps, meeting minimum fire safety criteria. A well-designed plan against fire and smoke ensures better safety from hazards. However, potential risks from fire can still have severe, long-lasting effects on healthcare environments. Numerous materials and equipment, such as electrical cables, low voltage electrical equipment, medical substances, chemicals, and gases, are combustible or can easily catch fire if mishandled (Sharma R. *et al.,* 2023). Precautions to prevent such accidents must be taken with sincerity and earnestness. A proactive and effective team should be dedicated to handling such accidents and taking necessary steps if needed (Sharma R. *et al.,* 2014). It's important to note that smoke often causes more damage than fire itself in terms of casualties due to smoke inhalation, a primary cause of fatalities in fire-related incidents. Reports suggest that cyanide can be detected in fire incident victims (Mydin, M.A. 2014). Smoke inhalation can cause severe inflammatory reactions, with pulmonary signs including dyspnea and coughing. For patients with prior medical conditions, health can deteriorate rapidly with additional complications. Smoke travels through ventilation

systems, duct channels, air conditioning, and vents, endangering patients in adjoining areas.

5. METHODOLOGY

The research methodology involves a combination of case studies, performance audit of passive and active fire and life safety systems, identifying the gaps & critical factors affecting the effective functioning of existing smoke management system in various healthcare facilities. Case studies were conducted on six different hospitals across India, including large super-specialty hospitals, spanning across both government sectors as well as private sectors in northern, western, eastern and southern India. The super-specialities hospitals in govt. sectors in western and eastern part of the country are 920 bedded hospitals and rest of the govt. & private sector hospitals in northern and southern part of the country are 540 to 720 bedded.

Further, in order to assess the effectiveness and performance of different smoke management system & strategies, interactions with healthcare facility managers, hospital administrators, architects, engineers, and fire safety professionals were made during field visits and later through different rounds of survey questionnaires with domain experts to gather insights into current practices, challenges, and opportunities for integration, on a case-by-case basis.

6. System Approach

6.1 Framework for Smoke Management in Healthcare facilities

During the event of a fire in a healthcare facility or any other building, it is highly uncertain to estimate the production of smoke/ toxic fumes and its prediction is also quite impractical. Therefore, devising a proper framework for efficient and effective management of smoke is imperative to ensure safety of lives of occupants, infrastructure and uninterrupted hospital operations. In this endeavour many techniques and combination of strategies may also require to be incorporated into the hospital emergency management plan, including containment of smoke, dilution, extraction strategies, emergency evacuation strategies and system design taking into account the systems interconnectivity and interoperability to provide a robust, reliable and effective smoke management system.

6.1.1 Interconnected Systems

A comprehensive and integrated system-level approach is needed to propose a framework that accounts for the interconnected nature of smoke management systems, integrating smart building technologies for real time monitoring of the fire safety systems and automated response to potential fire incidents, integrated building management system, internet of things (IoT) sensors, and automated alert system to enhance fire detection, response time and coordination of emergency services.

6.1.2 Risk Assessment

Identifying potential hazards, conducting risk mapping, and performing risk assessments are essential components to integrate into the system approach. These steps help identify critical and vulnerable areas within the hospital infrastructure, allowing for the tailored integration of smoke management and passive fire safety measures with evacuation strategies.

7. Impact Assessment

7.1 Simulation Models

Computational fluid dynamics (CFD) and Consolidated fire and smoke transport (CFAST) simulation techniques are used to evaluate the behaviour of smoke travel within a hospital building, which help in predicting the fire-behaviour in actual fire situations and planning appropriate smoke control system and design strategies. These simulation techniques enable hospital administration and system integrators in decision making process to devise a fail-proof smoke management system & strategies for further strengthening the fire and life safety paradigm and uninterrupted critical hospital operations.

7.2 Cost-Benefit Analysis

A cost-benefit analysis is necessary to evaluate the economic feasibility of implementing the proposed systems approach, highlighting the overall benefits in terms of life and fire safety as well as business continuity for the healthcare facility. Additionally, the reputation and trustworthiness of the healthcare facilities in terms of patients' safety is not only an ethical consideration but also an intangible benefit that can have far-reaching outcomes.

8. Passive Fire Safety Measures

Passive fire safety measures form the foundation of a robust smoke management system. Fire-rated construction, including walls, partitions, ceilings, and doors, helps compartmentalize areas and restrict the spread of fire and smoke. Smoke barriers and partitions are essential for containing smoke and providing clear evacuation paths. Additionally, fire-rated doors and dampers help control smoke movement and prevent its spread to unaffected areas. Fire stops/sealants across the services penetrations, through walls and floors and fire-retardant coatings on internal surfaces and power cables help to restrict the spread of fire and smoke in healthcare settings.

9. Active Fire Protection Systems

Active fire protection systems work in conjunction with passive measures to detect and suppress fires. Fire detection and alarm systems, including smoke detectors and heat detectors, provide early warning to initiate evacuation procedures. Automatic sprinkler and water mist systems are crucial for rapidly suppressing fires and minimizing their growth. In areas with sensitive equipment or highly inflammable hazardous materials, specialized fire suppression systems, such as clean agent, foam or dry chemical powder systems, may be necessary.

10. Smoke Management System Components

An effective smoke management system combines various components to control smoke movement during a fire incident. These components include smoke ventilation systems that remove smoke from affected areas, pressurization systems to

prevent smoke ingress into common areas such as staircase shafts, lift lobbies, common corridors, and exit pathways/escape routes, and compartmentation strategies to limit smoke spread.
Integrating the smoke management system with the fire detection and alarm system ensures automated activation of smoke control measures, such as fire/smoke dampers, smoke barriers & curtains and HVAC control. Dilution or purging of smoke is another strategy that can be employed to provide occupants with adequate time to escape safely.

11. Smoke Control Design Strategy

11.1 Smoke Compartmentation: Smoke compartmentation involves dividing the hospital building into smaller compartments using fire-rated walls, floors, and ceilings. These compartments are designed to limit the spread of smoke and fire, allowing safe evacuation routes and reducing the risk of smoke inhalation for patients and staff. Smoke barriers should be provided to separate different areas, such as patient rooms, corridors, and stairwells, and should be designed to resist smoke movement and maintain compartment integrity.

11.2 Stairwell Pressurization: Stairwells are critical evacuation routes in hospital buildings. Pressurizing stairwells can help prevent smoke infiltration and maintain a smoke-free escape path. Positive pressure systems are installed in stairwells to create a pressure differential, ensuring that smoke cannot enter the stairwell and allowing for safe evacuation.

11.3 Atrium Smoke Control: Atrium spaces are common in modern hospital designs, and they pose specific challenges for smoke control. Atrium smoke control systems are designed to prevent smoke from spreading vertically and horizontally throughout the building. This can be achieved through smoke exhaust systems located at high points in the atrium, smoke curtains or barriers, and pressurization systems to maintain a smoke-free environment in adjacent spaces.

11.4 Smoke Exhaust Systems: Smoke exhaust systems are essential for removing smoke from affected areas, such as corridors, patient rooms, and other critical areas. These systems use mechanical ventilation to extract smoke and maintain tenable conditions for safe evacuation. Smoke exhaust fans and dedicated exhaust ducts should be strategically located to effectively remove smoke and control its movement within the building.

11.5 Dedicated Smoke Control Zones: Hospital buildings can be divided into dedicated smoke control zones, with each zone having specific smoke control measures tailored to its function and occupancy. These zones can be delineated based on factors such as floor levels, occupancy types, or functional areas. Designing smoke control measures specifically for each zone allows for more effective smoke containment and evacuation procedures.

11.6 Integration with Fire Alarm Systems: Smoke control systems should be seamlessly integrated with the fire alarm systems in hospital buildings. Upon detection of a fire, the fire alarm system should activate the appropriate smoke control measures, such as initiating smoke exhaust systems, pressurization systems, and closing fire-rated doors, dampers to contain the smoke and facilitate safe evacuation.

11.7 Computer Modeling and Analysis: Smoke control design strategies can be optimized using computer modeling and analysis techniques. Computational fluid dynamics (CFD) and Consolidated fire and smoke transport (CFAST) simulations can help evaluate the effectiveness of the smoke control system design, predict smoke movement and fire behaviour and identify potential areas of concern in hospital settings. These simulations aid in fine-tuning the design and ensuring its efficiency.
It is important to note that smoke control system & design strategies should comply with relevant fire & life safety codes, regulations, and standards specific to hospital buildings.

12. Collaboration Of All Stakeholders

Working closely with fire protection engineers, architects & planners, structural engineers, HVAC specialists, Fire services authorities, MEP engineers/consultants are essential for hospital developers & regulatory bodies, which is crucial for developing a comprehensive smoke control system & design strategy tailored to the specific requirements of hospital buildings.

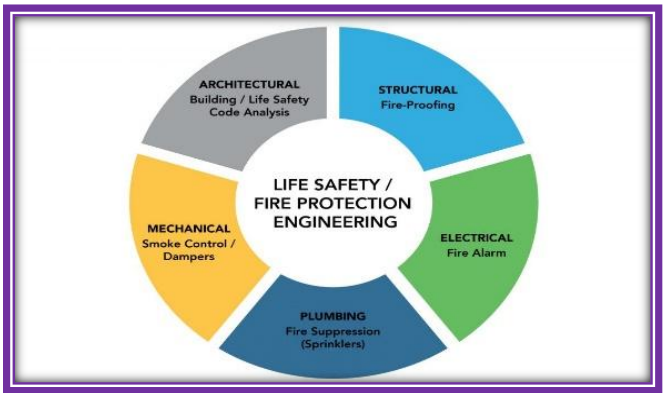

Fig 2: Collaboration of All Stakeholders

13. Evacuation Planning; Special Considerations & Technological Interventions

Emergency evacuation planning is a critical aspect of fire safety in healthcare facilities. Exit signage, evacuation routes, assembly points, and procedures for evacuating patients with special needs should be clearly defined and communicated to hospital staff.
The 'defend-in-place' approach and horizontal/progressive evacuation strategies should be well planned and rehearsed in advance to optimize patients' safety. Complete evacuation of all patients may not be practicable, particularly for those who are critically ill, bedridden, infectious, or on life support system.
Hospital building evacuation plans shall be predominantly displayed in corridors on all floors. Action in cases of fire and emergency evacuation procedures shall also be disseminated to the patients and visitors through audiovisual displays & public address system in visitors & patients' waiting areas, wards and corridors to optimize its outreach.

An intelligent and analytics-based emergency evacuation exit signage are available, which guides the occupants on a particular floor of the hospital buildings through a protected means of egress, identifying the smoke-free zones. Video management systems and analytics can also be incorporated while integrating the smoke management system and developing emergency evacuation plans in modern healthcare settings.

14. System Maintenance, Testing, And Training

Regular maintenance and testing of the smoke management system components are essential to ensure their proper functionality. Staff members should receive comprehensive training on fire safety protocols, evacuation procedures, and the operation of the smoke management system components. Regular mock drills and exercises should be conducted in different hospital blocks of buildings, coordinated and supervised by the local fire brigade, to assess the effectiveness of the integrated approach and identify areas for improvement. Follow-up actions on all observations and shortcomings noted during these practices should be addressed promptly. Proper documentation of training sessions and drill rehearsals should also be maintained for future reference.

15. RESULTS & DISCUSSIONS

During the research case studies, extensive field visits were undertaken across various super-specialities hospitals to assess the availability and functionality of passive measures, protection system, smoke management system layout and strategies for their effective integration into the building management system for seamless functioning. The system vulnerabilities were thoroughly evaluated to arrive at a decision and devise counter measures to plug those gaps/discrepancies in the system to optimize fire and life safety throughout the individual healthcare facility under study. On the basis of comprehensive risk evaluation, following key observations/discrepancies were noted, which may adversely affect the overall fire & life safety strategy in particular healthcare facility- -

1. Horizontal and vertical penetrations across walls and floors for cable shafts and other services, gas piping, HVAC ducts etc. were found opened on the majority of floors, allowing free smoke movement throughout the healthcare facility in majority of the all cases.
2. The concept of mechanical smoke ventilation systems for different floors was not incorporated into the building design in the majority of cases under study.
3. Graded fire rated compartmentation was not provided in any of the hospital case, to provide comparatively safer horizontal/lateral shift and allow sufficient time to the critical patients and other occupants till arrival of the fire & rescue service personnel.
4. Air pressurization system means of egress, staircase & lift lobbies were found defunct in the majority of the of the cases and system testing and maintenance records are not available.
5. In one of the private sector super-specialities hospital case, proper compartmentation with smoke curtains and fire & smoke check doors for staircase and lift lobbies, and even lift shafts were seamlessly provided and further integrated with manual call points, smoke detection, and alarm systems.
6. Except, one government sector super-speciality hospital case in western India, no other healthcare facility had integrated the HVAC system with the building management system (BMS) to facilitate efficient smoke management and control, in case of fire.
7. Fire check doors are generally hold open or anchored on either end to allow free movement of patients, visitors, and services due to a lack of awareness, which has defeated the very purpose of effective compartmentation and restricting fire and smoke spread.
8. In the majority of hospital cases, fire and smoke check doors do not provide effective sealing of the area and many of them have damaged door closure mechanism, push bars, and latches.
9. During peak hours, particularly at night, severe congestion on access roads and unregulated vehicular parking was observed in a private sector super-speciality hospital case, which may obstruct the access of fire and emergency rescue appliances, hydraulic platforms, and aerial ladders.
10. There is a serious lack of awareness & training on fire emergency protocols, coordinated emergency response, evacuation protocols and ability to operate fire protection system and smoke management systems in majority of the hospital cases.

16. Case Illustrations

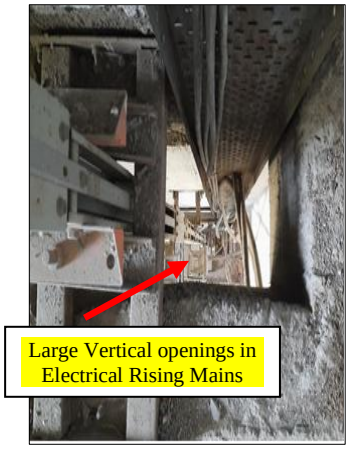

Fig. 3 (a) **Fig. 3 (b)** **Fig. 3 (c)**

Fig. 3 (a), (b) & (c): Large Vertical & Horizontal Openings across various Services

Fig. 4: Fire/Smoke Check doors hold open in Corridors

Fig. 5 (a) **Fig. 5 (b)** **Fig. 5 (c)**

Fig. 5 (a), (b) & (c): Protected Escape Routes in Corridors, Staircase and Lift Lobbies through Smoke Curtain & Fire door

17. CONCLUSION

An effective smoke management system is critical in healthcare facilities to ensure occupant safety during fire incidents. It not only maintains a tenable environment for safe evacuation but also assists firefighters and rescuers in locating fire sources and casualties. The success of fire-fighting and rescue operations relies heavily on the system's ability to control smoke effectively. A comprehensive, integrated approach—combining passive fire protection, active fire protection systems, and strategically designed smoke control mechanisms—is vital. Such an approach helps manage smoke movement, provides smoke venting, and maintains clear evacuation routes. Proper planning, installation, and commissioning of the smoke management system are essential, along with routine maintenance, regular performance evaluations, and coordinated emergency drills involving local fire services. These practices collectively ensure the system functions optimally and enhances overall safety in healthcare environments.

Declaration of competing interest

The authors declare that they have no known competing financial interests that could have influenced the research work reported in this paper.

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