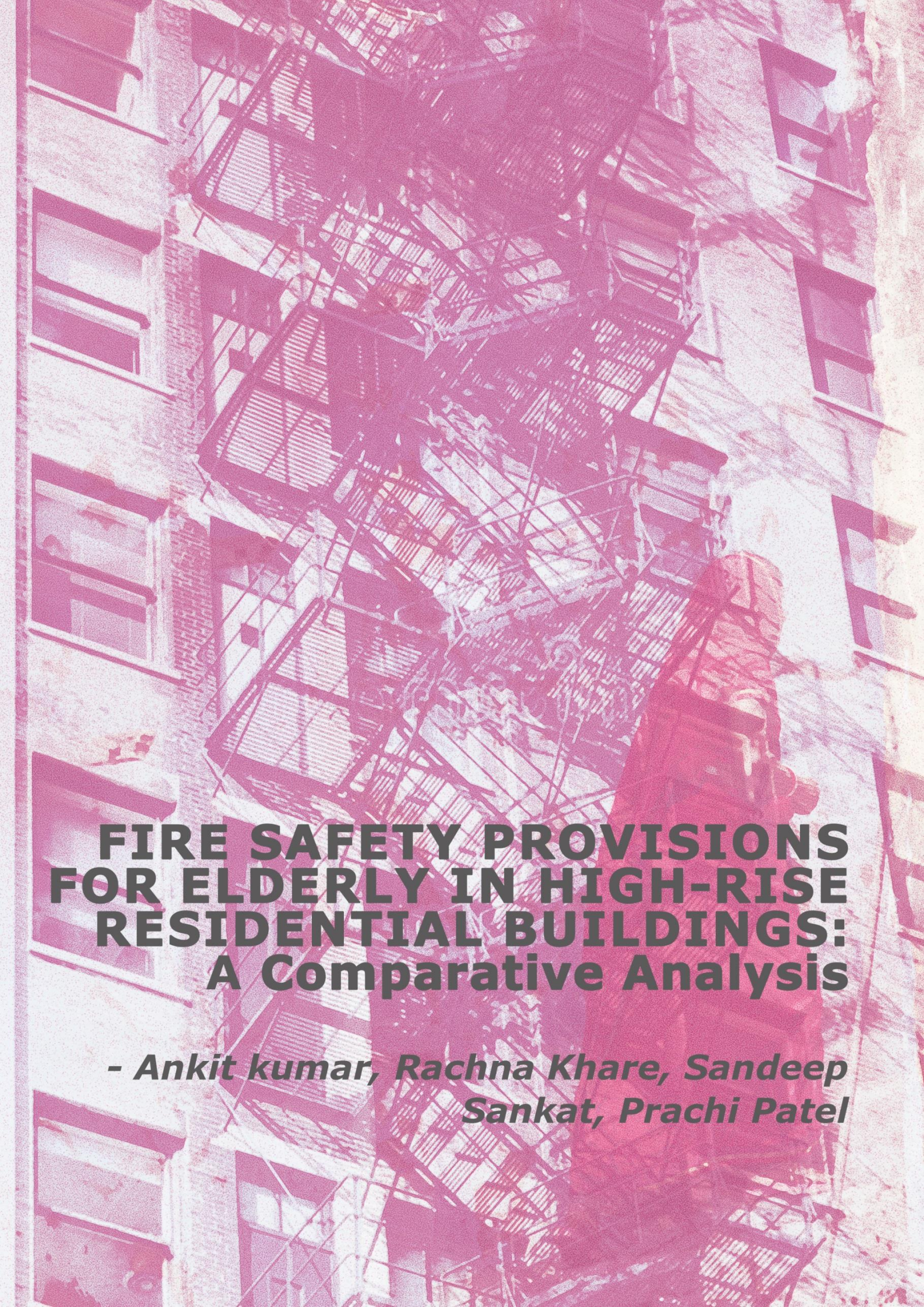

FIRE SAFETY PROVISIONS FOR ELDERLY IN HIGH-RISE RESIDENTIAL BUILDINGS: A Comparative Analysis

- Ankit kumar, Rachna Khare, Sandeep Sankat, Prachi Patel

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FIRE SAFETY PROVISIONS FOR ELDERLY IN HIGH-RISE RESIDENTIAL BUILDINGS: A COMPARATIVE ANALYSIS

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ABSTRACT:

The safety of the elderly during a fire in high-rise residential buildings is of significant concern. Most metropolitan cities worldwide have high-rise structures because of the scarcity of space. Vertical living comes with its pros and cons. Not only, it costs less and accommodates more people but also makes people residing more vulnerable to disasters like Fire. This study compares various codes and standards related to provisions made in the built environment for fire safety in a high rise for the elderly population. The study is based on the secondary data extracted from various national building codes and standards followed in various countries. Results reveal interesting facts about how some countries are much ahead regarding fire safety provisions for elderly populations. In India, this issue needs to be addressed immediately and precisely because the rate of urbanization, the rapid growth of the elderly population, and rural-to-urban migration are very high.This scenario is pushing people to live in such vertical structures, which in disaster need much attention. The current building designs and codes for fire safety in a high-rise are ergonomically designed for the able-bodied population. Still, they fail to include the needs of the elderly population. The revelations of this study would sensitize Architects, Planners, and Policymakers toward the unique needs of the elderly during Fire.

KEYWORDS: ***Fire safety; high rise buildings; elderly; building codes***

1 INTRODUCTION

Cities in India, like Delhi, Mumbai, Chennai, Bangalore, Kolkata, etc., are becoming increasingly urbanized. They act as magnet cities that pull populations from other regions for work and survival. This pull pressures these cities' available infrastructure, services, and facilities. A shift from low-rise living to high-rise is one outcome that has emerged due to development pressure on land. These buildings provide dwellings to many migrants who come for work and to the natives who find it an economical option compared to having a plot on land. High-rise buildings have many challenges which are not found in traditional low-rise buildings. Management of these buildings requires much attention to evacuation strategies, fire man's accessibility, and smoke control.

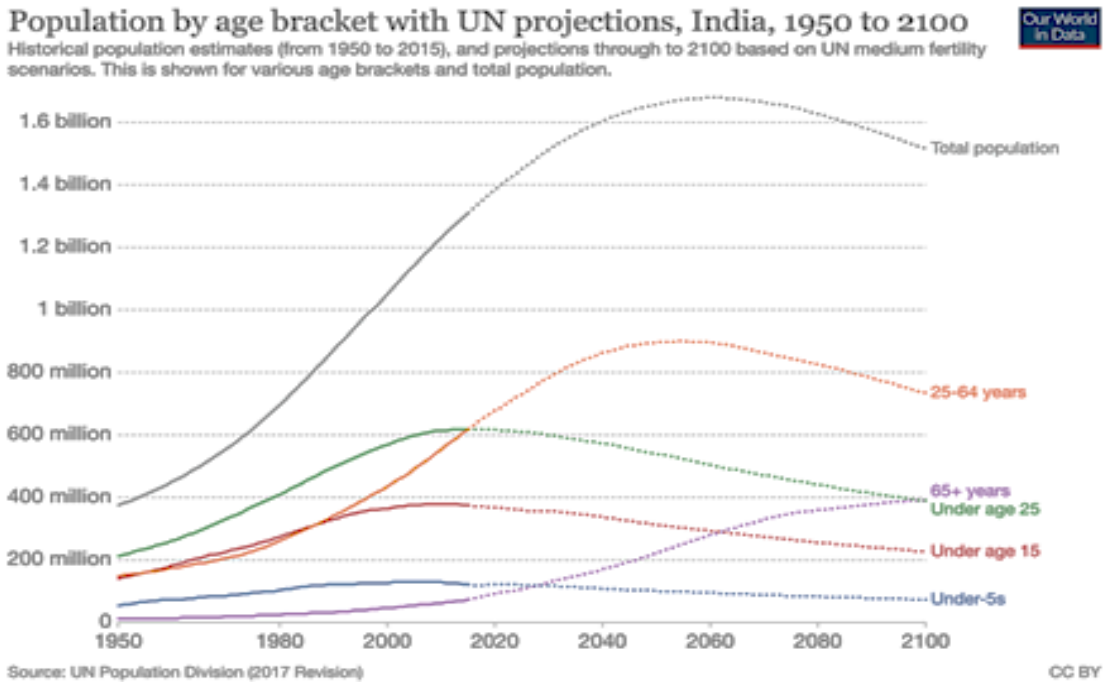

Figure 1 Population with age bracket, India, 1950-2100
Source: U.N. Population division (2017 Revision)

Evacuation during Fire is a significant issue in high-rise buildings. People on a high rise must travel great vertical distances to evacuate the building (NFPA, 2020). This issue is of much greater concern for the elderly as their physical ability to deal with disasters is less than younger people. The young and the adults living in high-rise buildings can take care of themselves during Fire, but when it comes to the elderly, they fail to evacuate the building safely. This issue needs urgent attention as the elderly (60 years and above) are growing faster than the general population (UNFPA, 2017). Today, people over 60 constitute 11 percent of the global population. By 2050, this proportion will be doubled to 22 percent, i.e., 2 billion older people. In India, the rate of growth of the elderly population is also high. It is likely to increase from 8 % in 2015 to 19 % in 2050 and, by the end of the century, to nearly 34 % of the total population in the country (USFA, 2017). The elderly population will outnumber children by 2050 as they constitute the fastest-growing segment due to longevity and a declining fertility rate. The improvements in health facilities, infrastructure, and medical care have led to the growing population of elderly globally. We cannot avoid living in high-rise buildings, but we can make them safe for all age groups. Fire is one of the significant issues in high-rise buildings.

Fire is one of the most frequent and widespread threats to public safety among all kinds of disasters. As per National Crime Records Bureau, 35 people in India die from Fire daily. Among the total fatalities of 12,748 in 2018, 63% of the fire deaths were of the country's vulnerable population (National Crime Records Bureau, 2018). The building codes and standards are obsolete and not as per the need of the vulnerable population. The fire departments in India need to be equipped more to handle the complexities involved in the safe evacuation of all the people.

Furthermore, many old high-rise buildings in India need to comply with the regulations of National building codes. Thus, the safety of

the elderly has become a significant concern in high-rise living in India, and there is an immediate need to re-look at the fire safety codes and standards. The paper attempts to understand the fire safety provisions, especially for the elderly, by comparison of building codes and standards across the globe.

2 HIGH RISE LIVING: A SOLUTION WITH PROBLEMS

The term "High rise" is also called Skyscrapers, tower blocks, tall buildings, multi-storey structures, and a building with many stories. Various countries have their definition of high-rise buildings, and it also varies from region to region. As per National Fire Protection Association, high-rise buildings are defined as "buildings greater than 75 feet (approximately 23 m) in height where the building height is measured from the lowest level of fire department vehicle access to the floor of the highest occupiable story" (NFPA, 2020). As per Emporis standards, high is defined as "A multi-story structure between 35–100 meters tall, or a building of unknown height from 12–39 floors" (Emporis, 2020). Buildings above 15 meters are high-rise per the National Building Code of India, 2016. The International Conference on Fire Safety in High – rise Buildings defines a high rise as "any structure where the height can have a severe impact on the evacuation. Building above 40 m is categorized as Ultra High-Rise Buildings. The China Fire code defines buildings over 100 m as Super Tall Buildings (Chow, Fong, Liu, Tai-keung, & Tsz-kit, 2013).

The advancement of technology has made high-rise living possible. Today more and more people prefer to stay in high-rise buildings. High-rises come with many benefits. It occupies less area on the ground giving room for open green spaces commonly used for recreation. If well-oriented, they give way to natural light ventilation and fresh air. The more you go high in a high rise, you are assured of being free from traffic noise. High-rises are also easily secured as the

building has fewer entry points. They can also offer better views. As residents share utilities, these buildings are easily maintained and managed. In the past few decades, high-rises are also considered lucrative investments by some in cities where they can be rented or leased easily. Apart from these benefits high-rises also have issues like limited gardening, as they offer only balconies. Moving heavy items from the ground floor to above is another challenge associated with such buildings. These buildings depend on elevators and staircases for movement. As elevators depend on power, if it fails, one can imagine the kind of endeavor the situation requires, depending on which floor one needs to reach. That is why elevators have alternate power backups to cope with such situations. Another major challenge with high-rise buildings is evacuation concerns during earthquakes or fires. Earthquake in the architectural profession is dealt with by by-laws associated with regions of different seismic zones, which governs building height, techniques, and design. This disaster is natural, so man has less control over its occurrence but provisions for the same help in coping with them. The high-rise buildings in Japan are built to survive earthquakes. It has one of the most resilient earthquake buildings in the world, as the buildings dance to the moves of the earth below them during an earthquake (Henriques, 2019). Among all the disasters, Fire is considered one of the worst disasters across the globe. Fire can occur anywhere, but when it happens in a high-rise building, it threatens a significant population as high rises are highly dense with limited exits. High-rise buildings are very complex and require extensive fire safety measures. The sharing of utilities and services becomes a significant concern. During a Fire, there is panic amongst people, which could lead to a stampede or mismanagement, resulting in loss of lives. One of the significant challenges in high-rise buildings is that all the fire safety management systems, such as fire alarms, smoke control, egress systems, and egress components, work together in an

integrated manner. (Heffelmire, Jalayerian, & Quiter, 2014). In a study by Rai, although the most significant motivating factor for people to live on high rise was better views and less pollution of noise and air, around 70 % of the respondents felt that fire safety is the biggest concern in high-rise living (Rai, 2011). This concern gravitates to the elderly as with age, their physical ability to quick response during disasters like Fire deteriorates. The other writing elaborates on specific issues and challenges of the elderly, which puts them at risk when they stay on a high rise.

3 ISSUES AND CHALLENGES OF ELDERLY LIVING IN HIGH RISE BUILDINGS

High-rise living evokes unsettling fear in all the residents, especially the elderly. One of the major problems faced by the elderly is their inability to move correctly. The various types of impairment which are the result of old age are:

a) **Mobility impairment, where the speed of movement and the distance that can be traveled is affected.**
b) **Sensory impairment affects the ability to see, hear, or smell**
c) **.**
d) **Intellectual or cognitive disability or mental health impairment, where the ability to understand what is happening and respond is affected.**
e) **Hidden disabilities, where the disability is not apparent or is triggered by the emergency. Hidden disabilities could include conditions like asthma or heart problems. (Census of India, 2011)**

This age-related problem increases the risk of the elderly during Fire. The elderly struggle to recognize the emergency and respond quickly during fire evacuations. This further delays their evacuation time. Hearing and vision also decrease with age, and due to this reason, they are unable to hear the fire alarm and act immediately. The

people suffering from low vision find it very difficult to see the Fire and smoke, causing delays in reacting and evacuating the buildings or reaching a safe place. The problem is further increased when they must escape through vertical means, including stairs and lifts. The vertical means of egress are not designed to meet the needs of the elderly and persons with disabilities.

Similarly, other chronic conditions like asthma and heart-related problems make the elderly more vulnerable to fire evacuations. Various studies also show that the average travel speed of the elderly is comparatively slower than non-disabled people increasing the travel time of evacuation. Further, fire safety provisions are often neglected, and the buildings must be designed per the codes and standards. The Fire safety codes and standards are also not as per the need of the elderly residents, and they become significant victims during fire safety evacuations.

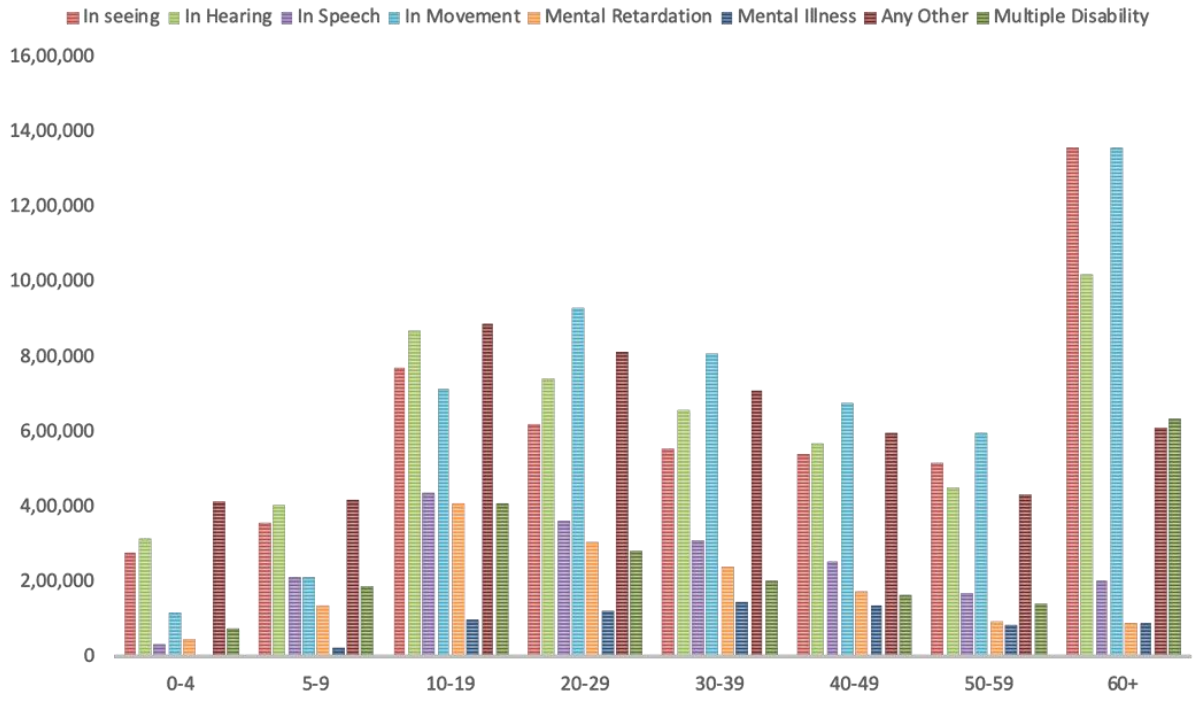

Figure 2: Disability of population with Age

[Source: C-Series, Table C-20, Census of India 2011]

4 MEANS OF EGRESS SYSTEMS IN HIGH RISE RESIDENTIAL BUILDINGS

Egress means moving out of the building safely during emergencies. A proper egress system ensures the occupant can safely exit the building during fire evacuations. Any obstruction faced by the occupants during exit may lead to severe consequences.

A means of egress is a continuous travel path from the apartment or any point in the building to a place of safety outside the building. The travel path shall be continuous and free from obstruction. The various components of Means of Egress include horizontal and vertical travel paths through corridors, stairs, ramps, lift lobbies, public ways, and familiar passages. A proper egress strategy and proper means of egress system ensure that all the occupants reach a place of safety without any hindrance. After September 11, 2001, and Grenfell Tower Fire on June 14, 2019, many studies were conducted on fire safety issues in high-rise residential buildings.

4.1 COMPONENTS OF THE EGRESS SYSTEM

The Means of Egress System consists of three major parts: Exit Access, Exit, and Exit Discharge.

1) **Exit Access: This component of the egress system leads from the last point of the occupied unit to the exit. This includes corridors, passageways, rooms, lobbies, and any other path of travel.**
2) **Exit: It is that component of the egress system which leads to a place of safety from the inside of the building or the exit access. The Exit system can be both horizontal and vertical. The Vertical Exit system is used for ascending or descending from the building and includes a staircase, ramps, fire towers, etc. The Horizontal Exit system is a place in the building or the adjoining building separated by a fire-resistant door, allowing the occupants to wait until any external help arrives.**

3) **Exit Discharge: It is that part of the means of the exit system from the termination of the Exit System to a place of safety or open area outside the building through a public way. (Nair, 2020)**

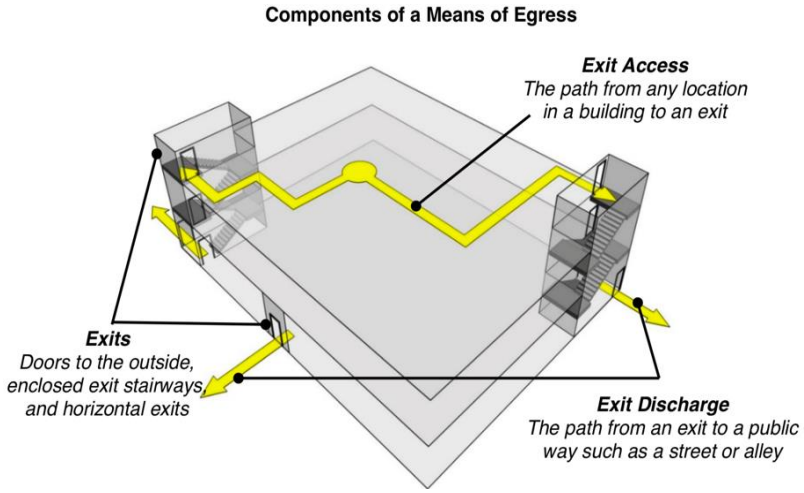

Figure3:Components of the Egress System

[Source: International Building Code (I.B.C., 2017)

The primary objective of any egress system is to facilitate the occupants to move from a place of hazard to a place of safety. The concept of an egress system becomes more critical in high-rise buildings because reaching a place of safety takes considerable time in high-rise buildings.

4.2 STATUTORY LEGISLATION IN INDIA

In India, the National Building Code, 2016 is the statutory code for fire safety provisions in the means of exit systems. Though some states in India have their own set of rules and regulations for fire safety, the provisions are majorly based on the National building code. The fire safety provisions in building design should be addressed and are not as per the codes and standards of India. This results in a lot of fire safety disasters in high-rise buildings. Further, no special provisions exist for the safe evacuation of the elderly and persons with disabilities. The government is trying to make all the buildings accessible by introducing various policies and regulations.

With the government policies like 'Sugamya Bharat Abhiyan,' most buildings are becoming accessible and barrier-free, especially public buildings in India. But we fail to address the problem of the elderly during Fire. The problem further increases regarding the safety and evacuation of elderly living in high-rise buildings. Through initial survey and case studies, it was found that the significant challenges faced by elderly living in a high rise are a) Safety equipment creating hindrances in the exit route, b) no proper fire exit map, c) poor illumination system, d) No provision of refuge floors, e) difficulty in opening the Fire rated doors of the exit route, f) no provision of firefighting lift, g) blockage of exit route due to various combustible material in the corridor, etc. The non – compliance with various provisions increases the risk of casualty of the Elderly population during a fire disaster. It is, therefore, necessary to analyze the building codes and provision of fire safety for the elderly and persons with disability systematically. Thus, through this study, various means of egress system provisions, especially for the elderly and persons with disabilities, are carefully analyzed and compared. There are various requirements for fire detection and suppression systems in the building regulations and codes. Still, the provisions that influence building design are only considered for the analysis.

5 PROVISIONS IN MEANS OF EGRESS SYSTEM FOR ELDERLY IN CODES AND STANDARDS: A COMPARATIVE ANALYSIS

For this study, the norms for fire safety from various countries were compared and analyzed. The various rules related to exit requirements, arrangement of exits and capacities of the exits, and special considerations for the elderly and persons with disabilities are considered for the study.

5.1 GENERAL EXIT REQUIREMENTS

The minimum number of exits required in any building in most countries is two, except for low-rise buildings ranging from 15m – 24 m. In some countries, occupancy per floor governs the total number of exits. As the occupancy per floor increases, the number of exits increases. As per Australia and Singapore's Fire safety building codes, a minimum of two exits are required for buildings over 24m and 15m, respectively. In the rest of the countries like the U.K., Hongkong, U.S.A., the number of exits depends on the number of Occupants per floor of the building (Refer Table 1). The I.B.C., U.S.A. requires at least two means of egress from all spaces and buildings with few exceptions. Some spaces and buildings can have one means of egress if the travel distance to an exit is short and the occupant load is low. The I.B.C. also mandates the provision of accessible means of egress in newly constructed buildings. The Approved Document B, U.K., states that one exit would suffice if it is through the Fire protected lobby.

As per the National Building Code of India, 2 Fire exits are only required in buildings that are more than 500 sqm in area. Ironically, many buildings in India are less than 500 sqm and are high-rise. As the Indian codes do not specify exits as per the height of the building or Occupancy per floor, there is no provision for alternate exits in most high-rise buildings. Building code discrepancies allow builders and developers to skip emergency exits for their monetary benefits. This puts the occupants at risk during Fire as two exits provide alternate routes if one exit is blocked. Besides several exits, maximum travel distance and dead-end corridors are crucial parts of the egress system. The maximum travel distance in all the codes ranges from 22.5m – 38 m in the case of Non- sprinkled buildings. The Indian code specifies 22.5m, which is better than other countries. The shorter the travel distance, the faster it takes to reach the exit. The means of egress during a fire are filled with smoke and

it takes a lot of time for occupants to orient themselves rightly and find a way to exit. So, it is essential to reduce the travel distance to reach a place of safety. The building codes of India fall very weak when it comes to the elderly and disabled population as there is no consideration in the means of egress system considering their specific needs.

Table 1. Number and Arrangement of Exit

PROVISIONS	INDIA	AUSTRALIA	U.A.E.	THE U.K.	U.S.A.	SINGAPORE	HONG KONG
NUMBER OF EXITS	**2 Exit If Floor Area > 500 m2**	**2 Exits If storey >6 or ht> 25 m**	**1if ht ≤15 m 2 ~ (0-500p) 3~ (500-1000) 4 >1000p**	**1 (Fire Lobby) 1~(0-60p) 2~60-600p 3 >600 p**	**1~0-50p 2~51 500p 3~501-1000p 4 >1001p**	**2 Exits > 24 M.**	**1~ 4-30 p 2~ 31-500p 3 ~501-750p 4 ~750-1000**
MAXIMUM TRAVEL DISTANCE	**22.5m (N.S.) 33.75(S)**	**22.5 M**	**61 m (S), 30 m (N.S.)**	**30 M**	**38 M**	**75M (S), 30M (N.S.)**	**24 M 45 M (Balcony Approach)**
DISTANCE BETWEEN EXITS	**22.5 M**	**45 M**	**1/2 Ds , 1/3 Ds**	**30 M**	**38 M**	**1/2 Travel Distance**	**48 M**
DEAD END CORRIDOR	**15 M (S) 7.5m(N.S.)**	**6 M**	**15m (S), 10.7(N.S.)**	**7.5 M**	**6.1 M**	**15m (S), 20m(N.S.)**	**24 m**

P- PERSONS (OCCUPANCY PER FLOOR), S – SPRINKLERED BUILDINGS,

N.S – NON – SPRINKLERED BUILDINGS, D.S. – DIAGONAL DISTANCE OF FLOOR

5.2 REFUGE AREA / HOLDING POINTS AND HORIZONTAL EXITS

The refuge area is an important component of the egress system. It holds occupants during Fire when evacuation is not possible. As the area is Fire and smoke-proof, occupants wait until external help rescues them. Compared to other country codes, India and U.A.E. do not emphasize having refuse areas. As per National Building Code, 2016, high-rise buildings with balconies do not require a refuge area till the height of 60 m (N.B.C., 2016). However, in other buildings, the refuge area shall be provided above 24 m and at every 15 m. Countries like the U.S.A., U.K., and Singapore insist on providing Refuge Areas with Voice Communication Systems for those unable to use the stairs (I.B.C., 2017). The Location of refuge areas shall be inside Fire protected lobbies directly connected to external stairways. The height of a building does not determine the need for a refuse area; rather, it is recommended to have it on every floor as a fire safety measure. This shows that Indian codes completely neglect the needs of the elderly and disabled population in an emergency. These people cannot escape by themselves, so the refuge area on all the floors should be a mandatory provision. Other provisions related to the number of wheelchairs, corridor width, and Location of refuge areas are at par with other countries' recommendations. (N.B.C., 2016)

Table 2. Refuge Area / Holding Points and Horizontal Exits

PROVISIONS	INDIA	AUSTRALIA	U.A.E.	THE U.K.	U.S.A.	SINGAPORE	HONG KONG
REFUGE AREAREQUIREMENT	**Above 24m, thereafter 15m**	**All Floor**	**Above 90 M**	**All Floors**	**All Floors**	**All stories except at the first floor**	**Every floor has more than an area of 200 m2.**
PROVISION OF WHEELCHAIR (N.O.S.)	**1 ~ 200 Ps**	**1**	**1 ~ 200 Ps**	**1**	**1 ~ 200 Ps**	**2**	**1**
SIZE OF WHEELCHAIR IN REFUGE AREA	**0.9 sq. mt**	**-----**	**0.76m x 1.22m**	**0.9 x 1.4m**	**-------**	**0.9m x 1.4m**	**1.5 m x 1.5 m**
WIDTH (CORRIDOR)	**1.2m**	**1 m ~ 100 ps**	**1.2 m**	**0.9m**	**1.21m**	**1.2m**	**0.85 m**
LOCATION OF PWD HOLDING POINTS	**Separate &Dedicated Area**	**Separate &Dedicated Area**	**Inside Protected Stairwell**	**Inside Protected Stairwell**	**Inside Protected Stairwell**	**Evacuation Lift lobby, Fire Lift, Staircase**	**Evacuation Lift lobby, Fire Lift, Staircase**

PROVISION OF A VOICE COMMUNI-CATION SYSTEM	**Yes**	**Yes**	**Yes, with the provision of pre-recorded messages**	**Yes**	**Yes, with Audio and Video Signals**	**Yes, with 24 hrs operated control point**	**Yes, with a closed-circuit intercom link**
HEIGHT VOICE COMMUNICATION SYSTEM	**-----**	**-----**	**0.9m 1.68 m**	**------**	**----**	**0.8m 1.2m**	**-0.9m - 1.2m**

5.3. FIRE ALARMS, SIGNAGES, AND ILLUMINATION SYSTEM

The Fire alarm is essential in the Means of Egress system to warn occupants during a Fire. The alarm gives the first clue of fire occurrence and implicitly signals the occupants to initiate the evacuation process at an individual level. Many countries have enhanced Fire alert systems by introducing a vibrating alert system along with flashlights to assure that the initial warning of Fire reaches everyone. The Fire Safety code of Singapore stresses Home Fire Alarm Devices(HFAD) with indicator lights installed in the Circulation area/ Escape Route, living room, corridor, and Stair Landing. Similarly, the codes of the U.S.A. and U.K. also stress on the importance of Fire alert system by the use of flashing beacons, vibrating pagers or pillows, and similar alert devices to consider the needs of people with hearing impairment. The National Building code of India though have provision of Fire alarms along with Visual

Alarms with flash lights but it fails to address any specific requirements inside the house within the apartment buildings.

Along with Fire Alarm systems, the signages and Illumination systems play a crucial role in guiding the Occupants to place of safety during fire evacuations. As fire results in a situation associated with panic, confusion, and anxiety, a proper orientation through signages can ease the evacuation process. The International Building Codes of U.S.A. requires all the Exits and Exit Doors to be marked with illuminated exit signs. Also, the code mandates the provision of tactile "EXIT" sign adjacent to doors and egress staircase, corridors, and the exit discharge route. The standard requires that all the signages meet both tactile and visual criteria. Both U.K and Australia also mandate the provision of tactile and braille signs in all the exits, exit access and exit discharge in order to address the needs of the Elderly. On the other hand, there is no clarity on the provisions in the National Building Code of India as both visual and tactile consideration are not provided in the signages. Lack of clarity in the codes and standards results in poor illumination and signages makes the vulnerable population at risk in India.

Figure 4 Examples of Signs Required to Meet Tactile and Visual Criteria [Source: (I.B.C., 2017)]

5.4 EXITS – STAIRS, CORRIDORS, RAMPS, EVACUATION LIFT

Stairways, handrails, Ramps and Evacuation lift forms the major part of the means of egress system. The I.B.C., 2018, mandates the provision of visual contrast on tread nosing or the leading edges of

treads which are helpful for people with low vision. The treads and landings should be designed in such a way to prevent the accumulation of water which will create problem for Elderly during evacuation Process. Further, as per A.D.A. standards, handrails are required on both sides and must be continuous within the full length of each stair flight. The handrail surfaces should be free from abrasive and sharp elements and facilitate power grip along the handrail length. The Building Code of U.A.E. also mandates the provision of a marking strip which can be applied as a paint that is integral with the nosing of each step (CDFCC, 2018). Singapore Codes also has the provision of non-slip mats or tiles at the upper landing of the staircase or placing of non-slip strips with contrast in color at the edge of each step of the staircase. All these provisions are very helpful for elderly people while evacuation. Almost all the building codes have the provision of slip resistant tiles or materials to allow the elderly to safely evacuate the building. Again, as per National Building Codes, dedicated provisions for safe evacuations of Elderly are missing in the mandatory provisions.

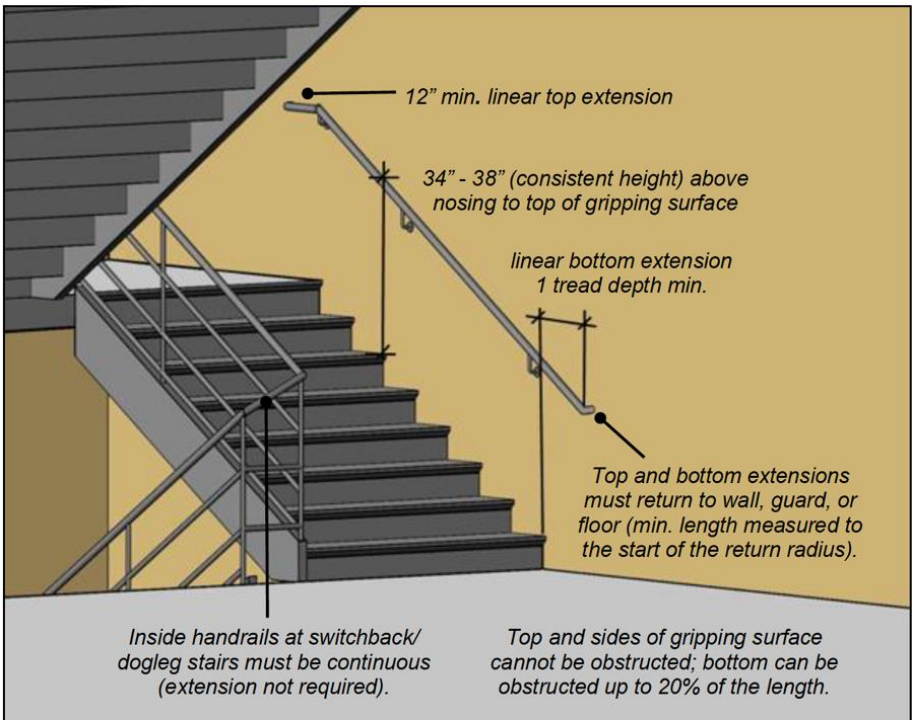

Figure 5 Stairway and Handrail Requirement[Source : (I.B.C., 2017)]

Most of the Building codes like U.K., U.S., U.A.E. and Hong Kong across the world talk about the provision of Evacuation lift, Wheelchair lift, Platform lift to be used by person with disabilities during fire evacuations. The Indian Code again have very less clarity on the use and provision of Evacuation Wheelchair lifts during fire evacuations.

The provision of Ramps in high rise building help in easy evacuation of elderly and person with disabilities. As per the Approved Document M, U.K., ramps can be used as a part of the Exit route. Similarly, Singapore Codes also allows the use of ramps as a Internal and External Means of Escape. The provision of slope in most of the codes are in the range 1:10 – 1:14. Again, the Indian code fail to address the clarity in ramps being used as a means of escape.

6 CONCLUSION

With the increasing urbanization, one finds a shift towards a high rise living. These buildings have a major challenge of coping up with disasters, especially Fire. The resilience of these buildings towards Fire depends on human measures in the form of architectural solutions. Some countries like U.S.A., U.K. and Singapore are much considerate towards specific provisions of Fire. Their Means of Egress system defined in building codes have been developed with much precision and tested simulations. Ironically, India being most populated, and it's cities being highly dense neglects major fire considerations as is reflected in the building codes. Most of the buildings in India also face management and maintenance issues. The fire safety equipment's are not fitted in the proper locations, which also leads to panic among the occupants. Lack of provision of signages and information hinders the evacuation of Elderly and Persons with Disabilities. Due to no clarity in the building code, most of the staircase lobby are open to lobby and corridor without the

provision of fire door which leads to smoke and Fire entering the stair lobby making it unusable during fire evacuations. This leads to people getting trapped and are not able to evacuate. Some basic necessary provisions like minimum two exits and availability of refuge area on every floor is not mandate in the code. This leads to panic situation during fire evacuations. As the general egress provision are weak, one finds a complete dearth of address towards specific needs of the elderly and people with disability. Thus there is a major need to develop a performance based fire safety framework for elderly to provide decision makers, professional bodies, local authorities a sound indicator of fire safety in high rise residential buildings for Elderly.

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