A Comparative Analysis of the Provisions of Smoke Control Systems in Buildings of National Building Code of India with other International Building Codes.

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Abstract— The paper aims to study the requirements for Smoke movement and Control in buildings provided in National Building Code of India (NBC) 2005 and compare the provisions for the same with that in the International Building Code (IBC) 2006 andNational Fire Protection AssociationNFPA 92A- Recommended Practice for Smoke Control Systems, 2000 Edition. It aims to study these documents in terms of their purpose, content and scope for Smoke Control in Buildings. It is an attempt to analyse and compare the approach to smoke control issues of each code.

Index Terms— Air changes, Evacuation, Fire prevention, Fire protection, Pressurization, Smoke control, Smoke movement, Smoke Venting, Toxic gases.

1 INTRODUCTION

Various past fire incidences in buildings and the number of fatalities due to it, has made fire prevention and protection one of the basic concerns for planning, design, construction and operation of buildings. Among all the building related fire deaths nearly three fourths are from inhalation of smoke and toxic gases produced in fires rather than from exposure to flame or heat. The great amounts of toxic products present in smoke are hazardous out of which Carbon mono-oxide (CO) is a major cause of deaths. It is therefore, desirable that all large and tall buildings of huge assemblage especially the escape routes are designed for Smoke control. This is more important for people awaiting evacuation to sustain their lives, especially in high rise buildings.

Smoke control is necessary for:

- the safety of persons by keeping the escape routes smoke free for evacuation.
- protection of persons and property by improving the conditions for fire fighting.
- achieving direct cost savings by allowing larger standard fire compartments and/or reduced fire performance requirements for load bearing structures.

The primary objective of smoke control is thus to reduce the hazard due to smoke by controlling its movement, and by reduction of its concentration to increase visibility.

The statistics in the below mentioned table 1 demonstrate that deaths (in UK) from furniture ignited in dwellings have more than doubled and that the majority of cases were caused by smoke and toxic gases.

Table 1: Causes of Deaths in Furniture Fires in Dwellings and in other Fires Classified by Survey Year (UK)

Type of fire and causes of deaths	1962	1967	1970	1972
All fire deaths	667	779	839	1078
Burns	480	322	358	459
Smoke or toxic fumes	150	382	425	502
Other	37	75	56	117
Deaths in furniture fires in dwellings	156	212	270	289
Burns	90	59	47	79
Smoke or toxic fumes	56	140	213	189
Other	10	13	10	21
Other deaths	511	567	569	789
Burns	390	263	311	380
Smoke or toxic fumes	94	242	212	313
Other	27	62	46	96

Source: Fire Safety in Buildings, Jain V.K, New Age International ltd. Publishers, second edition, 2010. (7)

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It is therefore important to consider measures which will help to minimize the smoke hazard by containing it to a space, regulating its movement and exhausting it to the atmosphere. The Building regulations and statutory control systems are directed primarily towards limiting the size of a fire, with the final objective of minimizing hazard to life and property. A fire may be confined to a specific area, but smoke can migrate to various parts of a building and is therefore a potential threat to occupants far removed from its source as well as to occupants in the immediate vicinity. Cases have occurred where occupants on floors far removed from the fire floor have lost their lives. The byelaws in many countries do not define, as a requirement, the design of buildings to ensure that the smoke does not enter the protected routes for escape in an emergency.

In India also the situation is not very different. The recent example being the fire at AMRI Hospital at Calcutta on 11th Dec 2011, in which the death toll was 89. While many patients died of burns, several others died due to suffocation caused by Carbon monoxide accumulation all over the building. The tragedy unfolded over many hours as patients were suffocated to death, some trapped in their beds, others dying in their sleep, too infirm to escape the smoke. The worst affected were the ICU patients who died due to asphyxiation.

Looking at the importance of Smoke control in buildings it becomes very necessary to review the provisions made in the National Building Code of India and the provisions inother countries, like International Building Code (IBC) 2006 and the National Fire Protection Association NFPA 92A– 2000.A comparative study of the provisions made in the National Building Code of India 2005, International Building Code (IBC) 2006 and the National Fire Protection Association NFPA 92A– 2000 (Recommended Practice for Smoke Control Systems) with respect to smoke control systems is carried out and tabulated in table 2.

TOPIC	NATIONAL BUILDING CODE OF INDIA-2005	NFPA92A 2000	INTERNATIONAL BUILDING CODE-2006.
SMOKE CONTROL SYSTEMS	No separate related section is provided. Few considerations on smoke venting are laid down in Section 3.4 under General requirements of all Individual Occupancies.	This recommended practice applies to the design, installation, testing, operation and maintenance of new and retrofitted mechanical air handling systems also used as smoke control systems. **NFPA 90 A**, *Standard for the installation of Air-Conditioning and Ventilating Systems, for requirements for the shutdown of smoke control systems and the use of smoke compartmentation.* **NFPA 92B** *Guide for Smoke Management Systems in Malls, Atria, and large areas, for maintaining tenable conditions within large zones of fire origin, and NFPA 204, Guide for Smoke and Heat Venting.*	Section 909applies to mechanical or passive smoke control systems to establish minimum requirements for the design, installation and acceptance testing for smoke control systems intended to provide tenable environment for evacuation and relocation of occupants.
a. Smoke Control Systems and applicability	Nil	Chapter 2 Discusses various types of smoke control systems and reviews advantages and disadvantages of each type.	Smoke control systems shall have systems designed in accordance with the 909 section and the generally accepted and well-established principles of engineering relevant to the design.
b.Principles of Smoke Control	Nil	Section 1.5 The principle factors that cause smoke to spread to areas outside a compartment like Stack effect, Temperature effect on fire, Weather conditions, particularly wind and temperature and Mechanical air-handling systems are covered.	Section 909.4 Factors such as Stack effect, Temperature effect of fire, Wind effect, HVAC systems, Climate are covered under this section.
c. Airflow	Nil	The principle of airflow at sufficient velocity is commonly used to control smoke movement through openings. The Design information for design velocity through an open door sufficient to limit smoke backflow during building evacuation is provided. *(Design in-*	Section 909.7 Airflow shall be directed to limit smoke migration from the fire zone is covered under this section. The geometry of the openings shall be considered to prevent flow reversal from turbulence effects.

		formation is provided in ASHRAE/ SFPE, Design of Smoke Management Systems).	
d.Design parameters	Nil	Section 1.6 Detailed engineering design information is contained in ASHRAE/SFPE, Design of smoke management systems, and the NFPA publication, Smoke movement and control in High rise buildings.	
e.Pressurisationofstaircase	Section 4.10 Pressurizatuon of staircase adopted for high rise buildings, buildings with mixed occupancy/ multiplexes with area more than 500 Sqm. Two methods of pressurization used are mentioned but not detailed out.	Section 2.3 A pressurizedstairwellsystem to be designed to meet the minimumand maximum pressure differences is elaborated. Section 2.2.2 mentions the stairwell pressurization system used in combination with other Smoke-control systems. The methods provided in *ASHRAE/SFPE, Design of Smoke Management Systems*, can be used to design systems to accommodate anywhere from a few open doors to almost all doors being open.	Section 909.6 The primary mechanical means of controlling smoke by pressure difference across smoke barriers is covered.
f.Elevator Smoke control	Nil	Section 2.4 Several methods of correcting the problem of smoke movement through elevator shafts have been proposed and investigated.	Section 909.21 Where elevator hoist way pressurization is provided in lieu of required enclosed elevator lobbies, the pressurization system shall comply with sections 909.21.1 through 909.21.11 .
g.Smoke venting	Section 3.4.12 No related section, included in General requirements of all individual occupancies. It mentions the provision of smoke venting facilities in form of roof vents, open and automatic in action, with 12 air changes per hour, and venting for basements in Annexure C. Smoke venting for industrial buildings is covered in Annexure D.	Section 3.2.4 A separate system supplying outside air for ventilation can be used for smoke control, which may though not be adequate for full pressurization.	Section 910 Smoke and heat vents, or mechanical smoke exhaust systems, and draft curtains shall conform to requirements of this section.
h.Zoned Smoke control	Nil	Section 2.5 The concept of zoned smoke control intended to limit the smoke infiltration into the stairwell withina building is discussed in this section. Design guidance on dilution temperature is provided in ASHRAE/ SFPE, *Design of Smoke management Systems*.	No related section.
i.Areas of refuge	Nil	Section 2.6 Smoke control for areas of refuge can be provided by pressurization. Methods of design for areas of refuge are presented in ASHRAE Transactions paper, *"Design of Smoke Control Systems for Areas of refuge."*	No related section.

j.BUILDING EQUIPMENT AND CONTROL Heating, Venting and air conditioning (HVAC) Eqipment	Section 3.4.11.2 Air conditioning and ventilating systems shall be so installed and maintained as to minimize the danger of spread of fire, smoke and fumes from one floor to other or from outside to other occupied building or structure (elaborated in Annex C.17)	Chapter 3.0 Conventional building HVAC systems can be used to provide building smoke control. Various types of equipment and controls and guidelines for adapting the majority of systems aredis-cussed.	Section 909.10 Equipments shall be suitable for its intended use and probable exposure temperatures for which the rational analysis indicates and as approved by fire code officer.
k.Smoke dampers	Section 3.4.11.2 Mentions the provisions of dampers designed to close automatically in case of fire thereby preventing spread of fire, smoke and fumes from one floor to another.	Section 3.3 Smoke dampers used to protect openings in engineered smoke control systems are classified and labelled in accordance with *UL 555S, Standard for Safety Leakage Rated Dampers for use in Smoke Control Systems.*	Section 909.10.4 Automatic dampers, regardless of the purpose for which they are installed within smoke control system, shall be listed and conform to the requirements of approved recognized standards.
l.Smoke Control System Analysis	Nil	Chapter 4.0 Design analysis of smoke control systems performed through design equations and network computer flow program is elaborated. The design equations for analysis of pressurised stairwells and elevator smoke control are based on equations provided in *ASHRAE/SFPE, Design of Smoke management Systems.* Several network computer models have been written to calculate steady state airflow and pressures throughout the building. CONTAM and ASCOS are two such models used.	Section 909.4 Emphasises on the requirement of rational analysis supporting the types of smoke control systems to be employed, their methods of operation, systems supporting them and method of construction to be utilized to be accompanied by the submitted construction documents. System to be designed taking into consideration stack effect, temperature effect on fire, wind effect, HVAC systems, climate, duration of operation.
m.Testing	Nil	Chapter 5.0 Recommendations for testing of smoke control systems is provided along with the test procedures. 1998 edition of NFPA 265 which incorporated tests for measurement of smoke opticaldensity, rate of smoke release and also total smokerelease. This was a unique feature which was notavailable in many other international standards.	Section 909.3 The special instructions and tests required by this section shall be conducted under the same terms in Section 1704. Section 909.18 Acceptance testing Devices, equipment, components shall be individually tested.
n.Smoke Barrier Construction	Nil	No related section	Section 909.5 Shall comply with 710 and constructed to limit leakage areas exclusive of protected openings.
o.**Design Fire**	Nil	No related Section	Section 909.9 Shall be based on rational analysis performed by the registered design professional and approved by the fire code official.
p.Detection and control systems	Nil	Section 3.4.5 An automatic smoke detection system can be used to automatically activate a zoned smoke-control system. The location and zoning of smoke detectors shall be carefully analysed to achieve a smoke detection	Fire control systems providing control or output signals to mechanical smoke control systems shall be equipped with a control unit complying with UL 864 and listed as smoke control equipment.

		system that will reliably indicate the correct zone.	
q.Engineered ventilation System	Nil	No related section	Section 909.20.4.2.1 Min. of 90 air changes required per hour exhaust from vestibule and sized for three vestibule simultaneously
r.Stand by power	Nil	Section 3.7 Whether standby is required should be considered for smoke control systems and their control systems. Generator required in 1 hr rated room with 2 hr fuel supply.	Section 909.20.6.2 Mechanical vestibule, shaft ventilation systems, and detection systems shall be powered by approved standby power system per Ch 27.
s.Smoke and Heat vents	Section 3.4.12 Smoke venting facilities for safe use of exit shall be automatic in action and natural draft smoke shall utilize roof vents or vents in walls etc. Smoke exhaust equipment to have minimum capacity of 12 air changes per hour.	Covered by NFPA 204 M	Section 910 Smoke and heat vents, or mechanical smoke exhaust systems and draft curtains shall conform to the requirements of this section.
t.Smoke proof enclosures	Nil	No related section.	Section 909.20 where required by Section 1022.10, a smokeproof enclosure shall consist of an enclosed interior exit stairway and an open exterior balcony or ventilated vestibule.

ANALYSIS AND RECOMMENDATIONS

This comparison and analysis has identified the differences between the National Building Code 2005, International Building Code and National Fire protection Association Code NFPA 101 for Smoke control in Buildings. NFPA 92A and IBC cover almost all types of systems used to address the impact of smoke from fire, with mandatory provisions for the design, installation, and testing of both new and retrofitted smoke control systems in buildings -- including openings and leakage through egress doors in stairways.

Both the IBC and NFPA 92A incorporate a holistic implementation of Smoke control requirements within their scope, and are revised on a regular basis for the same. The National Building Code, last revised in 2005, covers the Life and Fire Safety requirements in Part IV, but it does not have a separate section on Smoke Control systems in the building.Various points in the comparison are touched in the code but such details are not provided which will lead the designer to certain design solutions for Smoke control in buildings.In the NBC the Fire protection considerations for venting in Industrial buildingsis provided in Annexure D, but smoke venting forother occupancies is not considered at all.

Looking at the importance of Smoke Control in buildings there is an urgent need to include them as a separate section inthe National Building Codeof India to result in a holistic approach that can be readily utilized by design professionals for incorporating Smoke control in buildings.

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