Scenario in Developed Countries for Multistoried Buildings subjected to Multiple Hazards

Dr. Nilesh S. Jha
Faculty in Civil Engineering Department, Government Polytechnic Ahmedabad

Abstract

Developed countries like United States, Canada, Japan, European Countries and New Zealand have been using advanced technologies and tools for mapping hazards. However, in India, effective and efficient use of these tools and technologies has been a challenge. Geographic Information System (GIS), Remote Sensing (RS) and Ground Probing System (GPS) considered very important tools for mapping of hazards. GIS helps in effective storing, updating, accessing, map developing and sharing of information. It can thus act as a risk assessment tool for providing necessary information for planning, zoning and decision making *(lidija & Ivan, 2009)*. Mitigation strategies can be planned for any disaster using the information available and map formulated in GIS. For developing hazard maps, spatial information together with community based local knowledge is very important. The present research paper focuses on the practices adopted in countries like States, Canada, Japan, European Countries and New Zealand for multi-storeyed buildings for multiple hazards simultaneously. Comparision has also been made with procedures adopted in India for mapping hazards by studying relevant code for hazards.

Key Words: *Multiple hazards[1], Buildings[2], GIS[3].*

Introduction

The affected areas due to hazards in urban settlements include densely populated areas of old city; important buildings which include schools, hospitals, government offices, secretariats, lifelines like flyovers, bridges, buried utilities of water supply, sewerage, telephone lines, gas lines, electricity and heritage buildings. When these hazards strike, the city area has direct and indirect impact leading to a disaster. Cities of India are more prone to the risk of multiple hazards depending upon the geographical location and topography. The Government of India – UNDP Disaster Risk Reduction Program (2009 – 2012) has identified some of the cities in various states of India that are exposed to risks of multi-hazard. Developed countries like Japan, US, Europe and New – Zealand are exposed to the risk of Multihazard and they have prepared the Multihazard management plan for implementation whenever these hazard strikes the city. The focus of this research is to study the effect of the fire following the earthquakes and to compare the practices adopted in developed countries during planning stage and implementation stage of multistoried buildings so that the building is exposed to the calculated risk. Efforts have also been made to study the building codes of respective countries and compare it with NBC – 2005 for fire suppression techniques for multistoried buildings.

Effect of Fire following Earthquakes

The localities and populations affected by fire followed by earthquake are equally important. The time of the day is important as more human activity occurs during working hours, resulting in higher ignition rates due to pantry operational at those times [2]. Wind and humidity also play a dominant role in spread of fire. Wind Direction and speed plays a crucial role in fire spread and control. During dry atmosphere, it would take more time to control fire in comparison to humid atmosphere. Initially every citizen will try to suppress some fires, but when they realize that the fire is beyond their capabilities, they will scramble to call the fire department by telephone.

Impact of Fire following Earthquake [2]

Following are the list of impacts of fire following earthquake:

1. Loss of life
2. Loss of property, loss due to repairs/reconstruction and cost to insurance companies
3. Water supply will be affected. Water pressure could drop in some portion due to pipe breaks and tank ruptures.
4. Gas related ignitions also take place. Automatic gas shut-off valves are the best way to reduce these ignitions.
5. Communication system may be affected as saturation may reduce functionality for some hours.
6. Transportation can be a major problem as road and bridges may get damaged and would further lead to traffic jam resulting in delay in rescue operations.
7. Power often fails due to automatic system trip but certain electrical appliances can cause fire.

Codal Practices in Developed Countries and India

United States

The American Concrete Institute is the principal organization providing documentation for design of concrete structures. ACI/TMS 216.1-07, Code Requirements for Determining Fire Resistance of Concrete and Masonry Construction Assemblies*,* provides basic information for design of concrete structures to resist standard fire exposure. This document is being updated with new guidance for fire design. The Concrete Reinforcing Steel Institute has a handbook on fire resistance of reinforced concrete (CRSI 1980), and the Society for Fire Protection Engineering (SFPE). Handbook of Fire Protection Engineering (SFPE 2002) has a chapter on concrete design that gives an overview of concrete structures performance in fire [4].

Canada

Most design standards (concrete, wood, and steel) in Canada refer to the National Building Code of Canada (NBCC 2005) for fire resistance specifications, and a new standard for fibre-reinforced plastics (FRP) is CSA-S806, which was published in 2002 and includes design charts for the fire resistance design of FRP-reinforced concrete slabs [4].

European Union

By far the most comprehensive international documents for structural design of buildings and structures in fire conditions are the Structural Euro codes. The use of wood is restricted by impact of local and regional interpretation of fire regulations and lack of knowledge throughout the decision chain from regulator to designer [4]. All Euro codes relating to materials, have a Part 1-1, e.g. EN 1995-1-1, which covers the design of civil engineering works and buildings, and another Part 1-2, e.g. EN 1995-1-2, which deals with the structural fire design.

Performance-Based Engineering *(In Developed Countries)*

During recent years, all the above mentioned countries and other developed countries lay emphasis on Performance-Based Engineering (PBE). PBE is based on new building technologies and structural design to better meet heightened public expectations and to enable more reliable prediction and control of building performance [4] [3]. Building codes are key tools for managing fire risk in building construction in the interest of public safety, but the risks addressed by code provisions have been managed judgmentally.

PBE has focused particularly on two areas: fire engineering and earthquake engineering. The motivating factors behind PBE in the fire engineering area are strongly economic in nature. Fire protection is an integral part of the built environment. Performance-based fire protection design considers how fire protection systems perform given the selected building design and its expected fire loading. Various guidelines have also been prepared to suppress fire following earthquake by taking into effect the fire resistant design during the design stage of project.

The performance based design (earthquake and fire) in developed countries includes the following steps [7]

1. Resistance of construction materials is considered. The various thermal and mechanical properties to be used are thermal conductivity, specific heat, density, compressive strength, E, G, μ, α, η, w, tensile strength and creep parameters. Other factors considered are geometry of structural components, insulation by applying coatings, encasement or enclosure around components, rcc with adequate concrete cover.
2. Function in structural system i.e. allowable building height and floor area depending upon the maximum height that a fire fighting equipment can serve.
3. Performance objectives of the building. The analysis includes both thermal response and mechanical response of structural components and systems. Thermal and mechanical properties of structural materials are temperature-dependent. The deterioration in structural strength and stiffness with increasing temperatures, nonlinear material behaviour, effects of thermal expansion, and large deformations should be taken into account. The appropriate limit states include excessive deflections, connection fractures, and overall and local buckling.
4. Structural engineering task becomes more complex due to performance based analysis.

The above four steps clearly indicate that the planning of building is not the task of only structural engineer and architect but there are other key persons also who will have to take part actively. In developed countries, during the planning stage of multi-storied building, a team of structural engineer, civil engineer, chemical engineer, architect, mechanical engineer, electrical engineer and fire protection engineer is prepared and each of the major decisions are taken only after consulting the concerned person. For example, if a wall is intended to increase available occupant egress time or to eliminate the need for sprinklers in a particular area, then the interior designer must be made aware that the wall cannot be changed without changing the fire protection design [6].

1 Architectural [6]

Areas of concern to fire protection engineers that interface with architectural engineering include:

1. Locations of buildings
2. Exposures to buildings
3. Sizes of buildings
4. Sizes of fire areas
5. Building layout
6. Combustibility of building finishing materials
7. Security issues.

2 Chemical [6]

Areas of concern to fire protection engineers that interface with chemical engineering include:

1. Materials hazards
2. Materials storage
3. Process hazards evaluation
4. Process utilities

3 Electrical [6]

The bulk of the electrical work for most building projects is usually designing ordinary circuits for building electrical power and laying out the lighting systems.

Because fire alarm, security, and fire protection control systems must be wired, their design often falls to electrical engineers. Meeting the generic electrical code is not sufficient. To design these systems properly, the electrical engineers must be familiar with a host of electrically related fire protection requirements. Fire protection engineering interfaces with electrical engineering in the following areas

1. Building system controls
2. Fire detection and alarm systems
3. Extinguishing system control
4. Electric motor-driven fire pumps
5. Emergency lighting
6. Backup power supplies
7. Electrical equipment for hazardous (classified) locations
8. Electrical protection systems.

1 Mechanical [6]

Fire protection systems that interface with the mechanical discipline include:

1. Piped fire protection systems
2. Fire protection water supplies
3. Pneumatic power and control systems
4. Building HVAC systems
5. Smoke control and smoke management systems
6. Area ventilation systems.

5 Structural [6]

The interface between fire protection and structural engineering includes the following specific areas:

1. Combustibility/fire resistance of building structural materials
2. Fireproofing of building structural elements
3. Fire resistance ratings of barriers
4. Protection of openings
5. Deflagration venting for buildings
6. Flood, earthquake, snow, and wind design

Thus fire safety is provided in a multi-storied building by a combination of active fire suppression and passive fire protection. Active fire suppression includes fire fighting devices, smoke control systems and special extinguishing systems, including those using wet or dry chemicals, foam, or "clean" agents and automatic devices such as sprinklers. Passive fire suppression includes preventative measures like fire barriers, fire doors, and other insulations and spray applied fire protection that delays the effect of fire on structure, detection systems with interlocks for door or damper closure, HVAC shutdown, or process shutdown. In addition to this, multi-storied buildings are provided with fire alarm system consisting of interconnected devices and controls to alert building occupants to fire or dangerous conditions and provide emergency responders with information on those conditions. Clear and concise information will enable responders to operate efficiently and safely. Alarm devices indicate a situation requiring emergency action and normally activate evacuation signals [4].

Fire Systems in Use in Developed Countries

A fire alarm system consists of interconnected devices and controls to alert building occupants to fire or dangerous conditions and provide emergency responders with information on those conditions [6]. Clear and concise information will enable responders to operate efficiently and safely. Fire alarm systems monitor alarm-initiating devices such as manual pull stations, automatic detectors, or water flow indicators (Figure -1.1). If a signal is received, the control components process it via software programs or relays (Figure -1.2). The system then activates audible and visual evacuation notification devices (Figure -1.3); sends a remote signal to the fire service or other authorities; displays the location of the alarm; recalls elevators; and controls ventilation systems. Systems can vary widely in complexity.

FIGURE - 1.1: Initiating device (Smoke detector)

FIGURE - 1.2: Control Panel. (Source: OSHA: 3256 – 07N - 2006)

FIGURE – 1.3: Notification device (Horn / Strobe)

A basic, fundamental system consists of a control panel, initiating devices, and notification devices. On the other end of the spectrum are complex selective voice evacuation systems with integrated fire department phone communications systems. Detection systems have devices that automatically sense fire or smoke and are often integrated into fire alarm systems [6].

Fire Suppression System in India

In India, various guidelines and codes have been formulated by government of India with regard to different hazards for designing multi-storied buildings. Initiative has also been taken by Government of India – UNDP (2009 – 2012) to develop a Multihazard map for the country but this map has been formulated for the hazards like earthquake, flood, wind and cyclone only. Nowhere the effect of fire is taken which is very common after earthquakes. The National Building Code of India – 2005 addresses all the hazards but simultaneous effect of different combination is not taken into consideration. Further it is clearly mentioned and accepted by government of India that effective implementation of these codes has been a major challenge. The Ministry of Home Affairs has undertaken a study on fire hazard and risk analysis of fire services in the country and the objectives of the study are to identify gaps in existing fire services and futuristic strategy to bridge gap and steps for mitigating impacts of a fire hazard. Government of India has prepared a list of multi-hazard districts and it includes the city of Ahmedabad.

Further, basic materials used in buildings do not possess fire resistance [7]. Fire resistance is a property assigned to building elements that are constructed from a single material or a mixture of materials. A fire resistance rating is the fire resistance assigned to a building element on the basis of a test or some other approval system. Some countries use the terms fire rating, fire endurance rating, or fire resistance level, which are usually interchangeable [8].

The three failure criteria for fire resistance are stability, integrity, and insulation. To meet the stability criterion in a standard fire resistance test, a structural element must perform its load-bearing function for the duration of fire test without structural collapse [7]. The integrity and insulation criteria are intended to test the ability of a barrier to contain a fire and to prevent it spreading from the room of origin. To meet the integrity criterion, the test specimen must not develop any cracks or fissures that allow flame or hot gases to pass through the assembly. To meet the insulation criterion, the temperature of the cold side of the test specimen must not exceed a specified limit; usually an average increase of 110°C and a maximum increase of 180°C at a single point *(ASTM 2007)* [8]. An increasing international trend is for fire codes to specify the required fire resistance separately for stability, integrity, and insulation. For example, a typical load-bearing wall may have a specified fire resistance rating of 60/60/60, which means that a 1-hour rating is required for stability, integrity and insulation, respectively. If the wall was non-load bearing, the specified fire resistance rating would be - /60/60. A fire door with a glazed panel may have a specified rating of - /30/ - , which means that this assembly requires an integrity rating of 30 minutes, with no requirement for stability and insulation [8].

Preventive Measures for Fire in Developed Countries

The following preventive measures considered during planning phase of building enhance fire resistance in buildings and also can prevent structural collapse of building during earthquake followed by fire [7].

1. Control fuel quantity and locations.
2. Control fire spread.
3. Control ventilation characteristics.
4. Protect construction materials.

1. Fuel Control

Designers usually have limited control over the fuels that are brought into buildings. In large measure, the occupancy determines the fuel load inside buildings since much of the fuel in buildings is derived from its contents. For instance, ceramic floor tile and concrete-based floor finishes add no fuel to a building, and they have the added advantage of providing thermal inertia that absorbs heat and reduces fire severity. Painted plasterboard walls over metal studs contribute less fuel to a fire than do wood finishes and many manufactured cubicle partition systems. Similarly, plasterboard ceilings constitute lower fuel load (and better fire barriers) than do certain ceiling tiles.

2. Control of Fire Spread

Effective compartmentation of interior spaces can limit fire spread by creating barriers among spaces. Features of effective compartmentation include fire-rated partitions and proper protection of penetrations through these partitions. Fire-rated partitions prevent the passage of flames, hot gases, and heat transmission to the unexposed side of the barrier. This is typically accomplished by having the barrier extend from floor slab to floor slab particularly if non-fire rated ceiling tiles are used in the facility.

Additionally, architectural and functional features can effectively impact the potential for fires to spread. For instance, window size, orientation, and spacing from floor to floor can contribute to the fire intensity by influencing how easily fire spreads from one floor to another. Tall windows, closely spaced from floor to floor, in general are more likely to contribute to vertical spread than are smaller windows with deep spandrel panels in between.

3. Ventilation Control

As ventilation affects the temperature and duration of compartment fires, selection of ventilation characteristics can be used as part of a design strategy. Most predictive methods use the "ventilation factor", the area of the ventilation opening multiplied by the square root of its height, as input. Judicious selection of opening geometry is used to reduce fire severity in a compartment.

4. Protection of Construction Materials

Most of construction materials require insulation to achieve resistances that are commensurate with performance requirements in building codes. The amount of protection that designers must provide depends on the inherent resistance of the construction materials, geometry of structural components, and function in the structural system, and performance objectives for the building.

Fire protection for structural components is accomplished by some form of insulation, usually as applied coatings, encasement of components, and enclosures around components that separates the structural component from the fire environment [7].

The selection of materials for critical structural components will have a direct impact on strategies for providing fire resistance. For example, reinforced concrete components with appropriate detailing can sustain the effects of fire temperatures for relatively long periods if they have an adequate concrete cover over the steel reinforcement. The concrete cover over the steel reinforcement acts as insulation, and delays temperature rise in the steel reinforcement if it does not spall or crack during the fire event. The dimensions and the thermal conductivity of concrete components may be designed so that substantial time is required for the temperature of the steel reinforcement to rise to damaging levels.

Some building codes place criteria (i.e. allowable building height and floor area) on buildings as a function of occupancy, combustibility of materials of construction, and levels of protection. In those circumstances, the occupancy and size of a building can affect the suitability of certain materials of construction [9].

There is also provision of fire protection for existing buildings in code of developed countries [7]. Following are some of the steps that have to be followed for existing buildings;

1. Find and review the existing fire protection design basis.
2. If the design basis is not available, analyse existing building construction, building systems, occupancy, and fire protection systems.
3. Document the new facility goals.
4. Determine any changes required to meet the new goals.

5. Analyse the effects of anticipated changes.
6. Determine whether prescriptive or performance-based design will best serve the project.
7. Consider using combinations of prescriptive and performance based designs.

Conclusion

In India, till date we have been studying various hazards in isolation with each other. Various guidelines and codes have been prepared by government of India with regard to individual hazards for designing multi-storied buildings. Initiative has also been taken by Government of India – UNDP (2009 – 2012) [1] to develop a Multihazard map for the country but this map has been prepared for the hazards like earthquake, flood, wind and cyclone and that too for country as a whole and on regional basis, which do not take into account specific urban locations along with the infrastructure and available utilities. Further the effect of fire has not been taken which is very common after earthquakes. The National Building Code of India – 2005 [10] addresses all the hazards but simultaneous effect of different combination is not taken into consideration. Further it is clearly mentioned and accepted by government of India that effective implementation of these codes has been a major challenge.

The Ministry of Home Affairs has undertaken a study on fire hazard and risk analysis of fire services in the country and the objectives of the study are to identify gaps in existing fire services and futuristic strategy to bridge the gap and steps for mitigating impacts of a fire hazard. Government of India has prepared a list of multi-hazard districts and it includes the city of Ahmedabad [1].

The most important tool that is used for incorporating hazard consideration in land use - zoning is micro-zonation. Unless a detailed plot level micro-zonation is carried out for the city, it is not possible to prescribe detailed development guidelines and planning norms that will take into consideration the vulnerability of that region. Detailed micro-zonation of urban areas in India has only been undertaken for the city of Jabalpur by the Geological Survey of India (GSI). The generation of micro-zonation map of Ahmedabad city is in process by Indian Seismological Research.

Deeply concerned with very high stakes involving safety of buildings and infrastructure in the densely populated cities and risk of large scale damage of buildings and loss of lives, the Ministry of Urban Development, as a follow-up of the Vulnerability Atlas of India, is likely to undertake seismic micro-zonation of at least 60 to100 big cities in plain and hilly regions to be identified in consultation with the experts from Department of Science & Technology, Geological Survey of India, and eminent urban planners [8].

References:

1. Disaster Management in India (2012): Ministry of Home Affairs, Government of India – UNDP Disaster Risk Reduction Program, pg: 1 - 27.
2. Scawthan (2008): The Shakeout Scenario Supplemental Study; Fire following Earthquake, United States Geological Survey and California Geological Survey, pp: 1 – 33.

3. Botting & Buchanan (2000); Building Design for Fire after Earthquake, 12th World Conference on Earthquake Engineering, Auckland, New Zealand, pg – 1569 (8).
4. Phan, McAllister, Gross and Hurley (2010); Best practice guidelines for structural fire resistance design of concrete and steel buildings, Society for Fire Protection Engineers & National Institute of Science and Technology technical note 1681, pg: 217.
5. Fire service features of buildings and fire protection systems (2006); Occupational Safety and Health Administration, U. S. department of labour, (OSHA: 3256 – 07N), pp: 71
6. Lataille (2003): Fire Protection Engineering in Building Design, National Fire Protection Engineers, pp: 1 - 151.
7. FEMA US & R Response system / U. S. Army Corps of Engineers (2009); Structure Specialist Training Manual, STS2 – 1 – 3, Manual – 2.
8. Vulnerability Atlas of Gujarat (2005): Joint venture by UNDP - Gujarat State Disaster Management Authority (GSDMA)
9. Hall Jr. (2013): High Rise Building Fires, National Fire Protection Association, Fire Analysis and Research Division, pp: 1 – 51.