Study of Existing Practice for Multistoried Building subjected to Earthquake and Fire Simultaneously and Suggested Guidelines

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Abstract

Cities of India are coming up with towers due to restriction in space and cost implications as there is a limit to horizontal expansion. Old buildings / Spacious Detached bunglows have to give way for high-rise buildings with change in the provisions of General Development Control Regulations (GDCR) proposed by Urban Department, Government of Gujarat. In accordance to the new bye law that has come to force, Floor Space Index (FSI) of 4.0 is permitted for the plot abutting to the road width of 30.0 m or more. Due to this 14 – 20 storied buildings are coming up in the cities of Ahmedabad and Surat. The city of Ahmedabad has a history of devastation during the Bhuj earthquake of 2001. According to the Bureau of Indian Standards (BIS), 1893: 2002, Ahmedabad city comes in zone III category of Seismic hazard. The administration of Ahmedabad City is done through Ahmedabad Municipal Corporation and any building that is constructed within city limits has to be assessed for some requirements by AMC. Under this condition it is utmost import to study the existing procedure followed by local authorities like corporation for giving approval of building permission for construction. This research paper studies the practices adopted for multistoried buildings by local builders and contractors during planning stage, during construction, while taking permission from local authority and after securing permission from local authority considering the effect of earthquake and fire simultaneously. Further the entire process of corporation for building permission right from in-principle approval to awarding the Building Use Permission (BU) by corporation is also studied and some guidelines have been formulated based on the study. A check list has also been developed that can help the local authority for assessment before giving approvals for multistoried buildings.

Key Words: *Earthquake[1], Fire[2], Buildings[3]*

Background

The factors which affect the likelihood of small fires growing into large ones include the extent of earthquake damage, the type and density of buildings, wind conditions, loss of water supply and fire fighting capabilities. Control of fires in buildings after earthquakes is possible only if the buildings are earthquake resistant and fire resistant. Post Kutch earthquake of 2001, multi-storied buildings are designed considering earthquake loads but the consideration of combined effect of earthquake and fire simultaneously is missing. Buildings are designed for fire suppression but as per the new fire act, provision has been laid under Gujarat Development Control Regulation (GDCR) for many techniques only for active fire suppression.

Historic record shows that earthquake is followed by fire within the first 45 – 50 minutes of the earthquake [1]. It has also been observed that the number of fire could be less but their effect is tremendous. Fire spread may also occur depending upon the wind direction and condition as well as vicinity and availability of fuel available in the building.

To meet the demands from rapid urbanization taking place in the State of Gujarat, Urban Department, Government of Gujarat has come up with amendments in Gujarat Development Control Regulation (GDCR). As per the new guidelines laid under GDCR, Floor Space Index (FSI) up to 4.0 can be permitted for plot size of 5000 sq. m on road width of 30 m [2]. As a result of this, many multi-storied buildings are now constructed in these cities. But the material and furniture used for interior design of these buildings are mostly of wood,

particle board and dry grass under high pressure. Ahmedabad City is also supplied with Piped Natural Gas (PNG). This increases the vulnerability of buildings to fire.

Till date, there has been no occurrence of fire followed by earthquake in multi-storied buildings. But due to increased allowable height of buildings, use of highly inflammable materials within buildings, supply of gas through pipelines and lack of effective fire fighting equipment, the high rise buildings are now more vulnerable to earthquake followed by fire.

Through the present research, a multi-hazard map is developed for the city of Ahmedabad. The data related to parameters affecting earthquake is collected from various locations and private as well as government sources. Further, maps are developed based on the data collected and buildings are assessed for earthquake in ArcGIS software. On similar lines hazard maps for fire are also generated based on the parameters affecting fire in the city. The National Building Code – 2005 [3] and its commentary is also studied and reviewed for the present research for comparison of the existing norms with those in developed countries. The code related to the ductile detailing (IS 13920 – 1993), its review and comments given by *Dr. Jain & Dr. Murthy* [4] are also studied for developing guidelines. The Rapid Visual Screening method of assessment formulated by *Dr. Sinha & Goyal* [6] and *Dr. Arya* [5] is reviewed for preparing checklist for local authorities. The map will be a useful tool for local authorities like Ahmedabad Municipal Corporation (AMC) and Ahmedabad Urban Development Authority (AUDA) for building assessment.

Construction Practice in Ahmedabad

In accordance to the existing byelaws in GDCR, the total built- up area for any plot is governed by Floor Space Index (FSI) / Floor Area Ratio (FAR). Due to increase in the price of land, some amendment has been made in provisions of GDCR and FSI up to 4.0 is permitted depending upon the road width (Higher the road width higher the FSI). Buildings more than 15 storeys are coming up these days in the city of Ahmedabad, Rajkot, Surat and Vadodara.

In Ahmedabad city, most of the existing multi-storied buildings are of (G + 4) storey, but now many buildings (G + 10) or more are coming up. Basement stories are additional for parking. Height of each storey in case of residential buildings varies from 2.8 m to 3.2 m where as in case of commercial buildings / government buildings it is 3.6 m to 4.5 m. Reinforced concrete frame with masonry infilled (one brick thick – 4.5″ including plaster) is the most common structural system for RC buildings in case of buildings constructed by private parties but for buildings constructed by government agencies masonry infilled walls are two brick thick – 10″ including plaster in the entire country.

The size of columns is governed by the brick size and is generally 230 × 450 mm in G + 4 buildings and 230 × 600 mm in G + 10 buildings. The transverse dimension of 230 mm is driven by architectural considerations for the sole purpose that column should flush with the brick size. Slabs are usually 120 mm thick, and beam sizes vary from 230 × 400 mm to 230 × 750 mm. The masonry infill is usually in cement mortar of 1:6 proportions. Further due to the high cost of land, parking is often accommodated in the ground floor area of the building by avoiding infill brick wall. Due to this, the ground floor may be subjected to excessive deformations in comparison to upper floors. These multi-storied buildings are also provided with cantilever balconies and floating columns. Irregular buildings (in plan and elevation) were the most affected during the earthquake.

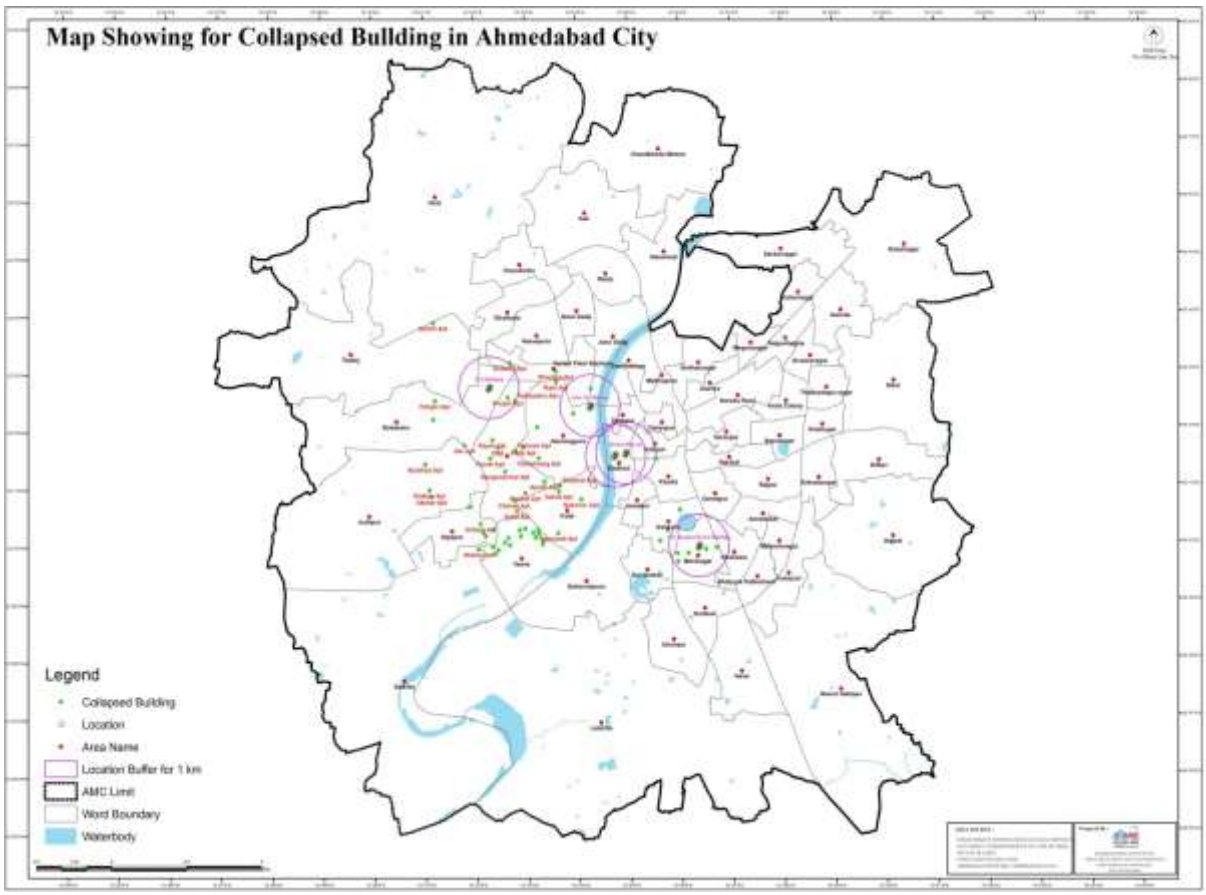
For high-rise buildings of G + 10 level, only one borehole up to the depth of 8 – 10 m based on the discretion of structural engineer was considered sufficient. Even depth of footing used to be about 1.5 m or at depth where yellow soil was found for G + 4 buildings and from 2.5 m to 3.5 m for G + 10 buildings. Buildings with basement are provided with raft foundations. Tie beams interconnecting the footings, and plinth beams connecting the columns at the ground story level were usually not provided pre-earthquake. Thus columns of ground floor were usually taller than those on a typical story, unsupported from the top of the footing to the first floor slab. However in case of multi-storied buildings designed as public buildings, tie beams and plinth beams are provided. There is also provision of Third Party Inspection (TPI) in case of public buildings. Only for this reason, government buildings performed exceptionally well and did not have any structural cracks. For instance, all of the 130 buildings that collapsed in Ahmedabad at about 250 km from epicentre, were privately owned and constructed.

As per IS: 1893 – 2002, India is divided into five Seismic Zones, Zones I to V. Zone I and zone II have been merged after 2001 earthquake [7]. Before this earthquake, design of the multi-storied buildings was not performed as per seismic code and provision of ductile detailing (IS: 13920-1993) was also not followed by private players. It is mandatory to follow the provisions of IS: 13920 for [8];

1. All buildings in Seismic Zones IV and V.
2. Buildings in Seismic Zone III having importance factor more than 1.0.
3. Industrial buildings in Seismic Zone III.
4. Buildings more than 5 stories in Seismic Zone III.

Prevalent practice for local authorities to give approval of buildings for constructions is based only on the architectural plans submitted by builders. Structural drawings are not scrutinized. Due to this there is likelihood of the buildings constructed by private builders not conforming to the seismic code provisions. The grade of concrete used for reinforced concrete ranges from M_{15} to M_{25}. Nominal mix is used to make concrete without a formal mix design. Volume batching is primarily employed instead weight batching. Indian Standards permit the use of potable water for construction. However, in the informal construction sector, water available at site is used for concreting without always verifying its suitability; some salts detrimental to the durability and strength of concrete may be present. Moreover, the quantity of water is tuned to ensure good workability, often resulting in higher water content than necessary and in porous hardened concrete. The ductile detailing code requires column bars to be spliced in the middle-half of the story. However, in general, the practice is to splice all column bars just above the floor slab. Since most buildings had weak RC frames, masonry infill played a crucial role in the survival of many buildings by providing lateral strength and stiffness. The quality of construction was not good in many buildings of the affected area with improper cement, sand and aggregate content.

Locations of 58 out of the approximately 130 buildings that collapsed in Ahmedabad are shown in Map - 1.



MAP – 1: Location of Collapsed multi-storied buildings in Ahmedabad

Discussion

Principal Reasons for failure of buildings in Ahmedabad city during 2001 earthquake

1. Quality of Concrete
2. Construction on reclaimed soil
3. Absence of Tie/plinth beams
4. Insufficient foundation depths
5. Absence of beams at sill level
6. Hollow plinth or soft storey
7. Stub or floating column
8. Odd shaped building
9. Erroneous structural design
10. Use of hand mixed concrete in columns

Generally in normal course, during the event of earthquake followed by fire, for a building with irregular layout and high rise building, the residents of upper floor would take more time for evacuation than the duration of an earthquake. Due to this, most of the occupants would be on staircase only just after the tremors of earthquake. It may also happen that the evacuation time may coincide to the flashover time period accompanied by heavy and sudden release of smoke. Considering this aspect, the design of the building should be such that it gives reasonable time to the occupants of the building for exit and spread of fire is restrained. Fire spread may also occur depending upon the wind direction and condition as well as fuel available in the building.

During an event of earthquake followed by fire, there would be various ignitions at various places and fire department can have many phone calls. There will be choke-up points at much location which may cause delay in rescue operations. This would be further coupled with inadequate resources, fire station itself damaged, non-availability of fireman during the given point of time and off-duty personal having difficulty in getting to work. It may also happen that some of the skilled fire fighters may have earthquake damage to their own property or families. Sometime even fire station may also have suffered damage during earthquake.

The best solution to this is capacity building and imparting skill and training to some of the permanent users of building / lift operators.

Procedure Adopted by Local Authority Vis-à-vis Suggested Guidelines

TABLE – 1: Suggested Guidelines for Local Authority

Sr. No.	Procedure Adopted by local body (Ahmedabad Municipal Corporation)	Observation	Suggestion / Recommendation
1.	Building plan approval/development permission is given on computer-aided system.	-	-
2.	The submission procedure usually takes place within a single day provided the application is made with all necessary documents.	-	-
3.	Applicant has to submit the plan in AUTOCAD format (soft copy and hard copy on paper) with all required documents, site photographs, NOC's, **Soil Investigation Report** and undertakings in pre-decided standardized formats.	Undertakings from Architects and Structural Engineer have been included in new provisions of GDCR	Electrical Engineer, Mechanical Engineer and Fire Safety Engineer should also be involved during this stage of project and undertaking should be taken from them also regarding the safety standards of building.
4.	Auto-cad based software is used with a provision of certain in-built **'checks and controls'** like FSI, ground coverage, built-up area, height of the building, margin and open spaces etc. with regard to **General Development Control Regulations (GDCR),** which automatically verifies the data entered and if found in order, it generates the amount of fees to be paid.	1. Design Criteria is not submitted 2. Structural Design of building is not submitted. 3. Vulnerability checks for hazards not submitted.	1. Performance based design of buildings should be adopted. ***** 2. Submission of structural design and drawings should also be submitted. AMC should get the structural design verified by third party for hazards depending upon vulnerability of building.
	*The analysis must include 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 failures, and overall and local buckling.		
5.	The case is then scrutinized manually.		-

TABLE – 1: Suggested Guidelines for Local Authority (cont'd)

Sr. No.	Procedure Adopted by local body (Ahmedabad Municipal Corporation)	Observation	Suggestion / Recommendation
6.	A special team of officers called Building Plan Scrutiny Pool (BPSP) scrutinizes the case in accordance with the provisions of GDCR. There after the approval is issued with computer generated permit of construction **(Commencement Certificate).**	1. Structural Design is not submitted 2. No check and reports on quality maintained during construction	Commencement certificate should be given only after proof checking of design is done by third party.
7.	The status of the plan can be known from the e-governance site of the corporation www.egovamc.com		-
8.	Case is then sent to the concerned zone office for site-verification and monitoring of construction.	Engineer from AMC visits the site occasionally and the inspection is related to built-up, FSI etc. only. No report on check for proper construction method, quality related to type of materials used, workmanship, curing procedures or structural detailing which is a very important aspect for the operational and functional life of building.	1. Monthly reports should be generated from ward office and submitted to zone office including structural design, detailing and quality of construction on site. 2. This should be further supported by periodic reports / checks, presence of site supervisors, photographs and video recording during various phases of construction. 3. Surprise visits should be made by competent authority at frequent interval especially before and during RCC work. 4. Third Party Inspection should be made mandatory.
9.	As per the new provision of GDCR, for building height more than 12 m, a fire protection consultant has to be appointed and opinion of Chief Fire Officer has also to be taken	These steps are for active fire suppression.	Checks for proper installations, functioning, regular refilling etc. should be included.

TABLE – 5.1: Suggested Guidelines for Local Authority (cont'd)

Sr. No.	Procedure Adopted by local body (Ahmedabad Municipal Corporation)	Observation	Suggestion / Recommendation
10.	The applicant/ engineer submit progress report at each stage and completion-report along with completion plan to obtain the occupancy certificate.		An undertaking should also be submitted by builder that no modification / alteration in premises will be done without prior intimation and approval.
11.	**Completion Certificate (occupancy permit)** is issued by the zone office after carrying out the inspection of site at recognized stages of construction (plinth, first storey, middle storey and top storey).	This is one time process for any building. Once this certificate is issued, the role of AMC is physically over.	The building should be monitored and inspected once every six months and the process of renewal of occupancy certificate should be brought into existence. Also type of additions and modifications should be recorded whether it is structural or non-structural.
12.	As per new Fire Act of UD - GoG, now builder will also have to submit certificate from Fire Officer related to the fire safety of building.	1. Fire Act is more related to active fire suppression and formulating institutional framework. 2. The expiry date of the fire fighting equipment installed is not known to the users of building.	1. Emphasis should also be laid on passive fire suppression. Extreme Care should be taken to check that the fire fighting system installed is of flexible material. 2. The maintenance and functioning of fire fighting equipment installed in the building should be done every year. 3. Important dates related to service / maintenance of safety equipment should be posted near lift wall and landing of staircase. 4. The name and contact details of nodal persons / skilled operators should also be posted at these places so that in case of any emergency any user can contact them without delay.

TABLE – 5.1: Suggested Guidelines for Local Authority (cont'd)

Sr. No.	Procedure Adopted by local body (Ahmedabad Municipal Corporation)	Observation	Suggestion / Recommendation
13.	There is provision in NBC – 2005 that exits should be clearly visible and the routes to reach exits should be clearly marked and signs should be posted to guide the occupants of floor concerned.	This is lacking in almost all multi-storied buildings and not strictly implemented by local authorities as noticed in all study buildings.	1. Building Use Permission granted by local authority should be linked with sign boards and markings as per the provision in NBC – 2005. 2. Also design of building should be such that Staircase, one of the most important components, does not fail during earthquake followed by fire. 3. All exit ways should also be properly illuminated.
14.	These provisions should be strictly enforced by law and there should be provision of heavy penalty for defaulters. This penalty should also be linked with cut in water supply and drainage connection as these are the basic amenities for the users of building. Awards/Rewards should be given in public to the builders/engineers/architects for quality construction work and strictly following the code provisions.		

Proposed Checklist for Local Authority

The Checklist developed as a tool for local authority is mentioned in Table –2.

TABLE – 2: Check list for RCC Multi-storied Buildings

Sr. No.	Particulars	
1	Name of Building	
2	Address with coordinates	
3	Usage of Building	
4	Age of Building	
5	Type of Building	
6	No. of Potential Users of Building	
7	No. of House Hold units in the Building	
8	No. of Household units and Users in perimeter of 100 m	
	Information to be Collected	**Yes / No**
9	Name of Structural Engineer, Fire Safety Engineer, Electrical & Mechanical Engineer along with licence has been submitted	
10	Height of Building / Height of each floor is mentioned	
11	Soil profile at site has been obtained by Soil Investigation	
12	Type of Foundation existing / recommended is given	
13	Depth of Ground Water Table from GL is mentioned	
14	Structural Changes made in building after getting BU permission	
15	Thickness of filler walls is mentioned	
16	Position of Staircase and Lift in Buildings (Symmetrical or Unsymmetrical)	
17	Damage to building during 2001 earthquake (for existing building)	
18	Is the building designed as per IS: 1893 – 2002, IS: 13920 – 1993 and NBC – 2005 for earthquake and fire safety	
19	Seismic criteria selected for design of building is given	
20	Test report of concrete, cement, steel and water of atleast 3 intermediate stages of construction available?	
21	Quality of Construction in the building has been check by taking samples?	
22	Any existing irregularity in existing plan or elevation of building	
23	Whether the building has been designed based on performance objectives? Is any simulation study been done for seismic performance?	
24	Has the Mechanical Engineer issued safety certificate?	
25	Has the Electrical Engineer issued safety certificate?	
26	Has the Fire Safety Personal issued safety certificate	

27	Whether Design criteria along with structural design and drawings is submitted to local authority	
28	Whether proof checking of structural design has been done by competent structural engineer	
29	Whether Third Party Inspection is done during construction	
30	Whether an undertaking is submitted by builder for maintenance, no alteration/modification in premises without prior intimation	
31	Whether fire fighting equipment's have been installed	
32	Whether the fire fighting equipment installed is made of flexible material	
33	Whether the pipeline used for water distribution is made up of brittle or ductile material	
34	Whether the pipeline used for domestic gas distribution is made up of brittle or ductile material.	
35	Are these Seismic Shut-off Valves accessible for rapid re-inspection as well as replacement as and when required? Whether the Signage indicating these locations been displayed at proper locations?	

Concluding Remarks

1. Newly constructed multi-storied public buildings are designed as earthquake resistant. Fire fighting equipment, smoke detectors and automatic devices such as sprinklers are also installed in these buildings. However periodic checking of operation and services are not conducted. Further, in case of emergency, for the operation of fire fighting equipment and sprinklers, skilled and trained person is required to be deployed. Such designated personnel are not available in any of the buildings under study. Hence basic equipment operation training should be given to the permanent users of the building. Mock drills should also be organised at regular intervals.
2. Guidelines have been suggested as shown in Table –1 to regulate and review procedures, which can help local authorities in planning, implementation and monitoring at all stages.
3. Parameters required to assess the vulnerability of buildings have been recommended as additions to the current check list used by local authorities for granting permissions for building construction. These are given in Table –2.

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