Earthquake resistant design in construction-A case in the Indian context

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With her progressive design thinking, leadership and strategic planning, Ar.Tapasya Das has opened up avenues for the success of many diverse projects in India and the USA. Her collaborative approach with government, private sectors and institutions are noteworthy. She has won awards and accolades for value engineering, process improvement and research. She is passionate about innovating sustainable solutions to provide unique and personalised experiences for the community.

Abstract

The consequence of earthquake can be reduced by taking certain preventive measures as per certain guidelines. We can take preventive measures in Earthquake prone areas, to prevent the loss of lives and material. This is extremely important to educate Architecture and Construction professionals & to create awareness among the public to follow the standard measures during the process of construction in earthquake prone areas. Collaboration between the oorganizations, government agencies, statutory bodies and reviewing of syllabus in design courses will address the view point of frequent earthquakes in different parts of the country. Thismay supportin reducing the damage.

Keywords

Construction; Earthquake prone areas; Preventive measures; seismic resistant design;seismic energy; seismic dampers; vibration control; sub structure; shear walls; seismic resistant materials

1.Introduction

An earthquake is devastating. It not only takes the toll on a cities population but also affects the man built structures. The effect of Kutch/Bhuj, Gujarat earthquake might not be same as of the similar intensities earthquake occurring in Istanbul, Japan or San Francisco because their buildings & bridges are designed & tested to withstand the seismic energies of earth.

India because of its unique location is a disaster prone country with 58.6% of land mass subjected to moderate to high intensity earthquakes. Certainly one cannot have a control on earthquake but an Architect in collaboration with his engineer can design a seismic safe structure which can withstand, absorb the seismic waves throughout the building & transfer it back to the ground without collapsing.

STHALA/ ISSN 2582-9491

The architect should have knowledge on seismic resistant design. Buildings flexibility, shape, strength, type of material & base of the building plays important role. It starts right with the conceptualization of the building. Architects in recent times are coming up with ideas of great seismic strengthening tricks to the new buildings.

But some buildings even in Los Angeles, California & Japan designed & built strictly to the seismic standards collapsed due to the tremors. That means there is no set of standard models, tools or techniques which 100% assures the seismic safety of the building.

It's only the theory based out of observations, numerous iterations of formulas which generated tools like ETABS, STAAD, ROBOT, TEKLA & others, though these tools are advantageous largely in reducing the damages to the buildings & its occupants during quake.

This research paper intends to understand the Architects contribution in seismic resistant design. As per an Architect, the building is made of set of components, how these components can be conceptualized, composed & designed to respond positively during the sudden intense shaking of ground thereby offering a resistance to the earth's seismic activity.

1.1 Various technology or techniques in earthquake resistant design:

Flexible foundation: base isolators or Floating foundation

Counter seismic forces with damping: Shock Absorbers: Pendulum dampers, vibration control devices

Shield Buildings from Vibrations

Reinforce the building structure: Symmetrical design, Diaphragms ,shear walls, Cross-Bracing, truss

Seismic resistant materials: structural steel, wood, modernelements: memory alloy, bamboo - capability for greater resilience& shape retention

Simulation techniques or Software tools like ETABS, STAAD, ROBOT, TEKLA etc

Test models like shake table

2. Earthquake resistant Architecture in Indian Context:

Though around India's 60% of land mass is earthquake prone, one can hardly see the seismic codes or regulations being stringently followed. Maybe coz of social belief in people that quake hits only once in fewer decades.

Table 2a : This table shows worst 5 quake hits in Indian history from 1934 to 2001.

YEAR	PLACE	Magnitude on Richter scale	DEATHS
1934	Bihar	8.1	30000
1950	Assam	8.6	1500
1991	Uttarakshi (Uttarakhand, Chamoli)	6.1	1000
1993	Maharashtra (Killari, Latur)	6.4	20000
2001	Gujarat (Bhuj)	7.7	20000

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Source-Five Major Earthquakes of India, Skymetweather.com

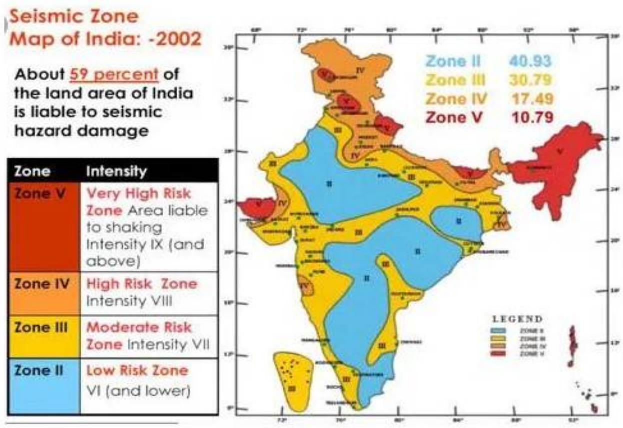

Figure 2b: Seismic zones of India

Source: Seismic zones in India, https://theconstructor.org/earthquake/seismic-zones-inindia/2211/

The project designed in seismic prone zones should follow certain guidelines of the National Building Code (NBC). Some of the important seismic codes to be adhered by buildings are as shown in the below table.

Table 1 : Seismic codes of the National Building Code

IS:1893 (Part 1)-2002	Indian Standards Criteria for Earthquake Resistant Design of Structures: Part 1 General Provisions and Buildings	This revision follows the methods of first calculating the actual force that is assumed to be experienced by the structure during the probability ofbiggest earthquake, if it were to remain elastic. Then the concept of response reduction due to ductile deformation or frictional energy dissipation in the cracks is brought into the code explicitly, by introducing the `response reduction factor' in place of the earlier performance factor.
IS:1893-1984	Indian Standard Criteria for Earthquake Resistant Design of Structures	This standard deals with earthquake resistant design of structures and is applicable to buildings; elevated structures; bridges; dams etc. It also gives a map which split up the country into five seismic zones based on the seismic intensity.
IS:4326-1993	Indian Standard Code of Practice	This standard

STHALA/ ISSN 2582-9491

	for Earthquake Resistant Design and Construction of Buildings	provides guidelines in finalisation of materials, special features of design and construction for earthquake resistant buildings including masonry construction, timber construction, prefabricated construction etc.
IS:13827-1993	Indian Standard Guidelines for Improving Earthquake Resistance of Earthen Buildings	The guidelines covered in this standard deal with the design and construction aspects for improving earthquake resistance of earthen houses, without the use of stabilizers such as lime, cement, asphalt, etc.

Source: Indian standards on Earthquake Engineering,https://bis.gov.in/other/quake.htm

The regulations in these standards do not ensure that structures suffer no damage during earthquake of all magnitudes. But, they ensure that structures are able to respond to earthquake shakings of moderate intensities without structural damage and of heavy intensities without catastrophic collapse.

Its extremely Important to follow these codes by Architects/Engineers to minimise the after effects of quake on life of people & property.

The first formal seismic code in India- IS 1893, was published in 1962. The Bureau of Indian Standards (BIS) has various seismic codes now, though the development of these codes started sometime back but not implemented to the extent as it should have been. (2011, Murty IITK)

The Knowledge and awareness what is imparted currently through academics or regulatory codes & guidelines is not adequate.

The clients generally aim to get more habitable space from a lesser FSI especially in developing countries like ours.

The need of the hour is to educate people on disaster mitigation rather than retrofitting after construction

The architect should shoulder the responsibility of ensuring proper seismic performance of the building since inception.

The base isolation technique in India was initially displayed only after the 1993 earthquake in 2001. (2014, Patel)

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Figure 2c-Shows the base isolation with lead Rubber

Source- Study on a Base Isolation system, Nirav.G.Patel,2014

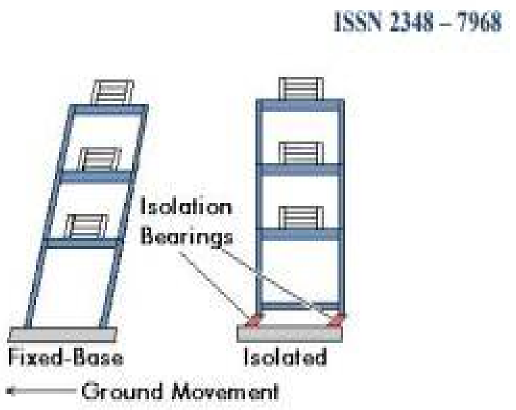


Figure 2d Seismic behavior of building With & without Isolator

Source- Study on a Base Isolation system, Nirav.G.Patel,2014

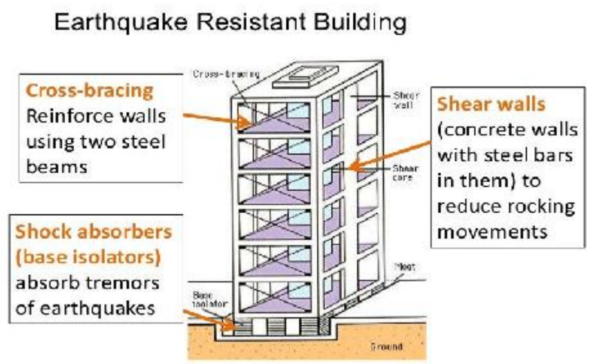


Figure 2e Shows components of a typical earthquake resistant building

Source: Slideshare.net, Swati Gaur

3. Japanese buildings resilience to an earthquake:

Sky scrapers or taller buildings which are more flexible have counterweight system installed at base that swings with the movement of the building to stabilize it. Ex: a network of diagonal trusses forming a wide base & narrowing at top, withstands the horizontal & vertical forces thereby offering building the requisite strength & flexibility

Smaller buildings are stiffer & vulnerable compared to taller structures hence are built on flexible foundations that can absorb movement in 6 directions and minimise the effects of the earthquake.

Foundation: to minimize the destruction during the seismic waves especially of high resonance frequency , the foundation beneath structure should be hard or bedrock rather than soft, sandy or landfills type

Materials: wood & steel framework is extensively used in fault zones.

The corners, pillars, edges or joints forming the weakest part of the building are additionally reinforced to withstand being

STHALA/ IS S N 2582-9491

bent, deformed or misshapen by earthquake forces.

Trains: Safety measures like guard rails & Seismometers are placed on every train track to monitor seismic activity. When signaled, the system even of bullet train automatically engages the breaks, & speeding train comes to a halt in time before the quake hits keeping its occupants safe.

Elevators automatically turn off during seismic activity and have to be checked before they operate again.

Gas, electricity and water linesshut down automatically when triggered preventing fires, floods, and explosions.

People: people are trained right from kindergarten stage to deal with earthquakes. They follow calm 'no panic' attitude ensuring the safest environment possible.

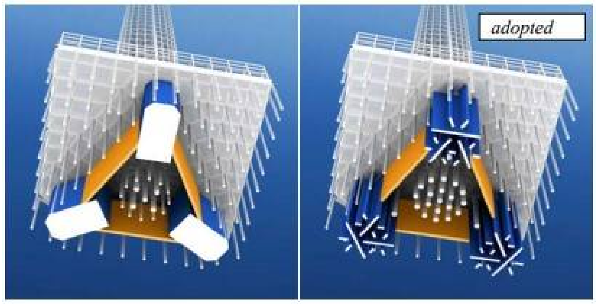
3.1: Case study: Tokyo Skytree Tower, Japan- Digital broadcasting Facility

It's the world's largest free standing tower & second tallest structure at 2080 feet height inspired by Japanese traditional temple Pagoda

At base the tower is equilateral triangle & as it tapers the cross-section becomes circular.

Seismic Design inventions: rigid substructure system, core shaft system & vibration control system

Rigid substructure system: The site is located at the banks of sumida river with extremely soft soil around. A reinforced concrete wall pile is adopted as basement with thickness 1.2m & depth 35m. It stands on a bearing stratum giving the rigidity to the structure above. This strategy was developed for seismic design as it makes use of a relative displacement between the rigid substructure & soft ground to gain the damping ability also the damping of radiation.



Counterweight plan SRC(bl.)and RC(ye.) wall pile plan
Figure 3 : Plan for Substructure

Figure 3f Counterweight plan of towers substructure system Typical & adopted

Source- Atsuo Konishi, Structural design of Tokyo Sky Tree.

Core shaft & vibration system: The main central shaft of reinforced concrete is attached to the outer tower structure for the first 410 ft above ground. A height of 1230 ft is surrounded by a framework of steel tubes fixed with oil dampers, which act as cushions during an earthquake. It does not support the tower, but functions as a counteract to any sway of the tower during quake & reduces around 40% of seismic waves.

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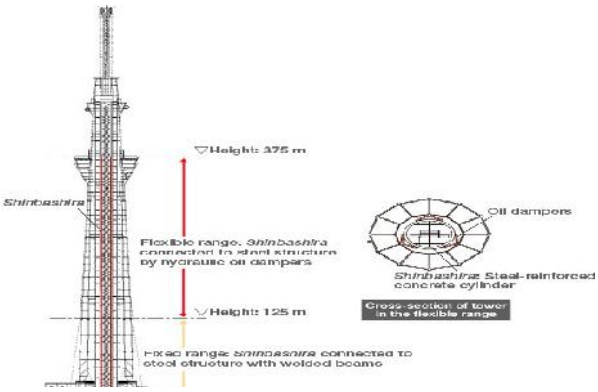

Figure 3g –Cross sectional detail of a Towers core column (shinbashira)

Source: Allen Karlovic, Pagodas Exceptional Earthquake Design

4. Way forward:

It can be marked that for the Earthquake-resistant construction, preventive measures have to be incorporated during the construction process. This includes incorporating new techniques that can be use of smart and resilient design. These are the technologies & materials that respond to specific external stimuli and carry out particular functions as a result of some inherent properties. It has also a crucial impact on the field of vibration control in cases of seismic disruption. Attempts should be made to involve architects and civil engineers to incorporate the features. New technologies will have a cost impact in the construction segment as that cannot be disregarded at the expense of lives of people. To avoid what we have witnessed during the earthquake in Gujarat in 2001, the most important strategy is to go along with the technology.

5. Conclusion

- The professionals in India should learn from these examples and work efficiently to produce a better end-product.
- The seismic codes or guidelines should not be violated by Architects especially in seismic prone zones, as architectural configuration when designed to seismic standards plays an important role in mitigating the earthquake effects.
- Architects should learn about earth quake resistant architecture, its scope & importance as a part of their academics & curriculum
- In developing countries like India, the architect should try to make understand /educate the client on importance of safety of building rather than help in achieving more habitable space or giving importance to building aesthetics.
- Architect should ensure the seismic performance of building in collaboration with structural engineers
- Government should initiate drills, demos, workshops & also to ensure implementation of earthquake resistant design guidelines
- Lessons learnt from post earthquake should be documented, analyzed & ensured that proper corrective measures are set forth for future references.

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STHALA/ ISSN 2582-9491