EARTHQUAKE ENGINEERING – A STANDARDS PERSPECTIVE

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INTRODUCTION

In the present era, occurrence of seismic events has become very common all over the world in which minor earthquakes are occurring nearly every day in some parts of the world. Each earthquake of high to severe magnitude results in huge loss of human lives, destruction of properties, buildings and infrastructure, and affects transportation of goods and services. Large amount of money and manpower is required to recover with the widespread destruction caused. To avoid the vagaries of these seismic events, design and construction of buildings and structures to resist earthquakes become utmost essential. As we know that earthquake is a natural disaster which occurs due to the movement/drifting of tectonic plates, it is difficult to forecast it. Hence, we can only design 'earthquake resistant' structures not 'earthquake proof' structures. Earthquake resistant design of structures generally aims that damage(s) can occur in the members of the building without collapse. Standards, being a tool to address problems of repetitive nature, are used by countries world-over to address the risk due to earthquakes as well. In the country, the Bureau of Indian Standards has therefore formulated a series of Indian Standards in the field to ensure proper planning, design and execution of buildings and built environment taking into cognizance the potential of the buildings and infrastructure so built to counter the earthquakes in a sustainable manner. This article discusses some of such efforts.

EARTHQUAKE

Earthquake is a natural phenomenon which is caused by the movement of tectonic plates past each other. During an earthquake, large amount of strain energy is released which travels in the form of seismic waves leading to huge ground shaking. This ground shaking induces lateral force on buildings and structures and leads to their catastrophic failure. The point on the fault where the slip starts is called as 'Focus' and the point vertically above it on the surface of the Earth is called as 'Epicenter'. The depth of focus from the epicenter, called as 'Focal Depth', is an important parameter in determining the damaging potential of an earthquake.

> **"We can only design 'earthquake resistant' structures not 'earthquake proof' structures."**

PHILOSOPHY OF EARTHQUAKE RESISTANT DESIGN

The engineers do not attempt to make earthquake proof buildings that will not get damaged even during the rare but strong earthquake; such buildings will be too robust and also too expensive. Instead, the engineering intention is to make buildings earthquake resistant; such

buildings resist the effects of ground shaking, although they may get damaged severely but would not collapse during the strong earthquake. Thus, safety of people and contents is assured in earthquake-resistant buildings, and thereby a disaster is avoided. This is a major objective of seismic design codes throughout the world. Broadly, ground shaking (Fig. 1) is classified on performance objectives as below along with their effect on buildings and structures:

a) Under **minor** but frequent shaking, the main members of the building that carry vertical and horizontal forces should not be damaged; however, building parts that do not carry load may sustain repairable damage.
b) Under **moderate** but occasional shaking, the main members may sustain repairable damage, while the other parts of the building may be damaged such that they may even have to be replaced after the earthquake; and
c) Under **strong** but rare shaking, the main members may sustain severe (even irreparable) damage, but the building should not collapse.

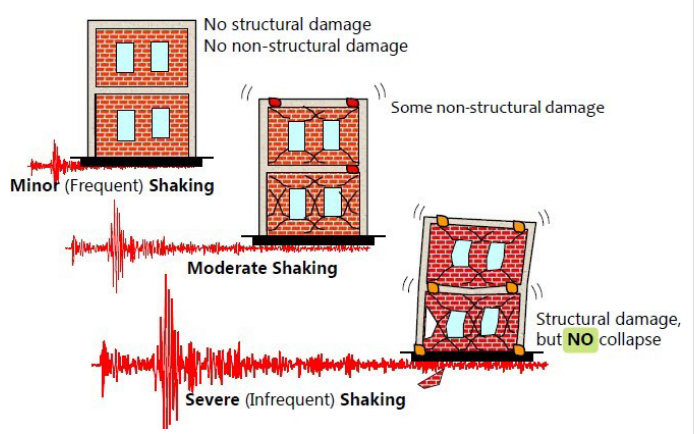

Fig.1: Performance objectives under different intensities of earthquake shaking

PREVENTION OF EARTHQUAKE AS PART OF DISASTER MANAGEMENT

The Disaster Management Act, 2005 of India defines Disaster Management (DM) as a continuous and integrated process of planning, organizing, coordinating and implementing relevant measures. Such activities are intended towards:

- Prevention;
- Mitigation (or risk reduction);
- Preparedness;
- Prompt response;
- Assessment of disaster effects; and
- Rehabilitation and reconstruction

Activities involved in the disaster management are categorized time wise as Pre-Disaster, During Disaster and Post Disaster. Pre-disaster activities are with a view to reducing the potential losses to men and material due to the hazard thereby minimizing losses during the onset of disasters. Activities that tend to the needs and provisions of victims with a view to alleviating and minimizing the suffering are classified as those during a disaster. Post-disaster activities involve all those performed to obtain rapid and durable recovery which does not replicate initial vulnerable conditions. The activities can therefore be indicated as in Table 1.

Table 1: Activities involved in Disaster Management

Phase	Activity
Pre-Disaster	Prevention and Mitigation Preparedness Early warning
During Disaster	Response (First stage after the Disaster Impact)
Post Disaster	Recovery Rehabilitation Reconstruction Development

Thus, it is evident that mitigating the effects of earthquake by way of designing the buildings and structures to resist such effects contributes significantly to the disaster management process. The same could potentially reduce the burden on the authorities and volunteers particularly in the post-disaster and so during disaster events.

ROLE OF STANDARDS IN EARTHQUAKE PREVENTION AND MITIGATION

Built environment, the abode to every individual and the network of infrastructure that support human activities and provide comfort, which are erected on/above/below surface of earth are subjected to earthquake ground motions.

An element of safety thus is pertinent to be intrinsically added right from the planning and design of buildings and structures, and the same needs diligent construction/erection in the site as intended. Standards, being technical documents frequently referred in the contracts ensure to instil a high level of confidence in the minds of parties concerned. Standards evolved on a consensus basis both at the national level (Bureau of Indian Standards) and at international level (International Organization for Standardization) thus serves as the right tool for the designers and practitioners.

National perspective

Geographically, for instance, India is bound on one side by the young but active mighty mountain range (Himalayas), by sea/ocean on three sides, and also within it contains the enormous Indo-Gangetic plains which pose a challenging soil type to the built environment. Considering the vast history of earthquakes recorded even before the 19th century, the ensuing devastation and failure of buildings and structures the then BIS (Indian Standards Institution) rightly codified the necessary engineering design requirements for earthquake resistant design as early as 1960s. In fact, in the field of cyclones, landslides, fires, etc. also the relevant guidelines were enshrined to be followed by the relevant professionals. A brief list of the relevant Indian Standards related to earthquake resistant design of new buildings and assessment & retrofitting of existing buildings is provided in Table 2.

Table 2: List of Indian Standards formulated by the Earthquake Engineering Sectional Committee, CED 39

Sl No.	IS Number	Title	No. of Amendments	Previous editions(s)
1	IS 1893:1984	Criteria for earthquake resistant design of structures (fourth revision)	2	1962,1966, 1970,1975
2	IS 1893 (Part 1): 2016	Criteria for earthquake resistant design of structures: Part 1 General provisions and buildings (sixth revision)	2	2002
3	IS 1893 (Part 2): 2014	Criteria for earthquake resistant design of structures: Part 2 Liquid retaining tanks (fifth revision)	1	-
4	IS 1893 (Part 3): 2014	Criteria for earthquake resistant design of structures: Part 3 Bridges and retaining walls	-	-
5	IS 1893 (Part 4): 2015	Criteria for earthquake resistant design of structures: Part 4 Industrial structures including stack-like structures (first revision)	2	2005
6	IS 1893 (Part 6): 2022	Criteria for earthquake resistant design of structures: Part 6 Base isolated buildings	-	-
7	IS 4326:2013	Earthquake resistant design and construction of buildings — Code of practice (third revision)	1	
8	IS 4967:1968	Recommendations for seismic instrumentation for river valley projects		
9	IS 4991:1968	Criteria for blast resistant design of structures for explosions above ground	-	-
10	IS 6922:1973	Criteria for safety and design of structures subject to underground blasts	-	-
11	IS 13827:1993	Improving earthquake resistance of earthen buildings — Guidelines	2	-
12	IS 13828:1993	Improving earthquake resistance of low strength masonry buildings — Guidelines	3	-
13	IS 13920:2016	Ductile design and detailing of reinforced concrete structures subjected to seismic forces — Code of practice (first revision)	2	-
14	IS 13935:2009	Seismic evaluation, repair and strengthening of masonry buildings — Guidelines (first revision)	-	-
15	IS 15988:2013	Seismic evaluation and strengthening of existing reinforced concrete buildings — Guidelines	-	-
16	IS 17848:2022	Confined Masonry for Earthquake Resistance — Code of Practice	-	-
17	SP 22:1982	Handbook on codes for earthquake engineering (WITHDRAWN)		

The basic tools for land and building development rely very much on the building bye-laws which are evolved basically out of another premium publication of BIS, namely the National Building Code of India 2016 (NBC 2016) which in turn refer copiously to over 1,000 Indian Standards as accepted standards and good practices.

Apart from the Indian Standards, around 30 guidelines related to disasters, templates for preparing Disaster Management Plans (including at District level), and guidelines on Medical Preparedness and Mass Casualty Management have since published by the National Disaster Management Authority (NDMA). Also, to guide the current and potential homeowners towards reducing losses in future in the aftermath of negative fallout of the earthquake, the Simplified Guidelines for Earthquake Safety of Buildings' had been published by NDMA and BIS visit: https://ndma.gov.in/Governance/Guidelines

Various guidelines on disaster management issued by the NDMA available at:
https://ndma.gov.in/ReferenceMaterial/NDMAGuidelines

are with a view to propagate the importance and reflectance of the safety in the built environment.

International scenario

The International Organization for Standardization (ISO) supported by various National Standards Bodies (including the Bureau of Indian Standards, the National Standards Body of India) across the world has a dedicated technical committee on 'Security and Resilience' ISO/TC 292 operating with the scope: "Standardization in the field of security to enhance the safety and resilience of society". Also, ISO/TC 262 deals with 'Risk Management' within in scope, "Standardization in the field of risk management".

A list of some of the important standards relevant to the theme of response and recovery of Disaster Management is included in Table 3.

More details are available at:
https://www.iso.org/committee/5259148.html

Table 3 - List of International Standards related to Disasters

Under ISO/TC 292 Security and Resilience	
ISO 22315:2014	Societal security — Mass evacuation — Guidelines for planning
ISO 22316:2017	Security and resilience — Organizational resilience — Principles and attributes
ISO 22319:2017	Security and resilience — Emergency management — Guidelines for monitoring facilities with identified hazards
ISO 22320:2018	Security and resilience — Community resilience — Guidelines for planning the involvement of spontaneous volunteers
ISO 22322:2015	Security and resilience — Emergency management — Guidelines for incident management
ISO 22324:2015	Societal security — Emergency management — Guidelines for public warning
ISO 22325:2016	Societal security — Emergency management — Guidelines for colour-coded alerts
ISO 22326:2018	Security and resilience — Emergency management — Guidelines for capability assessment
ISO 22327:2018	Security and resilience — Emergency management — Guidelines for implementation of a community-based landslide early warning system
ISO/TR 22351:2015	Societal security — Emergency management — Message structure for exchange of information
ISO/TR 22370:2020	Security and resilience — Urban resilience — Framework and principles
ISO 22395:2018	Security and resilience — Community resilience — Guidelines for supporting vulnerable persons in an emergency
ISO 22396:2020	Security and resilience — Community resilience — Guidelines for information exchange between organizations
ISO 22398:2013	Societal security — Guidelines for exercises
ISO 28002:2011	Security management systems for the supply chain — Development of resilience in the supply chain — Requirements with guidance for use
Under ISO/TC 262 Risk Management	
ISO 31000:2018	Risk management — Guidelines
ISO/TR 31004:2013	Risk management — Guidance for the implementation of ISO 31000
IEC 31010:2019	Risk assessment techniques

International Standards relating to seismic resistant design of structures are formulated by ISO/TC 98 'Bases for Design of Structures' under which there are three subcommittees as given as follows:

- ISO/TC 98/SC1:
  Terminology and Symbols, visit:
  https://www.iso.org/committee/50936.html
- ISO/TC 98/SC2:
  Reliability of Structures, visit:
  https://www.iso.org/committee/50944.html
- ISO/TC 98/SC3:
  Loads, Forces and other Actions, visit:
  https://www.iso.org/committee/50958.html

CONCLUSION

The administrative set up in the country towards regulating land and building development already through the building byelaws requires compliance to Part 6 Structural Design of NBC 2016. NBC, in turn cross refers to, as also is supplemented by the Indian Standards on earthquake resistant design. Part 2 'Administration' of NBC 2016 also stipulates periodic audit for structural sufficiency of special buildings including high rise (> 15 m) buildings. Thus, it is expected that all important buildings and structures are to be periodically verified, particularly against the standard used for the initial design. All the above not only help in ensuring structurally safe environment but reflect the commitment our nation has pledged under the Sendai Framework (2015–2030) and the United Nations Sustainable Development Goals.

REFERENCES

1. Paper titled 'Disaster Mitigation and Management – A Standards Perspective'Standards India, July 2020, Bureau of Indian Standards, New Delhi.
2. Publicly available resources of National Disaster Management Authority (NDMA), an apex Body of Government of India, New Delhi.
3. National Building Code of India 2016 (SP 7:2016), Bureau of Indian Standards, New Delhi.
4. Earthquake Tips, by IIT Kanpur and Building Materials and Technology Promotion Council (BMTPC), New Delhi, released every month from 2002 to 2004.