Starting from August 2004, *Resonance* is publishing in the Classroom section, a series of short articles, 'Earthquake Tips', related to earthquakes, their effects on civil structures, and design and construction of earthquake resistant buildings. The concepts are clearly explained with sketches and analogies. We hope the *Resonance* readers will benefit from this series of articles.

Earthquake Tips have been brought out by the Department of Civil Engineering, IIT Kanpur, and sponsored by Building Materials and Technology Promotion Council, New Delhi, India. These articles are reproduced here with permission from IIT Kanpur and BMTPC, New Delhi.

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Learning Earthquake Design and Construction
11. What are the Indian Seismic Codes?

Importance of Seismic Design Codes

Ground vibrations during earthquakes cause forces and deformations in structures. Structures need to be designed to withstand such forces and deformations. Seismic codes help to improve the behaviour of structures so that they may withstand the earthquake effects without significant loss of life and property. Countries around the world have procedures outlined in seismic codes to help design engineers in the planning, designing, detailing and constructing of structures. An earthquake-resistant building has four virtues in it, namely:

(a) *Good Structural Configuration:* Its size, shape and structural system carrying loads are such that they ensure a direct and smooth flow of inertia forces to the ground.

(b) *Lateral Strength:* The maximum lateral (horizontal) force that it can resist is such that the damage induced in it does not result in collapse.

(c) *Adequate Stiffness:* Its lateral load resisting system is such that the earthquake-induced deformations in it do not damage its contents under low-to-moderate shaking.

Keywords
Earthquake, Indian seismic code.

(d) *Good Ductility:* Its capacity to undergo large deformations under severe earthquake shaking even after yielding, is improved by favourable design and detailing strategies.

Seismic codes cover all these aspects.

Indian Seismic Codes

Seismic codes are unique to a particular region or country. They take into account the local seismology, accepted level of seismic risk, building typologies, and materials and methods used in construction. Further, they are indicative of the level of progress a country has made in the field of earthquake engineering.

The first formal seismic code in India, namely IS 1893, was published in 1962. Today, the Bureau of Indian Standards (BIS) has the following seismic codes:

IS 1893 (Part I), 2002, *Indian Standard Criteria for Earthquake Resistant Design of Structures* (5th Revision)

IS 4326, 1993, *Indian Standard Code of Practice for Earthquake Resistant Design and Construction of Buildings* (2nd Revision)

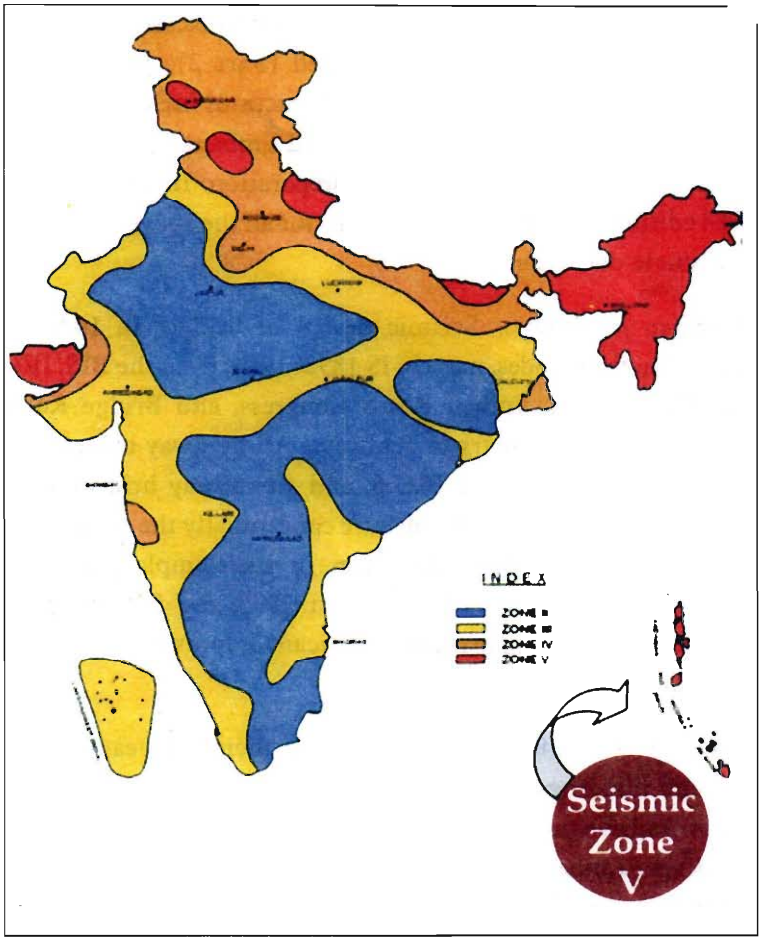
IS 13827, 1993, *Indian Standard Guidelines for Improving Earthquake Resistance of Earthen Buildings*

IS 13828, 1993, *Indian Standard Guidelines for Improving Earthquake Resistance of Low Strength Masonry Buildings*

IS 13920, 1993, *Indian Standard Code of Practice for Ductile Detailing of Reinforced Concrete Structures Subjected to Seismic Forces*

IS 13935, 1993, *Indian Standard Guidelines for Repair and Seismic Strengthening of Buildings*

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



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zones III, IV and V.

IS 1893: IS 1893 is the main code that provides the seismic zone map (*Figure* 1) and specifies seismic design force. This force depends on the mass and seismic coefficient of the structure; the latter in turn depends on properties like seismic zone in which structure lies, importance of the structure, its stiffness, the soil on which it rests, and its ductility. For example, a building in Bhuj will have 2.25 times the seismic design force of an identical building in Bombay. Similarly, the seismic coefficient for a single-storey building may have 2.5 times that of a 15-storey building.

The revised 2002 edition, Part 1 of IS1893, contains provisions that are general in nature and those applicable for buildings. The

other four parts of IS 1893 will cover: Liquid-Retaining Tanks, both elevated and ground supported (Part 2); Bridges and Retaining Walls (Part 3); Industrial Structures including Stack-Like Structures (Part 4); and Dams and Embankments (Part 5). These four documents are under preparation. In contrast, the 1984 edition of IS1893 had provisions for all the above structures in a single document.

Provisions for Bridges: Seismic design of bridges in India is covered in three codes, namely IS 1893 (1984) from the BIS, IRC 6 (2000) from the Indian Roads Congress, and Bridge Rules (1964) from the Ministry of Railways. All highway bridges are required to comply with IRC 6, and all railway bridges with Bridge Rules. These three codes are conceptually the same, even though there are some differences in their implementation. After the 2001 Bhuj earthquake, in 2002, the IRC released interim provisions that make significant improvements to the IRC6 (2000) seismic provisions.

IS 4326, 1993: This code covers general principles for earthquake resistant buildings. Selection of materials and *special features* of design and construction are dealt with for the following types of buildings: timber constructions, masonry constructions using rectangular masonry units, and buildings with prefabricated reinforced concrete roofing/flooring elements.

IS 13827, 1993 and IS 13828, 1993: Guidelines in IS 13827 deal with empirical design and construction aspects for improving earthquake-resistance of *earthen houses*, and those in IS 13828 with general principles of design and special construction features for *improving* earthquake resistance of buildings of *low-strength masonry*. This masonry includes burnt clay brick or stone masonry in weak mortars, like clay-mud. These standards are applicable in seismic zones III, IV and V. Constructions based on them are termed non-engineered, and are not totally free from collapse under seismic shaking intensities VIII (MMI) and higher. Inclusion of features mentioned in these guidelines may only

enhance the seismic resistance and reduce chances of collapse.

IS 13920, 1993: In India, reinforced concrete structures are designed and detailed as per the Indian Code IS 456 (2002). However, structures located in *high seismic regions* require ductile design and detailing. Provisions for the ductile detailing of *monolithic* reinforced concrete frame and shear wall structures are specified in IS 13920 (1993). After the 2001 Bhuj earthquake, this code has been made mandatory for all structures in zones III, IV and V. Similar provisions for seismic design and ductile detailing of steel structures are not yet available in the Indian codes.

IS 13935, 1993: These guidelines cover general principles of seismic strengthening, selection of materials, and techniques for repair/seismic strengthening of masonry and wooden buildings. The code provides a brief coverage for *individual reinforced concrete members* in such buildings, but does not cover *reinforced concrete frame or shear wall buildings* as a whole. Some guidelines are also laid down for non-structural and architectural components of buildings.

In Closure...

Countries with a history of earthquakes have well developed earthquake codes. Thus, countries like Japan, New Zealand and the United States of America, have detailed seismic code provisions. Development of building codes in India started rather early. Today, India has a fairly good range of seismic codes covering a variety of structures, ranging from mud or low-strength masonry houses to modern buildings. However, the key to ensuring earthquake safety lies in having a robust mechanism that enforces and implements these design code provisions in actual constructions.

Suggested Reading

[1] BMTPC, (2000), *Guidelines: Improving Earthquake Resistance of Housing*, Building Materials and Technology Promotion Council, New Delhi.

[2] Bridge Rules, (1964), *Rules Specifying the Loads for the Design of Super-Structure and Sub-Structure of Bridges and for Assessment of the Strength of Existing Bridges*, Government of India, Ministry of Railways (Railway Board).

[3] IRC 6, (2000), *Standard Specifications and Code of Practice for Road Bridges - Section II: Loads and Stresses*, Indian Roads Congress, New Delhi.

[4] IS 456, (2000), *Indian Standard Code of Practice for Plain and Reinforced Concrete*, Bureau of Indian Standards, New Delhi.

[5] SP 22 (S&T), (1982), *Explanatory Handbook on Codes for Earthquakes Engineering - IS 1893:1975 and IS 4326:1976*, Bureau of Indian Standards, New Delhi.

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