Living With Earthquakes

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abstract An earthquake can initiate severe damage to the civil infrastructure and bring disaster to public lives. This chapter describes a brief illustration of the causes and history of major earthquakes, the seismic conditions in India with emphasis on the northeast region, the disastrous effects, and the mitigation techniques to safeguard the civil infrastructures against such calamity.

Keywords Buildings; Liquefaction; Seismic waves; Seismograph; Tectonic plates

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Introduction

An earthquake is caused by the sudden release of potential energy in the Earth's lithosphere, producing seismic waves of various magnitudes of amplitude and frequency (Ohnaka 2013). The underground point of energy release is termed the 'epicenter,' and the seismic waves propagate toward the ground surface (Vassiliou and Hiroo 1982). Earthquakes can induce rapid vibration in the subsoil with high intensity, resulting in excess pore water pressure and decreased effective stress in the soil particles, leading to soil liquefaction that may adversely affect the stability of the underground foundation. In extreme circumstances, this may result in partial or complete collapse of the foundation and supporting structures (Bardet 2003; Dashti 2015). This chapter focuses on safeguarding civil infrastructure against possible seismic damage, with special reference to the earthquake-prone northeastern region of India.

Geological Aspects

The earth's interior consists of fragmented rock plates, called tectonic plates, which can move relative to each other due to the less viscous layer on which they sit. The movement of the plates causes stress to build up along their boundaries, known as faults, resulting in stored strain energy. When the stresses exceed the forces holding the plates in place, they slip along the fault, releasing an enormous amount of stored energy in a very short time. This energy travels through the earth's crust in the form of waves, causing the ground to shake during an earthquake. The sudden release of a large amount of energy can cause devastating destruction without warning.

About 225 million years ago, the earth's surface consisted of a single massive continent known as Pangaea. Over time, Pangaea began to break apart into two major continents, one of which was Gondwanaland that included Africa, South America, India, and Australia. Gondwanaland continued to split into smaller land masses, including the Indian plate, which drifted at a rate of 9 centimeters per year towards the Eurasian plate. The collision of these giant plates under enormous pressure led to the formation of the Himalayas (Rogers and Santosh 2003).

The earthquakes in India are due to the movement of the Indian plate. Currently, the Indian plate is drifting northeastward at a rate of 0.05 m/year, while the Eurasian plate is moving northward at only 0.02 m/year, as illustrated in Figure 3.1 (Prasath *et al.,* 2022). This differential motion causes the Eurasian plate to deform and the Indian plate to experience compression at a rate of 0.004 mm/year.

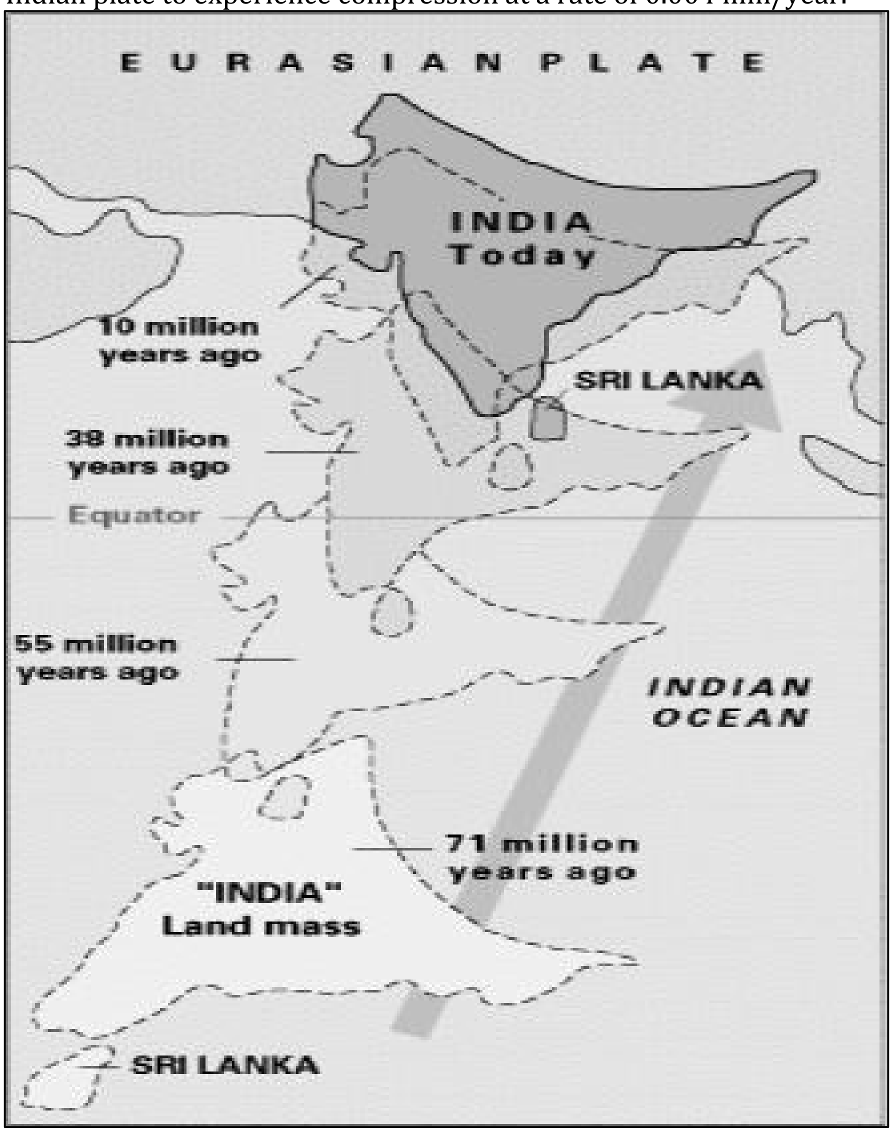

Figure 3.1. Sketch illustrating deformation of Indian plate over Eurasian plate.

According to the world seismic map, six countries, namely Mexico, Japan, California in the USA, Taiwan, Turkey, and India, are most vulnerable to earthquakes. Based on the varying geology and history of earthquakes, India is subdivided into four seismic zones: Zone II, III, IV, and V, as shown in Figure 3.2. Additionally, for urban planning and development, the metropolitan areas are micro-zoned based on local geology, soil profile, etc. (Walling and Mohanty 2009).

Seismography in North-Eastern India

As per the seismic zoning map of India, all seven states of the northeastern part of India, namely, Assam, Arunachal Pradesh, Sikkim, Meghalaya, Manipur, Mizoram, and Tripura, lie in a very high seismic-prone zone, i.e., zone V (Ghione *et al.,* 2021). The premier city of the northeast, Guwahati, was micro-zoned in the year 2008 by the Seismology Division, Department of Earth Sciences, Government of India. Seismic micro-zonation is a scientific approach to evaluating the seismic sensitivity and ground response to the seismicity of a particular area under rapid urbanization that is prone to severe earthquakes (Bansal and Verma 2013). The majority of casualties and property damage resulting from earthquakes are caused by the collapse of man-made structures rather than the earthquake itself. Earthquakes do not directly cause deaths or property damage, but rather it is the failure of buildings and infrastructure due to poor planning, inadequate design, substandard material quality, or poor workmanship that leads to the loss of life and property. The only way to reduce the risk of these losses is to promote awareness and preparedness, and to approach living with earthquakes in a scientific and systematic manner.

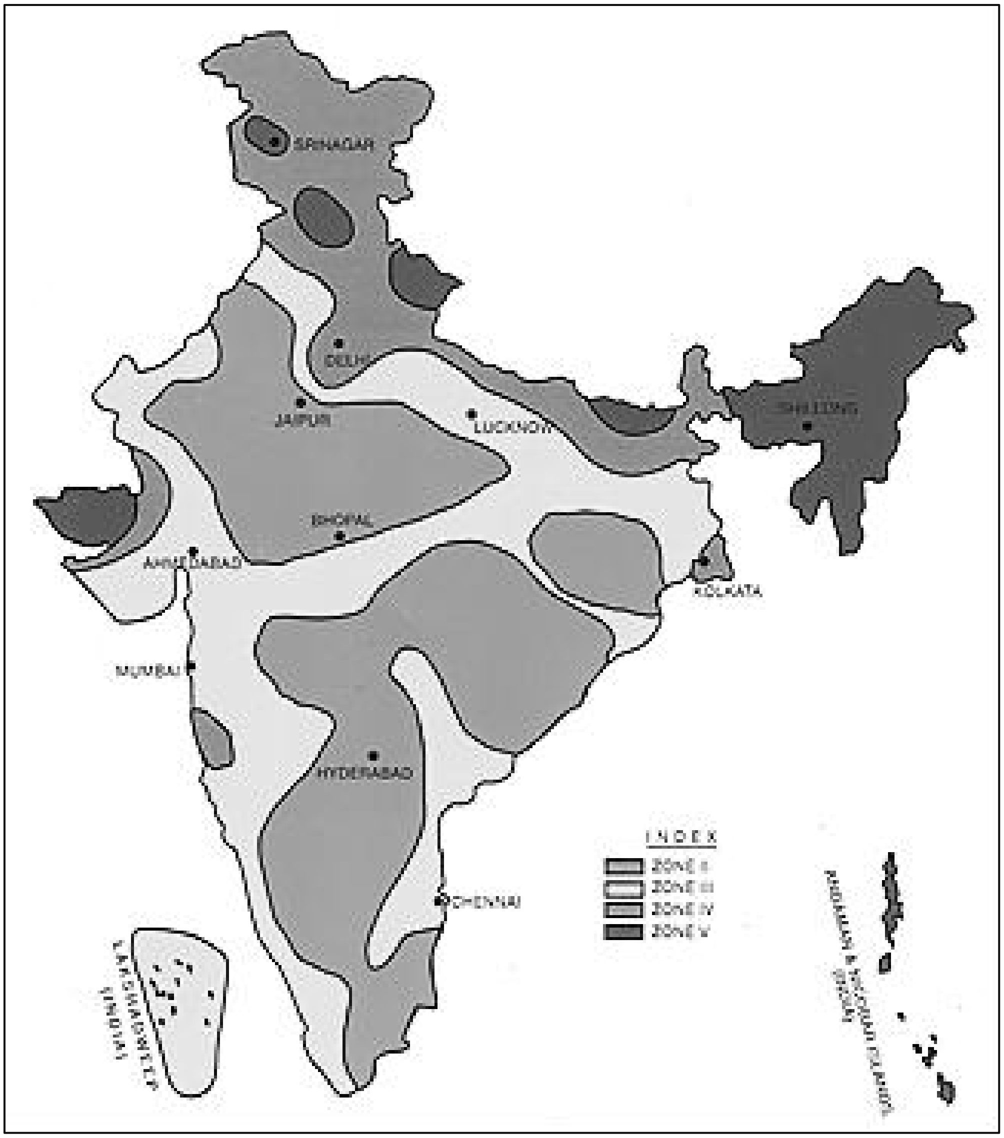

Figure 3.2. Seismic zoning map of India

Influence of Earthquakes on Civil Infrastructures

Earthquakes cause shaking of the ground in all directions. In addition to the normally designed loads, it is necessary to ensure the adequacy of the structure against sudden earthquake forces. Earthquakes cause sudden deflections to the entire building frame. The structural members, which consist of an RCC foundation with columns, tie beams, plinth beams, and floor beams with slabs, need to be properly designed to transfer the entire inertia forces, along with other combinations of loads, safely to the ground. Accuracy in soil investigation to evaluate the soil properties below the structures is therefore essential to ascertain the safe bearing capacity of the ground on which the building foundations are planned to rest, with dead loads, live loads, and sudden earthquake loads all in combination.
The idea behind ‘Earthquake Resistant Structures’ is that the structures should be engineered and built in

such a way that they can withstand the strong shaking of ground with repairable damages but without collapse, so that everything within the building structure is safe.

Safeguarding the Buildings

Proper soil investigation, careful planning, accurate structural design by competent professionals, selection of the right quality and quantity of building materials, and finally, proper workmanship in execution, under strict supervision and adaptation of all guidelines of BIS codes and the latest National Building Code (NBC), are the key factors for attaining a safe and sturdy structure.

Liquefaction of soil caused by an earthquake is another major factor that needs careful consideration for the safety and stability of structures in high-risk earthquake-prone zones. Due to liquefaction, the soil below the structures may lose its normal load-bearing characteristic, which can cause widespread destruction to manmade structures.

The structural response of a building frame during an earthquake depends critically on its overall shape, size, and geometry. Unfavorable architectural features that are detrimental to the earthquake response of the building should be avoided. Structural safety aspects of the buildings should get higher priority than their aesthetic appearance, particularly in the areas that fall under severe earthquake-sensitive zones.

Reinforced Cement Concrete (RCC) is a combination of sand, cement, and stone aggregates in specific grading and proportion called concrete along with the right qualities and right quantities of steel reinforcements. Like a healthy human body, a combination of muscles act as concrete and skeleton act as steel frame which gives strength to stand and move on the Earth.

Plain cement concrete is much stronger under heavy compressive loads, but its behavior under tension is poor. Steel bars respond very well under tensile loads due to their good ductile property. During an earthquake, tremendous multi-directional forces are applied suddenly on the building frame, causing deflection from its normal vertical position on the ground surface like an inverted pendulum. As a result, additional compressive and tensile forces are generated on the frame structure. The right sizes of the concrete members with the right quantity of steel reinforcements are to be determined during structural analysis by a competent Structural Engineer to make the building resistant to earthquake loads. Proper execution of the construction work at the site is also key to an earthquake-resistant building.

Legislation and Law Enforcement

The National Building Codes of India 2016 (NBC) and the Bureau of Indian Standards (BIS) Codes have recently been revised, taking into consideration all safety aspects, including the latest technological advancements in the construction industry, the development of techno-legal and techno-financial regimes, and the experience gained in dealing with natural calamities such as super cyclones and earthquakes suffered by the country (NBC 2016).

The "Construction Bye-laws" of all highly seismic-sensitive states in the northeast need to be reviewed and revised carefully, following the guidelines of NBC (2016) and the recommendations of the National Disaster Management Authority, Ministry of Home Affairs, Government of India. The process of registration of engineers and architects as consultants on record, including Structural Engineers on Record (SER) and Construction Engineers on Record (CER), and the submission of Structural Design Basic Reports (SDBP) as recommended by the National Disaster Management Committee under the Ministry of Home Affairs, should be made mandatory in all the states of the northeast under very high seismic zone (i.e., zone V) for all important and/or major construction projects.

Mishandling of the construction processes of all important structures by unqualified persons should be prevented as a part of pre-disaster management to minimize and control post-disaster management aspects by the authorities under strict rules and regulations.

An earthquake is a natural calamity that cannot be predicted, prevented, or diverted. The technical ability and dedication of the technical consultants, the honest attitudes and approaches of the owners, builders, contractors, and the public in general, as well as the alertness and proper initiatives of the concerned authorities and action plans for generating awareness and preparedness, are all prime factors in making our shelters safe and healthy for us to enjoy life on this beautiful, clean, and green earth.

Everyone's collective efforts can reduce the risk of loss of life and property during the sudden violent earthquake. Proper learning and preparedness to live with the sudden shaking of the earth is the only solution for minimizing damage and enjoying life without fear.

Conclusions

Earthquake is a major disaster to human civilization, causing severe damage to civil infrastructure under extreme circumstances. The specific influence of earthquakes on buildings and other infrastructures, prevention, and remedial measures to be undertaken, together with law enforcement, with particular reference to India, have been discussed in this chapter.

Conflict of Interest Statement

The author declares that there is no conflict of interest.

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