CHAPTER 1

INTRODUCTION

1.1 GENERAL

One of the most frightening and destructive phenomena of nature is a severe earthquake and its terrible after-effects. India is highly susceptible to frequent damaging earthquakes. Regions in Northern India, particularly the Himalayan belt, have experienced earthquakes at regular intervals that have caused immense damage in the past. Central and south India were hitherto assumed to be relatively safe from major seismic activities. However, damaging earthquakes occur all over India. After the Bhuj earthquake in 2001, BIS has revised the zonal classifications. This raises the possibility that no area of our country is safe from earthquakes.

Recent earthquakes have shown how some buildings are completely destroyed or simply collapse, while others maintain their geometric configuration but fall over from the base or shift several yards from their original location. In the former, bad construction, faulty design of members and elements not properly connected, lead to a break, split or bend. In the later, due to excessive structural rigidity, the buildings collapse and the whole structure is destroyed as they are not designed to withstand the violent forces released during earthquakes, thus leading to considerable loss of life and property.
During past earthquakes, reinforced concrete (RC) frame buildings that have columns of different heights within one storey, suffered more damage in the shorter columns as compared to taller columns in the same storey. Two examples of buildings with captive columns are shown in Figure 1.1. Poor behaviour of captive columns is due to the fact that in an earthquake, a tall column and a short column of same cross-section move horizontally by the same amount (Figure 1.2). However, the captive column is stiffer as compared to the tall column, and it attracts larger earthquake force. Stiffness of a column means resistance to deformation – the larger is the stiffness, larger is the force required to deform it. If a captive column is not adequately designed for such a large force, it can suffer significant damage during an earthquake. This behaviour is called captive column effect. The damage in these short columns is often X-shaped cracking – this type of damage of columns is due to shear failure.

Figure 1.1  Buildings with captive columns (Murty 2005)  
Figure 1.2  Comparison of short column and long column (Murty 2005)

In a partially RC frame structure, infill panels are made shorter than the column length. These columns are unable to flex under the lateral loads from the earthquake due to the in-plane stiffness of the infill (Figure 1.3(a)). Hence, the columns are confined to flexure only in between the top of the
infill wall and the bottom of the beam of the frame. In this case, excessive shear forces occur in the column length $l_s$. Therefore, columns can seriously be damaged during an earthquake and this situation can cause collapse of the building (Figure 1.3(b)). This form of damage observed frequently in an earthquake damaged building is due to the captive column effect.

![Figure 1.3(a) A frame with partial Infill and (b) Captive column behaviour](image)

Some of the captive column failures observed in the past earthquakes are shown in Figure 1.4.

![Figure 1.4 Typical captive column failures during past earthquake](image)

Damage to structural column (“captive column”) due to restraint caused by partial height masonry wall in the 2001 Peru Earthquake (Photo courtesy of Eduardo Fierro, BFP Engineers).

Sichuan Earthquake –2008, Captive column failure, Hanwang High School

Captive columns and large diameter drain pipes and aggregate were noted in some columns Taiwan Jiji Earthquake 1999

Figure 1.4 (Continued)