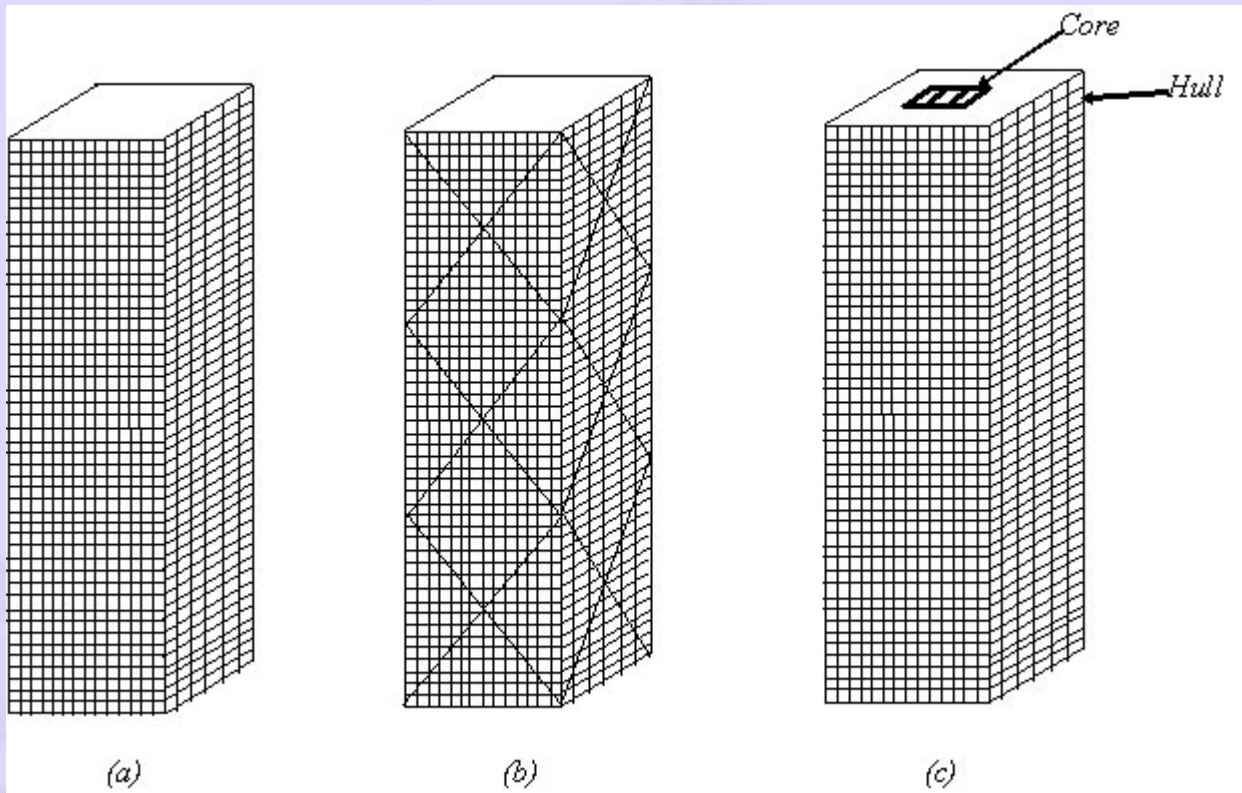


### 3.6 Advanced structural forms

The bracing systems discussed so far are not efficient for buildings taller than 60 stories. This section introduces more advanced types of structural forms that are adopted in steel-framed multi-storeyed buildings taller than 60 storeys.

#### Framed -tube structures



**Fig. 3.14(a) Framed tube (b) Braced framed tube (c) Tube-in-Tube frame**

The framed tube is one of the most significant modern developments in high-rise structural form. The frames consist of closely spaced columns, 2 - 4 m between centres, joined by deep girders. The idea is to create a tube that will act like a continuous perforated chimney or stack. The lateral resistance of framed tube structures is provided by very stiff moment resisting frames that form a tube around the perimeter of the building. The gravity loading is shared between the

tube and interior columns. This structural form offers an efficient, easily constructed structure appropriate for buildings having 40 to 100 storeys.

When lateral loads act, the perimeter frames aligned in the direction of loads act as the webs of the massive tube cantilever and those normal to the direction of the loading act as the flanges. Even though framed tube is a structurally efficient form, flange frames tend to suffer from shear lag. This results in the mid face flange columns being less stressed than the corner columns and therefore not contributing to their full potential lateral strength. Aesthetically, the tube looks like the grid-like façade as small windowed and is repetitious and hence use of prefabrication in steel makes the construction faster. A typical framed tube is shown in Fig.3.14 (a).

### **Braced tube structures**

Further improvements of the tubular system can be made by cross bracing the frame with X-bracing over many stories, as illustrated in Fig. 3.14(b). This arrangement was first used in Chicago's John Hancock Building in 1969.

As the diagonals of a braced tube are connected to the columns at each intersection, they virtually eliminate the effects of shear lag in both the flange and web frames. As a result the structure behaves under lateral loads more like a braced frame reducing bending in the members of the frames. Hence, the spacing of the columns can be increased and the depth of the girders will be less, thereby allowing large size windows than in the conventional framed tube structures.

In the braced tube structure, the braces transfer axial load from the more highly stressed columns to the less highly stressed columns and eliminates differences between load stresses in the columns.

### **Tube-in-Tube structures**

This is a type of framed tube consisting of an outer-framed tube together with an internal elevator and service core. The inner tube may consist of braced frames. The outer and inner tubes act jointly in resisting both gravity and lateral loading in steel-framed buildings. However, the outer tube usually plays a dominant role because of its much greater structural depth. This type of structures is also called as Hull (Outer tube) and Core (Inner tube) structures. A typical Tube-in-Tube structure is shown in Fig. 3.14c.

### **Bundled tube**

The bundled tube system can be visualised as an assemblage of individual tubes resulting in multiple cell tube. The increase in stiffness is apparent. The system allows for the greatest height and the most floor area. This structural form was used in the Sears Tower in Chicago. In this system, introduction of the internal webs greatly reduces the shear lag in the flanges. Hence, their columns are more evenly stressed than in the single tube structure and their contribution to the lateral stiffness is greater.