Chapter two

Literature review

2.1. Introduction

A multi-storey building must resist the combined effects of horizontal and vertical loads; it is composed of foundations, frameworks and floor slabs.

The framework comprises columns and beams together with horizontal and vertical bracings, which stabilize the building by resisting horizontal actions (wind and seismic loads).

Floor slabs are supported by beams so that their vertical loads are transmitted to the columns. They are made of reinforced concrete or composite slabs using profiled steel sheets.

Since there are lots of possibilities of bracings and connections, choosing the appropriate one and minimizing the structure cost is the major concern in the design of steel buildings.

The main reason for choosing the wind forces as the main source of lateral force is that the most severe damages in multi-storey steel structures are caused by winds. For example, in the United States between 1986 and 1993, hurricanes and tornadoes caused $41 billion in insured catastrophic losses, compared with $6.18 billion for all other natural hazards combined (Taranath, Wind and Earthquake Resistant Buildings, 2005).

2.2. Structure materials

The principal modern building materials are masonry, concrete (mass, reinforced and pre-stressed), structural steel and timber. All materials listed have particular advantages in given situations, and construction of a particular building type can be in various materials, e.g. a multi-storey building can be loadbearing masonry, concrete shear wall or frame or steel frame. One duty of the designer is to find the best solution which takes account of all requirements economic, aesthetic and utilitarian.

The principal uses, types of construction and advantages of the main structural materials are as follows:

2.2.1. Masonry

Load bearing walls or columns in compression and walls taking in-plane or transverse loads. Construction is very durable, fire resistant and aesthetically pleasing. Building height is moderate, say to 20 stories.

2.2.2. Concrete

Framed or shear wall construction in reinforced concrete is very durable and fire resistant and is used for the tallest buildings. Concrete, reinforced or prestressed, is used for floor construction in all buildings, and concrete foundations are required for all buildings.

2.2.3. Structural steel

Load bearing frames in buildings, where the main advantages are strength and speed of erection. Steel requires protection from corrosion and fire.

Structural steels are alloys of iron, with carefully controlled amounts of carbon and various other metals such as manganese, chromium, aluminum, vanadium, molybdenum, niobium and copper. The carbon content is less than 0.25%, manganese less than 1.5% and the other elements are in trace amounts. The alloying elements control grain size and hence steel properties, giving high strengths, increased ductility and fracture toughness. The inclusion of copper gives the corrosion resistant steel Corten. High-carbon steel is used to manufacture hard drawn wires for cables and tendons.

A comparison of the steels used in various forms in structures is given in table (2.1) .

Table (2.1): Strengths of steels used in structures:

Steel type and use	Yield stress (N/mm2)
Grade 43—structural shapes	275
Grade 50—structural shapes	355
Quenched and self-tempering	500
Quenched tempered-plates	690
Alloy bars—tension members	1030
High carbon hard-drawn wire for cables	1700

2.3. Type of structures

The structural engineer adopts a classification for structures based on the way the structure resists loads, as follows (General types of structures):

- Gravity masonry structures.
- Framed structures.
- Shell structures.
- Tension structures.
- Pneumatic structures.

2.4. Steel frame structures

Steel-framed structures .maybe further classified into the following types:

- Single-storey, single or multi-bay structures which may be of truss or stanchion frames or rigid frame of solid or lattice members.
- Multi-storey, single or multi-bay structures of braced or rigid frame construction.
- Space structures (space decks, domes, towers etc.).
- Tension structures and cable-supported roof structures.
- Stressed skin structures.

2.5. Multi-storey buildings

2.5.1. Introduction

The tallness of a building is relative and cannot be defined in absolute terms either in relation to height or the number of stories. But, from a structural engineer's point of view the tall building or multistoried building can be defined as one that, by virtue of its height, is affected by lateral forces due to wind or earthquake or both to an extent that they play an important role in the structural design. Tall structures have fascinated mankind from the beginning of civilization. The Egyptian Pyramids, one among the seven wonders of world, constructed in 2600 B.C. are among such ancient tall structures.

Such structures were constructed for defense and to show pride of the population in their civilization. The growth in modern multistoried building construction, which began in late nineteenth century, is intended largely for commercial and residential purposes.

The development of the high-rise building has followed the growth of the city closely.

The process of urbanization, that started with the age of industrialization, is still in

progress in developing countries. Industrialization causes migration of people

to urban centers where job opportunities are significant. The land available for buildings to accommodate this migration is becoming scarce, resulting in rapid increase in the cost of land. Thus, developers have looked to the sky to make their profits. The result is multi- storied buildings, as they provide a large floor area in a relatively small area of land in urban centers.

In developed countries a very large percentage of multistoried buildings are built with steel whereas steel is hardly used in construction of multistoried frames in developing countries even though it has proved to be a better material than reinforced concrete.

The use of steel in multi-storey building construction results in many advantages for the builder and the user. The reasons for using steel frames in the construction of multi-storey buildings are listed below:

- Steel frames are faster to erect compared with reinforced concrete frames. The availability of the building in a shorter period of time results in economic advantages to the owner due to shorter period of deployment of capital, without return.
- In comparison with concrete construction, steel frames are significantly lighter. This results in very much reduced loads on foundations.
- The elements of framework are usually prefabricated in the factory under effective quality control thus enabling a better product. This form of construction results in much reduced time on site activities, plant, materials and labour, causing little disruption to normal life of the community, unlike wet concrete construction process.
- The use of steel makes possible the creation of large, column-free internal spaces.
- The framework is not susceptible to delays due to slow strength gain, as in concrete construction.
- The material handling capacity required at site in steel construction is less than prefabricated concrete construction.
- Steel structure occupies lesser percentage of floor area in multistoried buildings.
- The steel frame construction is more suitable to withstand lateral loads caused by wind or earthquake.

2.5.2. Specific basis of comparisons for Multi-storey buildings

Many different systems are used and many parameters can be varied in design. Some important aspects of the problem are as follows:

- Overall framing.
- Flooring.
- Design method.
- Fire protection.
- Foundations.
- Stability:

Various systems or framing arrangements can be used to stabilize multi-storey buildings and resist horizontal loads. The building may be braced in both directions, rigid one way and braced the other or rigid in both directions. Alternatively, concrete shear walls or lift shafts can be used to provide stability. Tube construction is used for very tall buildings.

These systems are illustrated in section (2.5.3).

2.5.3. Structure system

The structural form of a tall building depends on a number of factors, some are given below:

- Internal planning
- Material and method of construction
- External architectural treatment
- Location and routing of service system
- Nature and magnitude of horizontal loading
- Height and proportion of building

Here are the top systems Construction, which is one of the parts thereof, contain of bracings in additional to rigid frame:

2.5.3.1. Rigid -Frame Structures

Rigid frame structures consist of columns and girders joined by moment –resistant connections. The lateral stiffness of a rigid -frame bent depends on the bending stiffness of the columns, girders, and connections in the plane of the bent (Figure 2.1). The rigid frame's principal advantage is its open rectangular arrangement, which allows freedom of planning and easy fitting of doors and windows. If used as the only source of lateral resistance in a building, in its typical 20 ft (6 m)-30 ft (9m) bay size, rigid framing is economic only for buildings up to about 25 stories. Above 25 stories the relatively high lateral flexibility of the frame calls for uneconomically large members in order to control the drift.

Rigid -frame construction is ideally suited for reinforced concrete buildings be- cause of the inherent rigidity of reinforced concrete joints. The rigid -frame form is also used for steel frame buildings, but moment -resistant connections in steel tend to be costly.

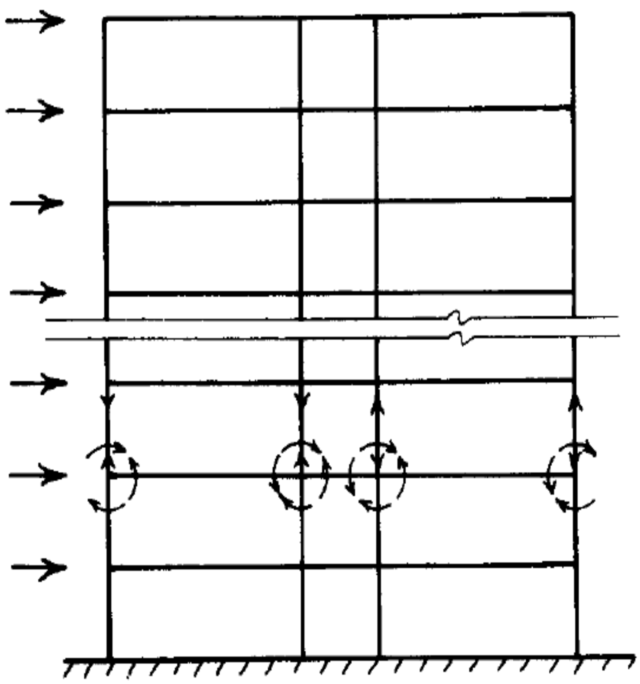

Figure 2.1: rigid frame

2.5.3.2. Braced -Frame Structures

In braced frames the lateral resistance of the structure is provided by diagonal member’s that together with the girders forms the "web" of the vertical truss with the columns acting as the "chords" (Figure 2.2). Because the horizontal shear on the building is resisted by the horizontal components of the axial tensile or compressive actions in the web members, bracing systems are highly efficient in resisting lateral loads.

Bracing is generally regarded as an exclusively steel system because the diagonals are inevitably subjected to tension for one or the other directions of lateral loading. Concrete bracing of the double diagonal form is sometimes used, however, with each diagonal designed as a compression member to carry the full external shear.

The efficiency of bracing, in being able to produce a laterally very stiff structure for a minimum of additional material, makes it an economical structural form for any height of building, up to the very tallest.

A major disadvantage of diagonal bracing is that it obstructs the internal planning and the location of windows and doors.

The traditional use of bracing has been in story -height, bay -width modules (Figure 2.2) that are fully concealed in the finished building more recently however external larger scale bracing, extending over many stories and bays (Figure 2.3), has been used to produce not only highly efficient structures, but aesthetically attractive buildings.

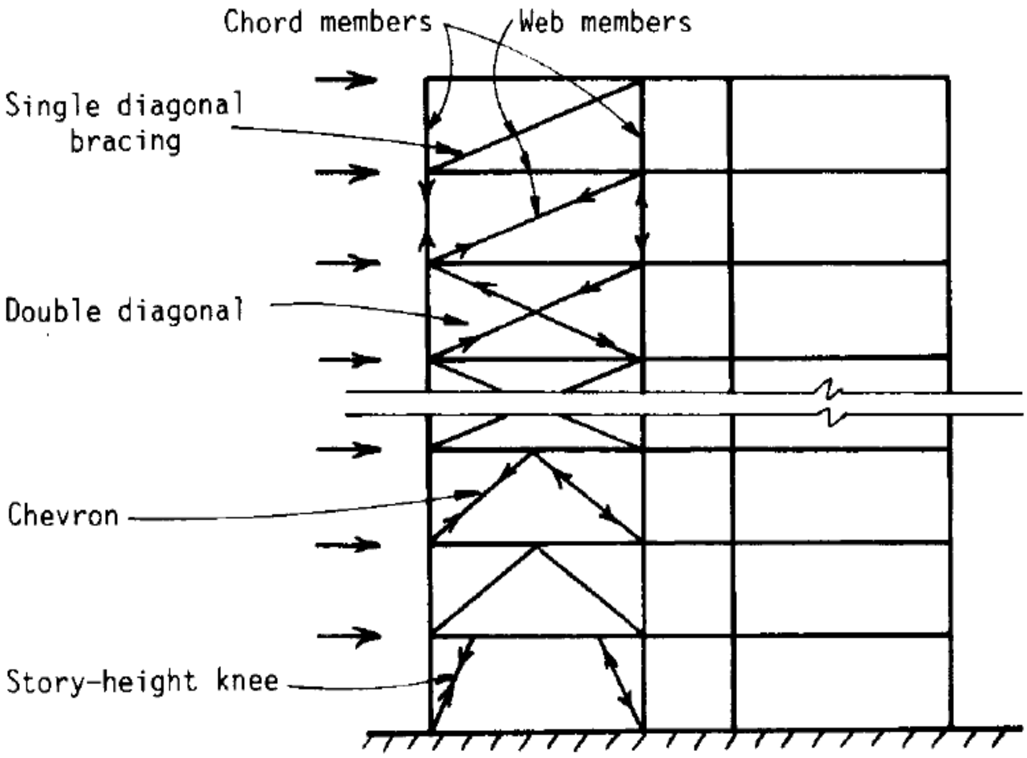

Figure 2.2: braced frame showing different type of bracing

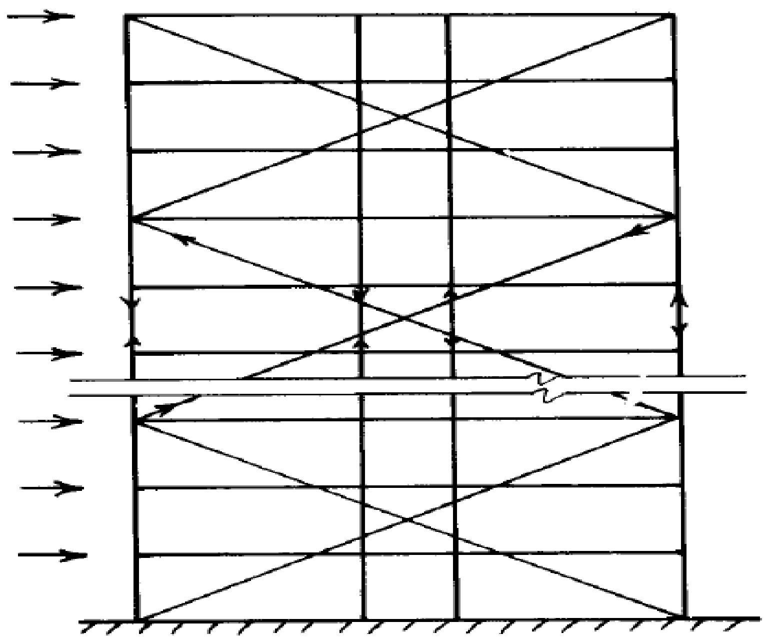

Figure2.3: Large-scale braced frame

2.5.3.3. Framed -Tube Structures

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 frames consist of closely spaced columns, 6-12 ft (2-4

m) between centers, joined by deep spandrel girders. Although the tube carries all the lateral loading, the gravity loading is shared between the tube and interior columns or walls.

When lateral loading acts, the perimeter frames aligned in the direction of loading act as the "webs" of the massive tube cantilever, and those normal to the direction of the loading act as the "flanges".

The tube is suitable for both steel and reinforced concrete construction and has been used for buildings ranging from 40 to more than 100 stories.

To improving the efficiency of the framed tube, thereby increasing its potential for use to even greater heights as well as allowing greater spacing between the columns, is to add diagonal bracing to the faces of the tube (this type of frame tube call Braced -Tube Structures). This arrangement was first used in a steel structure in 1969, in Chicago's John Hancock Building (Figure 2.4).

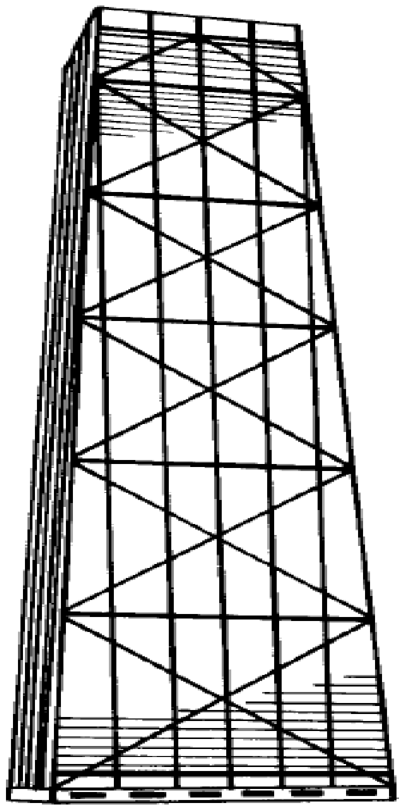

Figure 2.4: steel braced tube

2.5.3.4. Outrigger -Braced Structures:

This efficient structural form consists of a central core, comprising either braced frames or shear walls, with horizontal cantilever "outrigger" trusses or girders connecting the core to the outer columns (Figure 2.5a). When the structure is loaded horizontally, vertical plane rotations of the core are restrained by the outriggers through tension in the windward columns and compression in the leeward columns (Figure 2.5b).

At the outrigger level, the large, often two-story, depths of the outrigger and perimeter trusses make it desirable to locate them within the plant levels in the building.

The degree to which the perimeter columns of an outrigger structure behave compositely with the core depends on the number of levels of outriggers and their stiffness's. Multilevel outrigger structures show a considerable increase in their effective moment of resistance over single outrigger structures. This increase diminishes, however, with each additional level of outriggers, so that four or five levels appear to be the economic limit. Outrigger -braced structures have been used for buildings from 40 to 70 stories high, but the system should be effective and efficient for much greater heights.

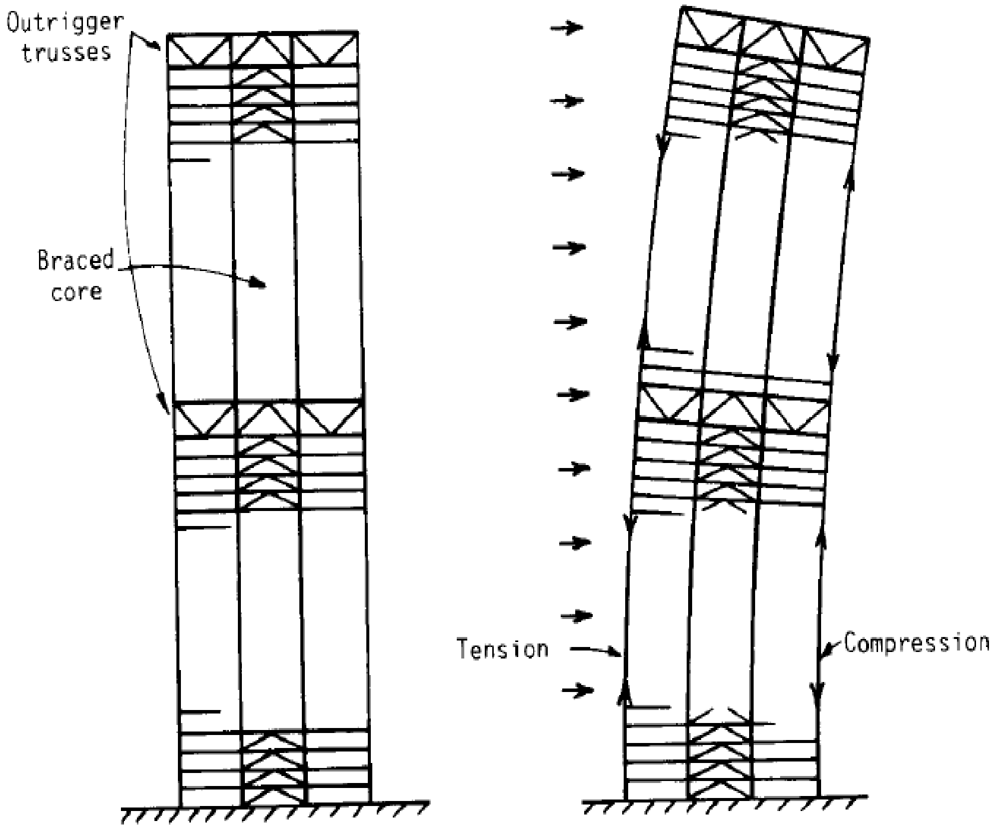

Figure 2.5: (a) Outrigger -braced structure; (b) outrigger -braced structure under load.

2.5.3.5. Suspended Structures

The suspended structure consists of a central core, or cores, with horizontal cantilevers at roof level, to which vertical hangers of steel cable, rod, or plate are attached. The floor slabs are suspended from the hangers (Figure 2.6).

The advantages of this structural form are primarily architectural in that, except for the presence of the central core, the ground story can be entirely free of major vertical members, thereby allowing an open concourse; also, the hangers, because they are in tension and consequently can be of high strength steel, have a minimum sized section and are therefore less obtrusive.

The structural disadvantages of the suspended structure are that it is inefficient in first transmitting the gravity loads upward to the roof -

level cantilevers before returning them through the core to the ground, and that the structural width of the building at the base is limited to the relatively narrow depth of the core, which restricts the system to buildings of lesser height.

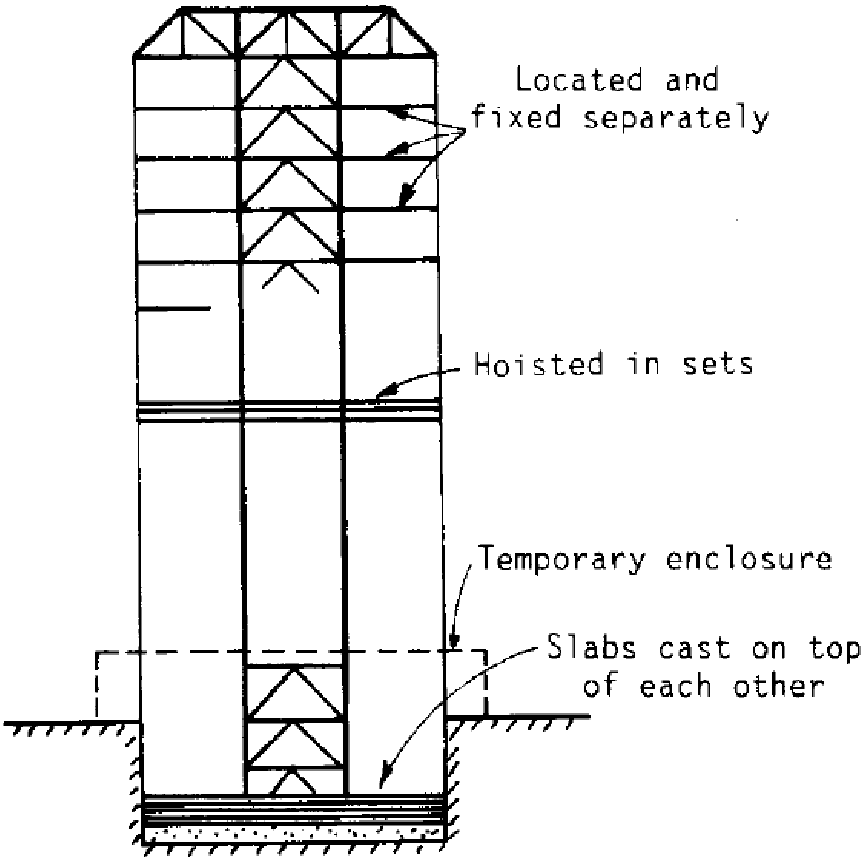

Figure 2.6: suspended structure

2.5.3.6. Space Structures

The primary load -resisting system of a space structure consists essentially of three-dimensional triangulated frame as distinct from an assembly of planar bents whose members serve dually in resisting both gravity and horizontal loading. The result is a highly efficient, relatively lightweight structure with a potential for achieving the greatest heights. The 76 -story Hong Kong Bank of China Building (Figure 2.7) is a classic example of this structural form.

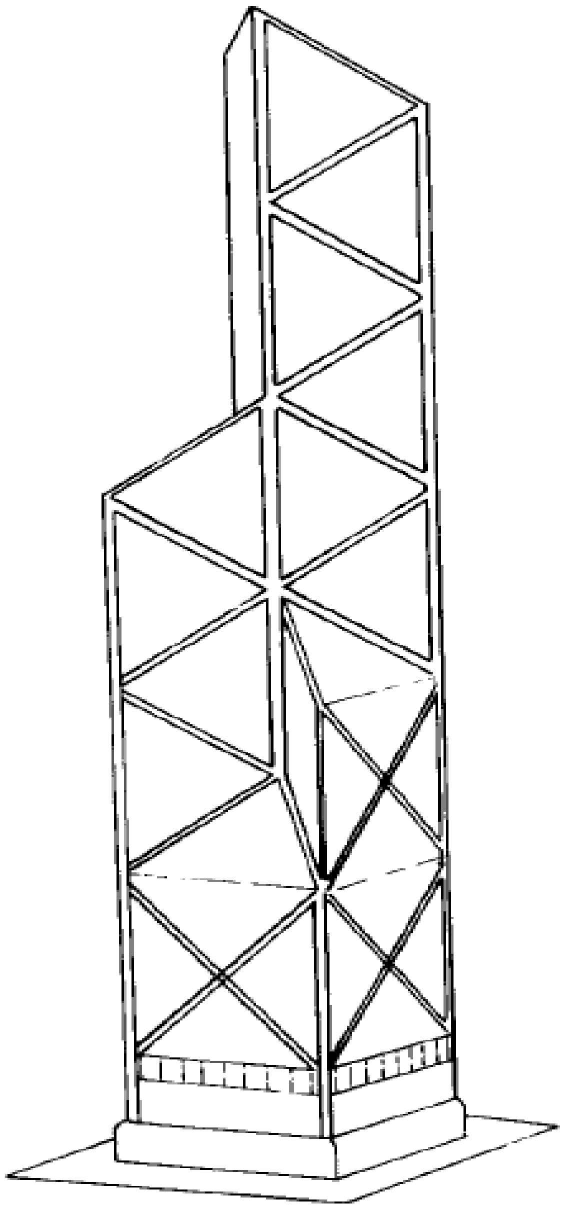

Figure 2.7: Space structure

2.5.4. Anatomy of multi-storey buildings

The vertical or gravity load carrying system of a multi-storey steel-framed building
comprises a system of vertical columns interconnected by horizontal beams, which supports the floors and roofing. The resistance to lateral loads is provided by diagonal bracing or shear walls or rigid frame action between the beams and columns. Thus, the components of a typical steel-framed structure are:

2.5.4.1. Floor structure

The floor system generally serves two purposes:

• Primarily the floor carries vertical dead and imposed load and transmits these loads through beams to the columns/walls.

• The floor also has to act as a horizontal diaphragm that ties the building together, stabilizes the walls and columns and transmits horizontal wind load to rigid frames, braced bays or shear walls.

The spacing of supporting beams must be compatible with the resistance of the floor slabs. Floor slabs may be made from pre-cast concrete, in-situ concrete or composite slabs using steel decking.

2.5.4.2. Walls

Walls in steel-framed buildings may be classified as follows:

• Structural shear walls located in bays on the perimeter, around cores or in other suitable areas—these are of reinforced concrete or composite construction incorporating steel columns. All-steel braced bays with fireproof cladding serve the same purpose. These walls carry wind and vertical load.

• Non-load bearing permanent division and fire-resistant walls—these are constructed in brick and block work and are needed to protect lifts, stairs and to divide large areas into fireproof compartments.

• Movable partitions—these are for room division.

• Curtain walls—these include glazing, metal framing, metal or precast concrete cladding panels, insulation and interior panels.

• Cavity walls with outer leaf brick, inner leaf breeze block—these are common for medium-rise steel-framed buildings.

2.5.4.3. Connections

The most important aspect of structural steel work for buildings is the design of connections between individual frame components. Depending upon the structural
behavior, the connections can be classified as following:

1. Simple connections: The connection is detailed to allow the beam end to rotate freely and the beam behaves as a simply supported beam. Such a connection transfers shear and axial forces between the connecting members but does not transfer bending moment.

2. Rigid connections: The connection is detailed to ensure a monolithic joint such that the angle between beam and column before deformation remains the same even after deformation. Such a connection transfers shear, axial force and bending moment from the beam to the column.

3. Semi-rigid connections: Due to flexibility of the joint some relative rotation between the beam and column occurs. When this is substantial, the joints are designed as semi-rigid.

2.5.4.4. Steel members

A. Columns

Columns are the structural components which transmit all vertical loads from the floors to the foundations. The means of transmission of vertical load is related to the particular structural system used for the framework .

The location of columns in plan is governed by the structural lay-out. The most common grid arrangements are square, rectangular, or occasionally triangular, according to the choice of the global structural system. The spacing of columns depends upon the load-bearing resistance of the beams and floor structures.

B. Beams

Beams support the floor elements and transmit their vertical loads to the columns.

In a typical rectangular building frame the beams comprise the horizontal members which span between adjacent columns; secondary beams may also be used to transmit the floor loading to the main (or primary) beams.

C. Bracings

All-steel, open or closed sections are used as in section (2.7.2).

2.5.4.5. Foundations

Foundations transfer the loads from the building structure to the ground.

2.6. Braced Frames

2.6.1. General introduction

Bracing is a highly efficient and economical method of resisting horizontal forces in a frame structure. A braced bent consists of the usual columns and girders, whose primary purpose is to support the gravity loading, and diagonal bracing members that are connected so that the total set of members forms a vertical cantilever truss to resist the horizontal loading. The braces and girders act as the web members of the truss, while the columns act as the chords. Bracing is efficient because the diagonals work in axial stress and therefore call for minimum member sizes in providing stiffness and strength against horizontal shear.

Historically, bracing has been used to stabilize laterally the majority of the world's tallest building structures, from the earliest examples at the end of the nineteenth century to the present time. The Statue of Liberty, constructed in New York in 1883, was one of the first major braced structures. In the following three decades large numbers of braced steel -frame tall buildings were erected in Chicago and New York. The 57 -story, 792 -ft -high, braced steel Woolworth Tower, completed in 1913, established a height record, which it held until the 77 -story, 1046-ft -high Chrysler Building and the 102 -story, 1250 -ft -high Empire State Building (Figure 2.8) were completed in 1930 and 1931, respectively.

One or two story height bracing, as used generally in the earlier high-rise steel structures, is an effective and still widely used arrangement. Recently, however, a much larger scale form of bracing, traversing many stories and bays, has also been used to considerable structural and architectural advantage in medium- and high-rise buildings, thereby extending significantly the repertoire of bracing concepts.

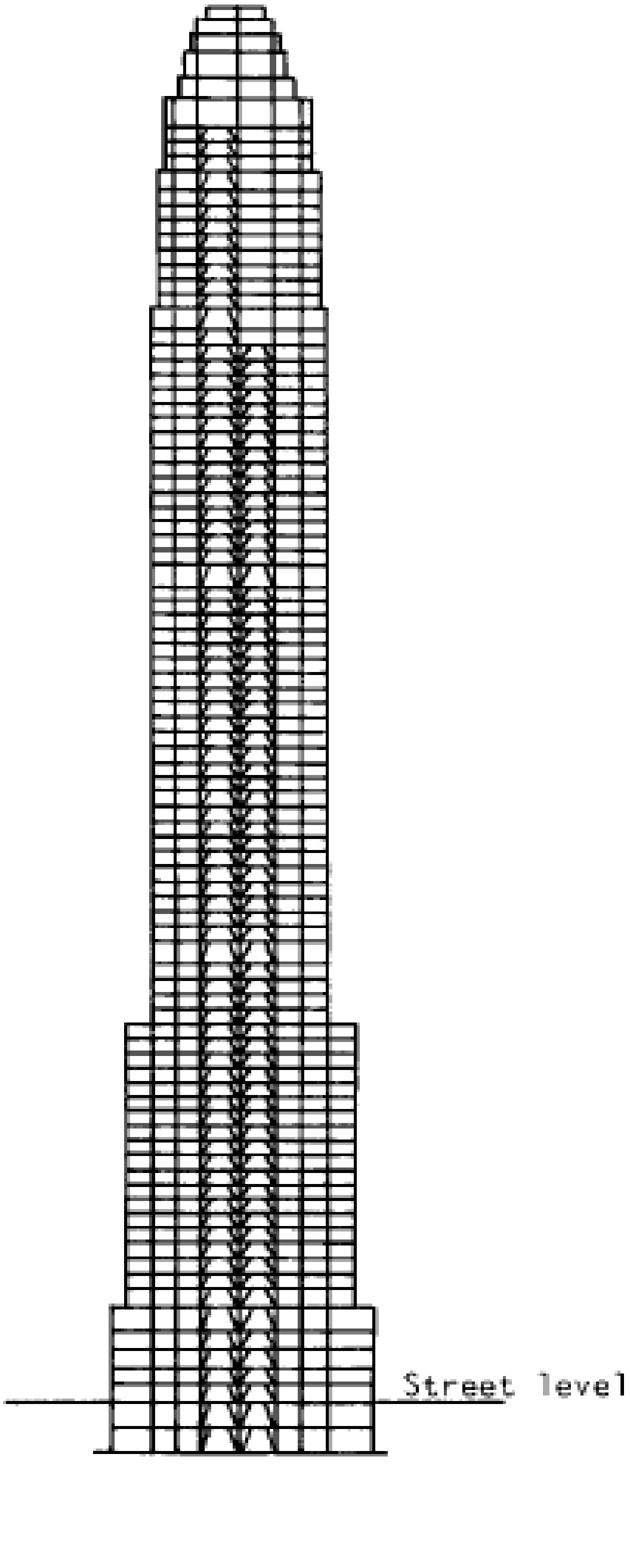

Figure 2.8: Empire State Building: typical braced bent

2.6.2. Type of bracings

Bracing can be categorized into the following types:

2.6.2.1. Diagonal bracing {single and double}

This type of bracing is preferred when the availability of the opening spaces in a bay of frame are required. Diagonal bracing is obstructive in nature as it blocks the location of opening which ultimately affects the esthetic of the building elevation. It also sometimes hinders the passage for use.

Diagonal bracing can be single diagonal or double diagonal as shown in (Figure 2.9). if there is no architectural limitation.

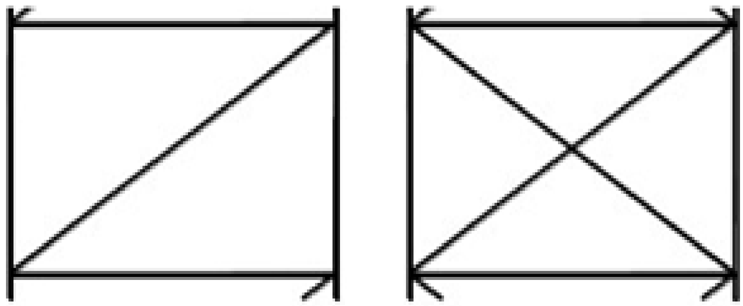

Figure 2.9: Diagonal bracings

2.6.2.2. K-bracing and v bracing

The full diagonal bracing is not used in areas where a passage is required. In such cases, k-bracings are preferred over diagonal bracing because there is a room to provide opening for doors and windows etc. as shown in (Figure 2.10).

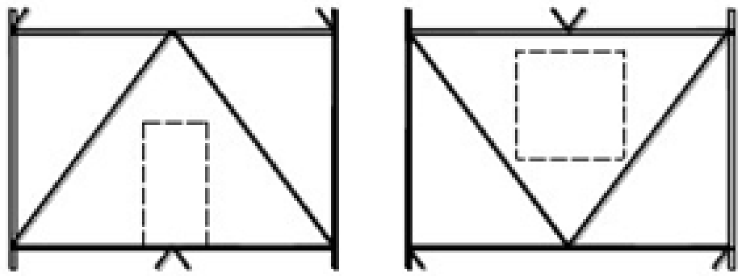

Figure 2.10: K-bracing and v bracing

2.6.2.3. Eccentric bracing

Besides K-bracing, there is another type in which door and window openings can be allowed known as eccentric bracing as shown in (Figure 2.11). Such type of bracing arrangement cause the bending of the horizontal members of the web of braced bent. Generally these types of braced bents resist the lateral forces by bending action of beams and columns.

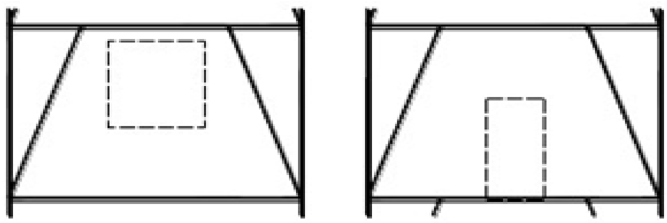

Figure 2.11: Eccentric bracing

2.6.2.4. Quadrant bracing

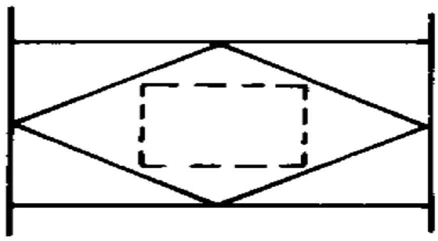

Figure 2.12: quadrant bracing

2.6.2.5. Other types of bracings

Which are comes from:

a. change the dimension of shape:

For example:

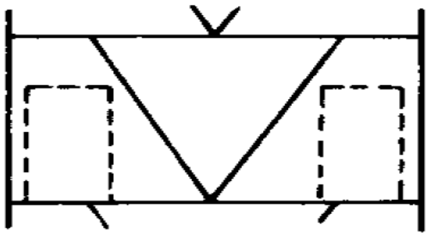

Figure 2.13a: modified v bracing

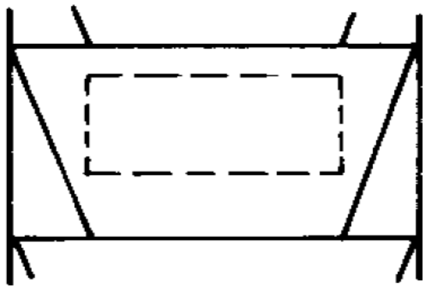

Figure 2.13b: modified Eccentric bracing

b. hardening of main shape:

For example:

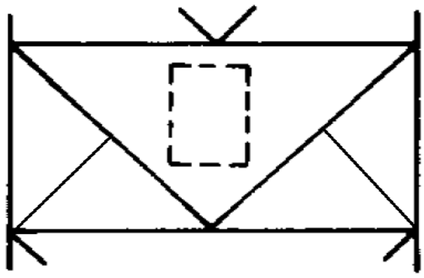

Figure 2.14a: hardening v bracing

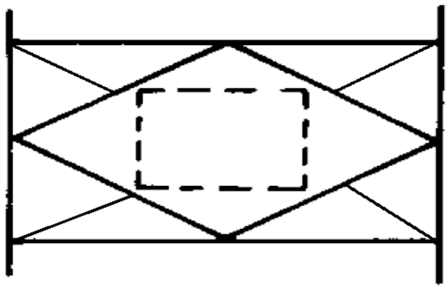

Figure 2.14b**:** hardening quadrangular bracing

2.6.3. Behaviour of bracing

Because lateral loading on a building is reversible, braces will be subjected in turn to both tension and compression; consequently, they are usually designed for the more stringent case of compression. As an exception to designing braces for compression, the braces in the double - diagonal system are sometimes assumed to buckle in compression, and each diagonal is designed to carry in tension the full shear in the panel.

A significant advantage of the fully triangulated bracing types (Figure 2.15a -e) is that the girder moments and shears are independent of the lateral loading on the structure. Consequently, the floor framing, which, in this case, is designed for gravity loading only, can be repetitive throughout the height of the structure with obvious economy in the design and construction.

In bracing systems in which the diagonals connect to the girder at a significant distance from the girder ends, for example, those in (Figure 2.15c, d, e, and h) the girder can be designed more economically as continuous over the connection, thus helping to offset the cost of the bracing. A further advantage of this type of bracing system is that the braces, in having one or both ends connected to the beam, which is relatively flexible vertically, do not attract a significant load as the columns shorten under gravity loading.

Eccentric bracing systems (i.e., systems in which the braces are not concentric with the main joints) may be used to design a ductile structure for an earthquake- resistant steel -framed building. The bracing acts in its usual elastic manner when controlling drift against wind or minor earthquakes. In the event of an overload during a major earthquake, the short link in the beam between the brace connection and the column in (Figure 2.15 f, g, k, and i) and the link in the beam between brace connections in (Figure 2.15h) serves as a "fuse" by deforming plastically in shear to give a ductile response of the structure. Such braced systems combine high elastic stiffness and a large inelastic energy dissipation capacity that can be sustained over many cycles.

The roles of the "web" members in resisting shear on a bent can be understood by following the path of the horizontal shear down the bent from story to story.

Referring to (Figure 2.16) and considering four typical types of bracing subjected to the total external shear, that is, neglecting the lesser effects of the horizontal forces applied locally at the floor levels, the vertical transmission of horizontal shear can be traced. In (Figure 2.16a) the diagonal in each story is in compression, causing the beams to be in axial tension; therefore, the shortening of the diagonals and extension of the beams give rise to the shear deformation of the bent. In (Figure 2.16b) the forces in the braces connecting to each beam end are in equilibrium horizontally, with the beam carrying an insignificant axial load. In (Figure 2.16c) half of each beam is in compression and the other half in tension, whereas in (Figure 2.16d) the end parts of the beam are in compression and tension with the whole beam subjected to double curvature bending. With a reverse in the direction of the horizontal load on the structure the actions and deformations in each member of the bracing will also be reversed.

The roles, if any, of the web members in picking up compressive force as the structure shortens vertically under gravity loading can be traced similarly. As the columns in (Figure 2.17a and b) shorten, the diagonals are subjected to compression, which can be developed because of the tying action of the beams. In (Figure 2.17c) the ends of the beams where diagonals are not connected are not stiffly restrained by the columns' bending rigidity; therefore the beams cannot provide the horizontal restraint that the diagonals need to develop a force. Consequently, the diagonals will not attract significant gravity load forces. Similarly, in (Figure 2.17d) the vertical restraint from the flexural stiffness of the beam is not large; therefore, as in the previous case, the diagonals experience only negligible gravity load forces. If the type of bracing system allows the diagonals to attract compressive loading due to gravity loading on the structure, the diagonals should be either designed to carry the compressive forces or, to avoid backlash in the lateral load behaviour of the structure due to the braces having buckled, they must be detailed short and pre- stressed in tension during erection.

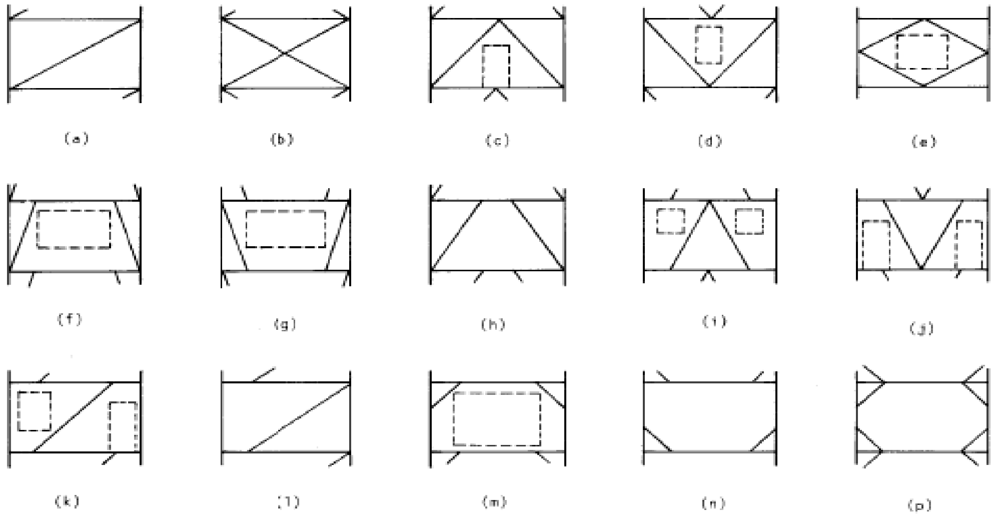

Figure 2.15: types of bracing

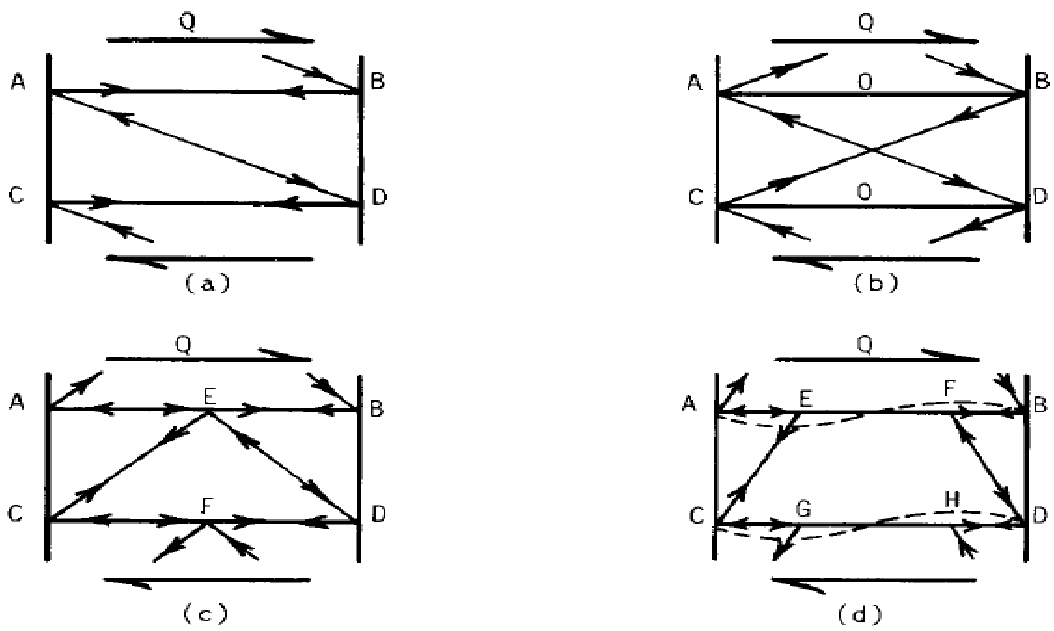

Figure 2.16 Path of horizontal shear through web members: (a) Single-diagonal bracing. (b) double-diagonal bracing. (c) K –bracing. (d) story-height knee bracing.

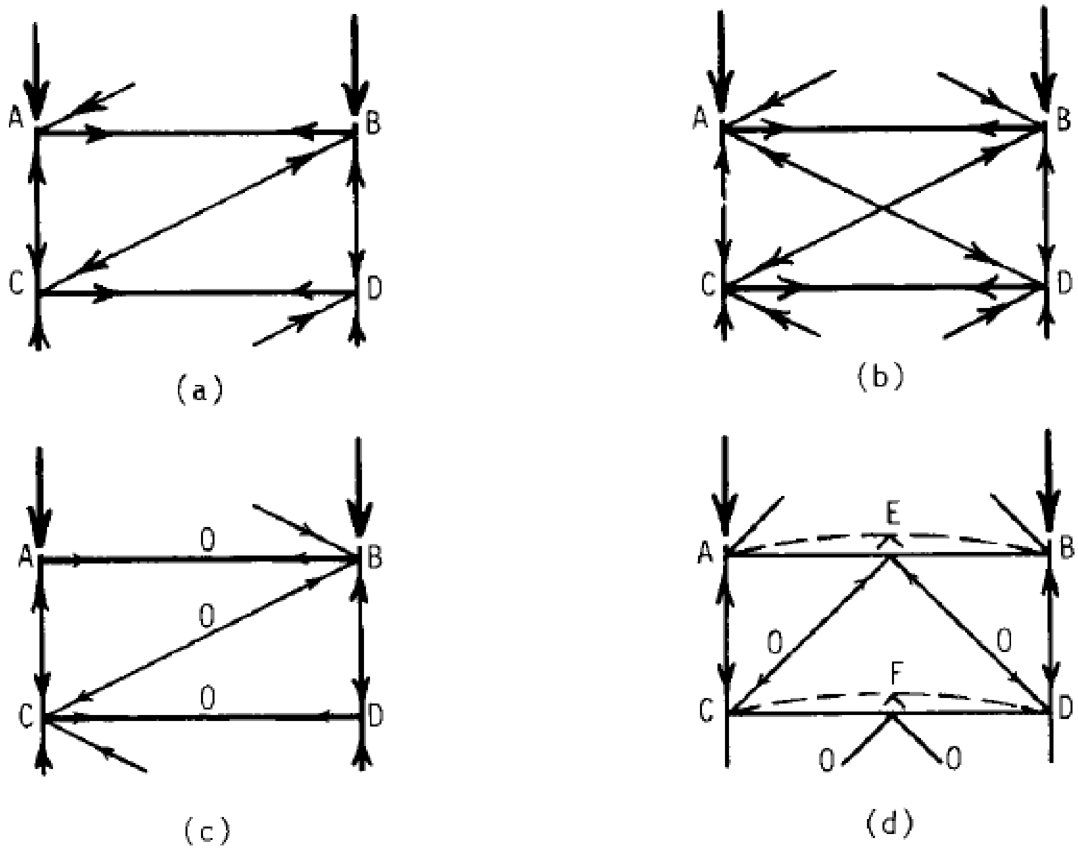

Figure 2.17: Path of gravity loading down bent. (a) Single -diagonal, single -direction bracing: (b) double -diagonal bracing: (c) single -diagonal, alternate –direction bracing: (d) K -bracing.

2.6.4. Behaviour of bracing bent

A braced bent behaves under horizontal loading as a vertical cantilever truss. The columns act as the chords in carrying the external load moment, with tension in the windward column and compression in the leeward column. The diagonals and girders serve as the web members in carrying the horizontal shear, with the diagonals in axial tension or compression depending on their direction of inclination. The girders act axially and, in some cases, in bending also.

The effect of the chords' axial deformations on the lateral deflection of the frame is to tend to cause a "flexural" configuration of the structure, that is, with concavity downwind and a maximum slope at the top

(Figure 2.18a). The effect of the web member deformations, however, is to tend to cause a "shear" configuration of the structure (i.e., with concavity upwind, a maximum slope at the base, and a zero slope at the top; Figure 2.18b). The resulting deflected shape (Figure 2.18c) is a combination of the effects of the flexural and shear curves with a resultant configuration depending on their relative magnitudes, as determined mainly by the type of bracing.

In bents that are braced in a single bay, horizontal loading causes a maximum tension at the base of the windward column of the braced bay. The more slender the bay, the larger the tensile force. Depending on the tributary area of slab supported by the column, the tension will be partly or wholly suppressed by the dead load of the structure. For height -to -width ratios of braced bays greater than about 10, however, the probability arises of uplift forces that are too large to handle. In multi-bay bents this problem can be avoided by placing successive story bracing in different bays of the bent, as in (Figure 2.19) In this arrangement the column axial forces caused by horizontal loading will be significantly smaller.

In providing for architectural requirements it is sometime necessary to use different types of bracing in different bays of the same bent, or in bays of different parallel bents. This does not present a particular problem, except that care should be taken to ensure that the lateral stiffness's of the individual braced bays are comparable.

In some situations, because of setbacks or transition levels, it is not possible to locate the braces in a single vertical plane throughout the entire height of the structure. In these cases the shear can be transferred from the braced bents above the setback or transition to those below by the horizontal -plane rigidity of the floor slab or by horizontal bracing in the plane of the floor.

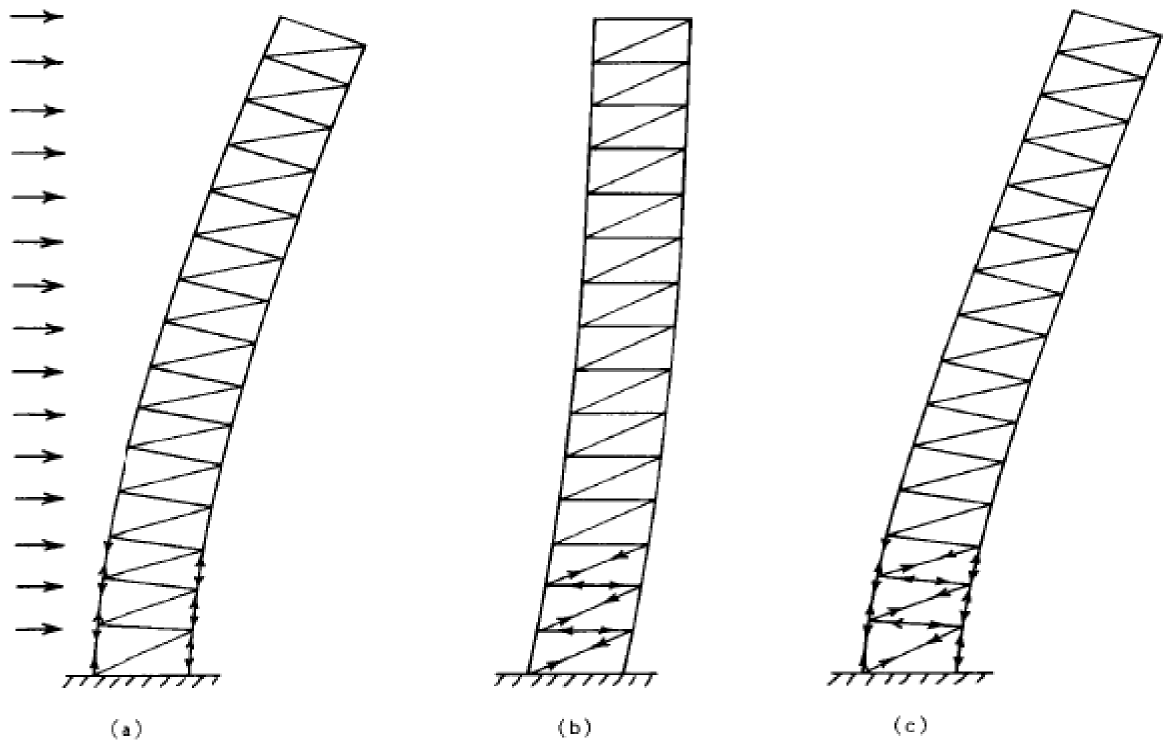

Figure (2.18): (a) flexural deflection (b) shear deflection (c) combined deflection

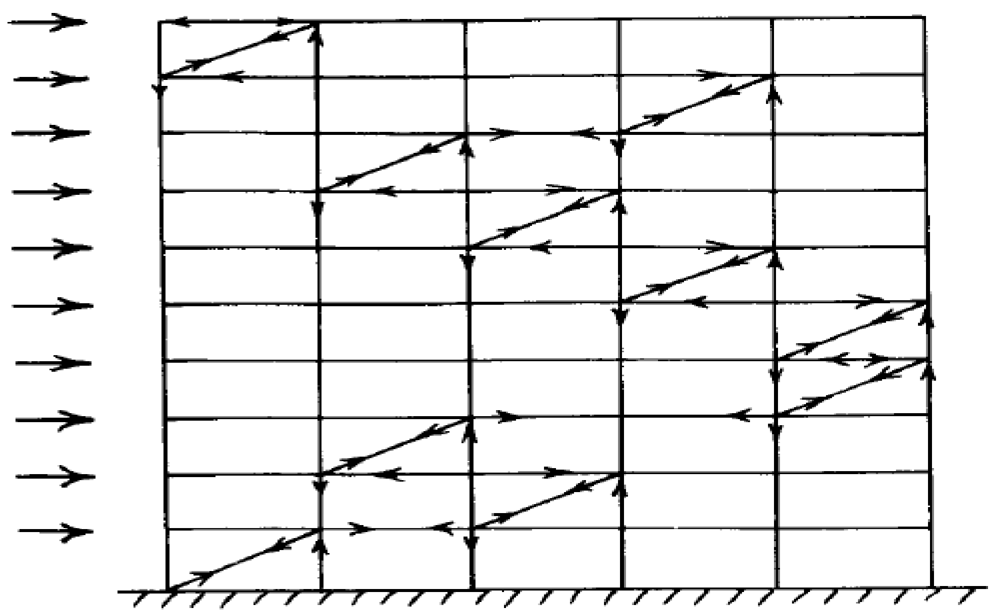

Figure (2.19): Bracing in different bays of a bent.

2.7. Type of loading

2.7.1. Dead loads

The dead load includes loads that are relatively constant over time, including the weight of the structure itself, and immovable fixtures such as walls, plasterboard or carpet. The roof is also a dead load. Dead loads are also known as permanent or static loads

2.7.2. Live loads

Live loads, or imposed loads, are temporary, of short duration, or a moving load. These dynamic loads may involve considerations such as impact, momentum, vibration, slosh dynamics of fluids and material fatigue.

Live loads, sometimes also referred to as probabilistic loads, include all the forces that are variable within the object's normal operation cycle not including construction or environmental loads.

Roof and floor live loads are produced during maintenance by workers, equipment and materials, and during the life of the structure by movable objects, such as planters and people.

2.7.3. The lateral load

Most lateral loads are live loads whose main component is horizontal force acting on the structure. Typical lateral loads would be a wind load against a facade, an earthquake.

Most lateral loads vary in intensity depending on the building's geographic location, structural materials, height and shape. The dynamic effects of wind and earthquake loads are usually analyzed as an equivalent static load in most small and moderate-sized buildings. Others must utilize the iterative potential of the computer.

The design wind and earthquake loads on a building are substantially more complex than the following brief discussion, but various Building

Codes describes the design wind load determination in more detail such as in the American and British standards.

2.8. Calculate Wind force (according to British standard 6399)

Two alternative methods are given:

1. A standard method, which uses a simplified procedure.
2. A directional method, from which the simplified method was derived.

The standard method gives conservative values for standard orthogonal load cases and a simplified method for buildings up to 100 m in height and for significant topography. The directional method gives a more precise value for any given wind direction, particularly for sites in towns, and where topography is significant.

Procedure for calculating wind loads (using standard method):

Stage 1: Determines the dynamic augmentation factor from the basic geometric and structural properties of the building.

Stage 2: Depending on this value, a check is performed on the level of dynamic excitation to determine whether standard method can be applied or not.

Stage 3: Determines the basic wind speed.

Stage 4: Determines a site wind speed.

Stage 5: Assesses the exposure of the site in terms of the terrain roughness and the effective height.

Stage 6: Having assessed the exposure of the site, this stage offers the choice between the standard method and the directional method.

Stage 7: Determines the effective wind speed which corresponds to a datum size of loaded area.

Stage 8: Converts the effective wind speed into an equivalent dynamic pressure.

Stage 9: Selects pressure coefficients corresponding to the form of the building

Stage 10: Determines the wind loads to give the characteristic wind load for static design.

2.9. Methods of analysis

2.9.1. Member force analysis

In the majority of modern design offices all but the simplest of braced high-rise structures are now analysed by computer using a frame analysis program. To remind the reader of other possibilities, however, simple hand methods of analysis that may be used for statically determinate, or certain low -redundancy, braced structures will be reviewed. Such methods given in many references one of them as mentioned in Tall Building Structures: Analysis and design (Bryan Stafford Smith and Alex Coull).

2.9.2. Drift analysis

Braced bents deflect with a combination of flexural and shear components: the flexural component results from the column axial deformations, and the shear component from the brace and girder deformations.

In considering the deflected shape of a braced frame it is important to appreciate the relative influence of the flexural and shear mode contributions, due to the column axial deformations and to the diagonal and girder deformations, respectively.

To allow a statically determinate analysis, it is usually assumed both that the shear is shared equally between the tension and compression braces, or that the compression brace has buckled and the tension brace carries the entire shear.

Deflections may be analysed by hand, either exactly, using the virtual work method, or approximately, using a combination of the moment area method and a shear deflection formula as mention in reference tall building structures(Bryan Stafford Smith and Alex Coull). An advantage of the virtual work method is that it indicates which members contribute most significantly to the deflection, therefore providing guidance as to which members should be adjusted to control the deflection.

2.9.3. Virtual Work Drift Analysis

In this method a force analysis of the structure subjected to the design horizontal loading is first made in order to determine the axial force P_j in each member j, as well as the bending moment M_x at sections X along those members subjected to bending (Figure 2.20a). A second force analysis is then made with the structure subjected to only a unit imaginary or "dummy" horizontal load at the level N whose drift is required (Figure 2.20b) to give the axial force $\bar{P}_{jN}$ and moment $\bar{m}_{xjN}$ at section X in the bending members. The resulting horizontal deflection at N is then given by:

$$\Delta_N = \sum \bar{P}_{jN} \left\{\frac{PL}{EA}\right\}_j + \sum \int_0^{L_j} \bar{m}_{xjN} \left\{\frac{M_x}{EA}\right\}_i dx \qquad \text{\{equation (2.1)\}}$$

In whichL_j,A_j, and I_j are the length, sectional area, and moment of inertia for each member f, and E is the elastic modulus. The first summation in the last equation refers to all members subjected to axial loading, while the second refers to only those members subjected to bending.

If the drift is required at another level, n, of the structure, another dummy unit load analysis will have to be made, but with the unit load applied only at level n. The resulting values $\bar{P}_{jN}$ and $\bar{m}_{xjN}$ will be substituted in the last equation to give the drift.

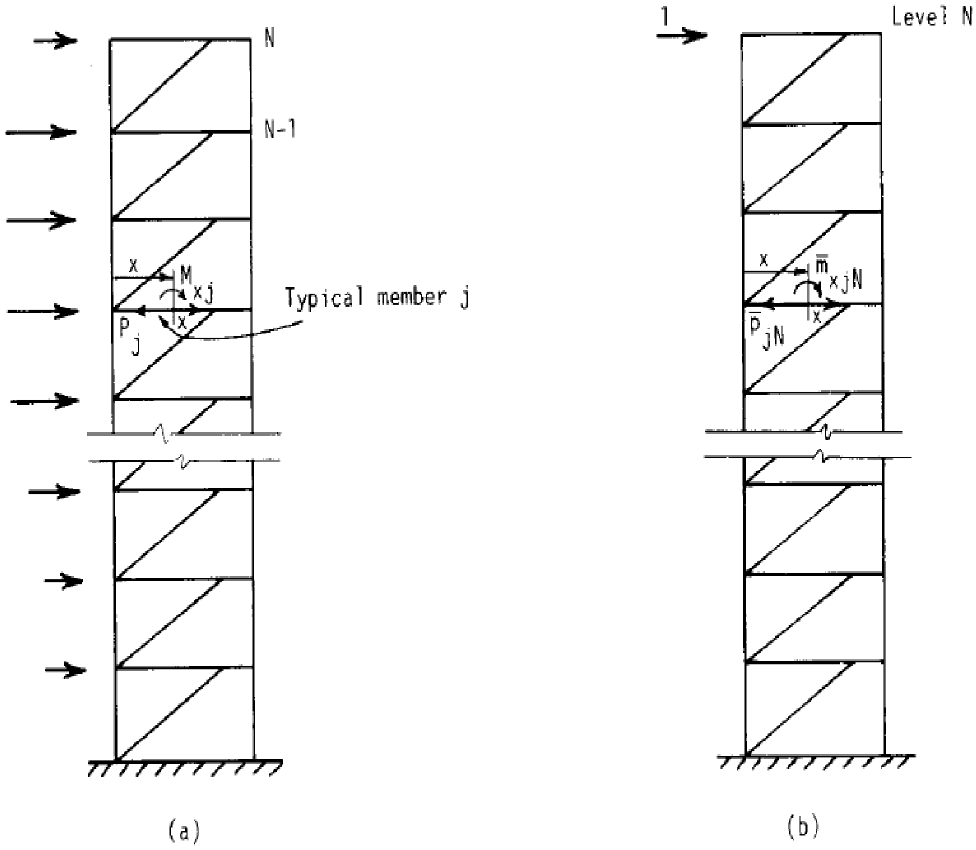

Figure 2.20:

(a) Member forces due to design horizontal loading

(b) Member forces due to unit dummy loading.

The virtual work method is exact and can easily be systematized by tabulation. An adequate assessment of the deflected configuration, the total drift, and the story drifts can be obtained by plotting the deflection diagram from the deflections at just three or four equally spaced points up the height of the structure, requiring one design load force analysis plus three or four "dummy" unit load analyses.

2.10. The finite element method

The finite element method is a numerical method that can be used for the accurate solution of complex engineering problems. The method was first developed in 1956 for the analysis of aircraft structural problems. Thereafter, within a decade, the potentialities of the method for the solution of different types of applied science and engineering problems were recognized. Over the years, the finite element technique has been so well established that today it is considered to be one of the best methods for solving a wide variety of practical problems efficiently. In fact, the method has become one of the active research areas for applied mathematicians. One of the main reasons for the popularity of the method in different fields of engineering is that once a general computer program is written, it can be used for the solution of any problem simply by changing the input data.

2.11. Etabs program

Etabs is a special-purpose computer program developed specifically for building structures. It provides the Structural Engineer with all the tools necessary to create, modify, analyze, design, and optimize building models.

Creation of models has never been easier - intuitive drawing commands allow for the rapid generation of floor and elevation framing. Computer added design (CAD) drawings can be converted directly into ETABS models or used as templates onto which ETABS objects may be overlaid. The state of the art SAP solver allows extremely large and complex models to be rapidly analyzed and supports nonlinear modeling techniques such as construction sequencing and time effects (e.g. creep and shrinkage).

Design of steel and concrete frames (with automated optimization), composite beams, composite columns, steel joists, and concrete and masonry shear walls is included, as is the capacity check for steel connections and base plates.

2.12. Stiffness and drift limitation

One simple parameter that affords an estimate of the lateral stiffness of a building is the drift index, defined as the ratio of the maximum deflection at the top of the building to the total height. The control of lateral deflections is of particular importance for modern buildings in which the traditional reserves of stiffness due to heavy internal partitions and outer cladding have largely disappeared. It must be stressed, however, that even if the drift index is kept within traditionally accepted limits, such as $(\frac{l}{500})$, it does not necessarily follow that the dynamic comfort criteria will also be satisfactory. Problems may arise, for example, if there is coupling between bending and torsional oscillations that leads to unacceptable complex motions or accelerations. In addition to static deflection calculations, the question of the dynamic response, involving the lateral acceleration, amplitude, and period of oscillation, may also have to be considered.

The establishment of a drift index limit is a major design decision, but, unfortunately, there are no unambiguous or widely accepted values, or even, in some of the National Codes concerned, any firm guidance. The designer is then faced with having to decide on an appropriate value. The figure adopted will reflect the building usage, the type of design criterion employed (for example, working or ultimate load conditions), the form of construction, the materials employed, including any substantial infills or claddings, the wind loads considered, and, in particular, past experience of similar buildings that have performed satisfactorily.

Design drift index limits that have been used in different countries range from 0.001 to 0.005. To put this in perspective, a maximum horizontal top deflection of between 100 and 500 mm would be allowed in a 33 -story, 100-m high building, or, alternatively, a relative deflection of 3 to 15 mm over a story height of 3 m. Generally, lower values should be used for hotels or apartment buildings than for office buildings, since noise and movement tend to be more disturbing in the former. Consideration may be given to whether the stiffening effects of any internal partitions, infills, or claddings are included in the deflection calculations.

The consideration of this limit state requires an accurate estimate of the lateral deflections that occur, and involves an assessment of the stiffness of cracked members, the effects of shrinkage and creep and any redistribution of forces that may result, and of any rotational foundation movement. In the design process, the stiff-ness of joints, particularly in precast or prefabricated structures, must be given special attention to develop adequate lateral stiffness of the structure and to prevent any possible progressive failure. The possibility of torsional deformations must not be overlooked.

In practice, non -load -bearing in-fills, partitions, external wall panels, and window glazing should be designed with sufficient clearance or with flexible supports to accommodate the calculated movements. Sound engineering judgment is required when deciding on the drift index limit to be imposed. However, for conventional structures, the preferred acceptable range is 0.0015 to 0.003 (that is, approximately $l/650$ to $l/350$), and sufficient stiffness must be provided to ensure that the top deflection does not exceed this value under extreme load conditions.