HIGH RISE STRUCTURAL SYSTEMS

Architectural Building Construction - SEMESTER - VII (4TH YR) 2017-18

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A LOW RISE / HIGH RISE BUILDING AS DEFINED BY EMPORIS DATA COMMUNITY

-low-rise building (ESN 49213)

Definition:

A low-rise building is an enclosed structure whose architectural height is below 35 meters, and which is divided at regular intervals into occupiable levels. It encompasses all regular multi-story buildings which are enclosed, which are below the height of a high-rise, and which are not entirely underground.

-high-rise building (ESN 18727)

Definition:

A high-rise building is a structure whose architectural height is between 35 and 100 meters. A structure is automatically listed as a high-rise when it has a minimum of 12 floors, whether or not the height is known. If it has fewer than 40 floors and the height is unknown, it is also classified automatically as a high-rise

https://www.emporis.com/building/standard/15/low-rise-building

INTRODUCTION AND DEFINITION

High rise is defined differently by different bodies.

Emporis standards-
“A multi-story structure between 35-100 meters tall, or a building of unknown height from 12-39 floors is termed as high rise.

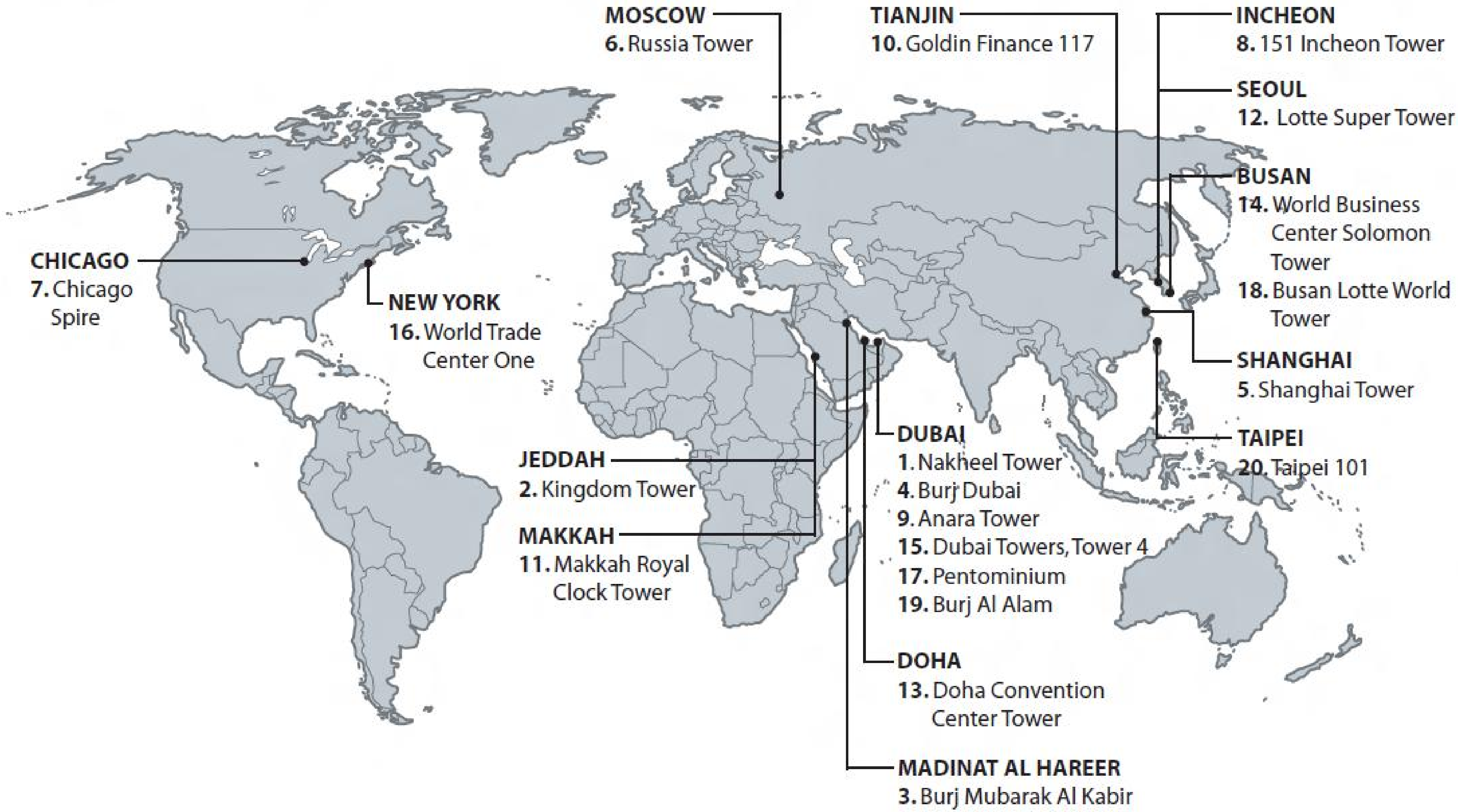
The International Conference on Fire Safety –
"any structure where the height can have a serious impact on evacuation“

Building code of Hyderabad,India-

A high-rise building is one with four floors or more, or one 15 meters or more in height.

Massachusetts, United States General Laws –
A high-rise is being higher than 70 feet (21 m).

Locations: The Tallest 20 in 2020



Criteria: The Tallest 20 in 2020

#	Continent	Buildings	Percent
1	Asia	24,302	33.16 %
2	North America	22,863	31.20 %
3	Europe	13,114	17.89 %
4	South America	9,903	13.51 %
5	Oceania	2,244	3.06 %
6	Africa	859	1.17 %

Skyscrapers in Regions

(Tables source: Emporis Corporation April 2004)

Most Skyscrapers

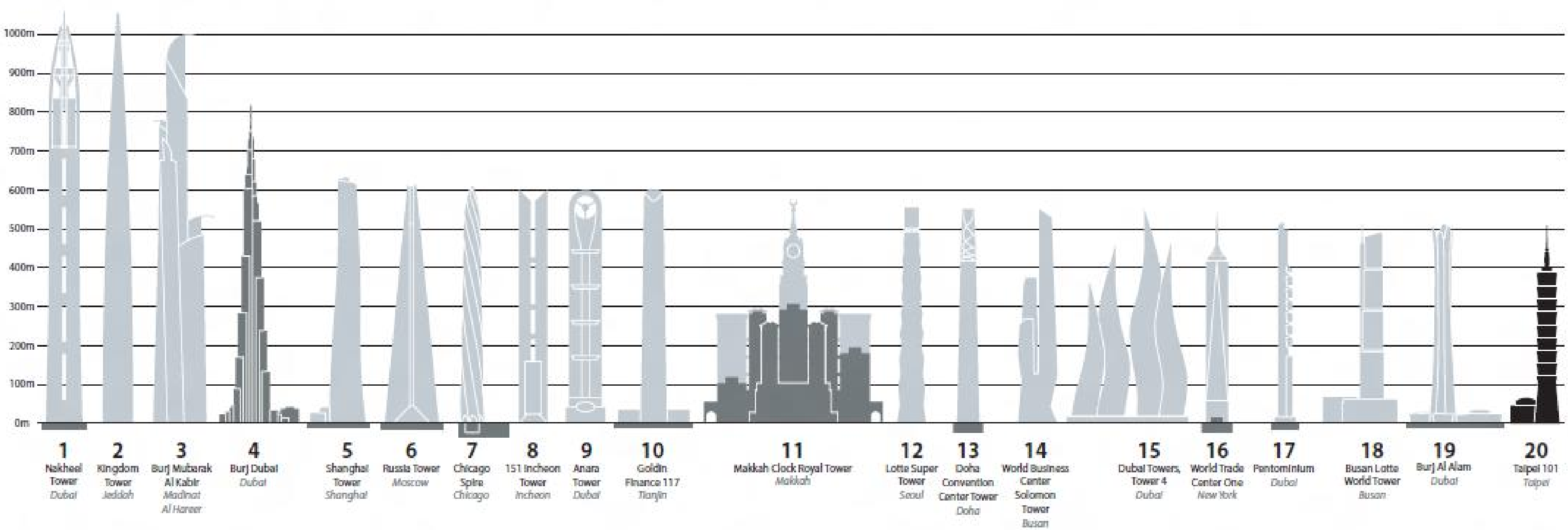
#	City	Buildings
1.	Hong Kong	7,254
2.	New York City	5,317
3.	Singapore	3,489
4.	Istanbul	2,090
5.	São Paulo	2,043
6.	Rio de Janeiro	1,854
7.	Toronto	1,582
8.	Tokyo	1,466
9.	Buenos Aires	1,410
10.	London	1,277
11.	Chicago	1,024
12.	Bangkok	706
13.	Osaka	685
14.	Sydney	652
15.	Caracas	650
16.	Milan	625
17.	Seoul	589
18.	Shanghai	523
19.	Kuala Lumpur	515
20.	Vancouver	501
21.	Madrid	500
22.	Curitiba	495
23.	Mumbai	476
24.	Honolulu	431
25.	Los Angeles	416

Council on Tall Buildings and Urban Habitat

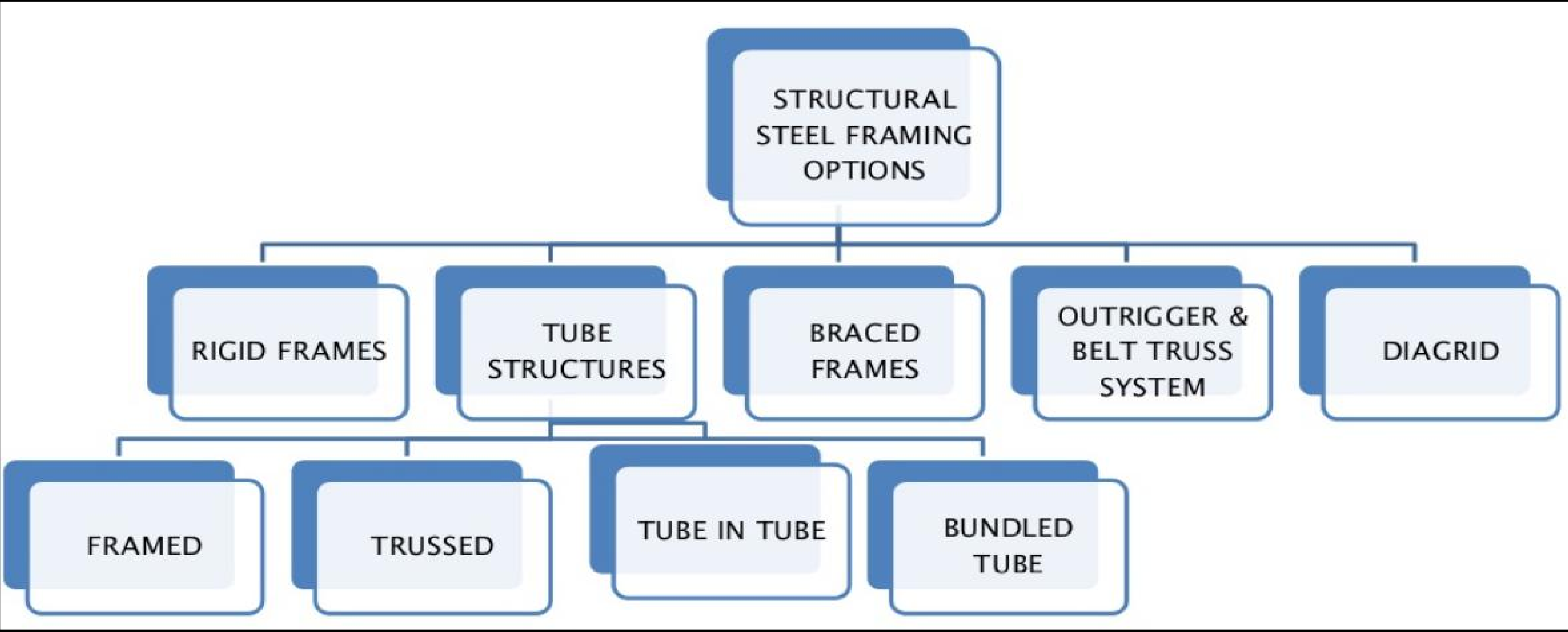
The Tallest 20 in 2020

CTBUH Projection, Second Edition, January 2009

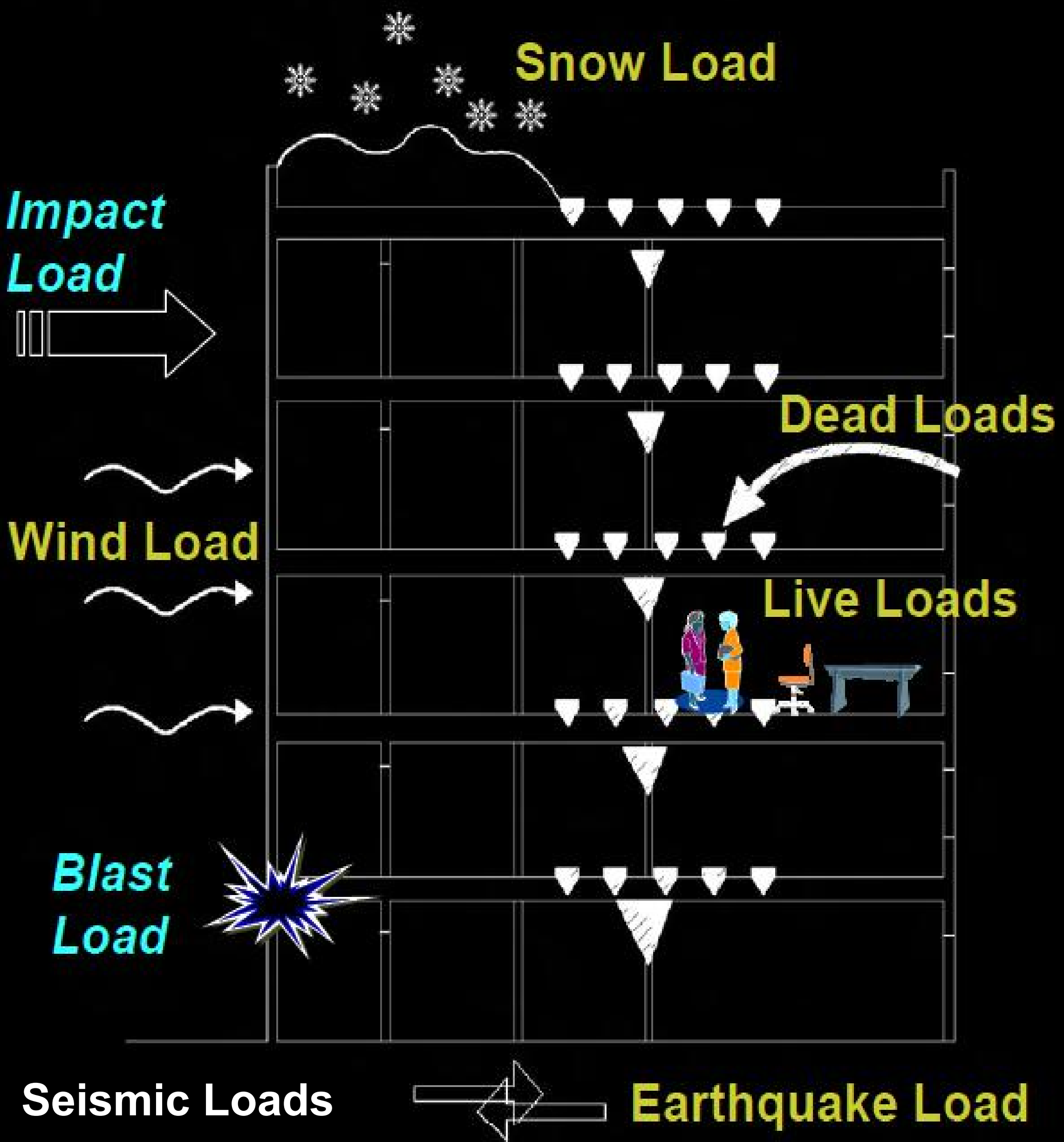
Due to the current economic climate, some buildings on this list may have slowed construction / development pace or have been put 'on hold' recently. The current intention, however, is that all projects on the list will be completed, though that may change in the coming months / years. Only buildings that are fully in the public domain and fulfill all the criteria listed at the end of this document are included in the CTBUH Tallest 20 in 2020 – there may well be other proposed buildings that would make the list, but are for client / project confidentiality reasons not yet publicized. Also, due to the changing nature of early stage designs and client information restrictions, some height data for 'proposed' tall buildings that appears on this list is unconfirmed.



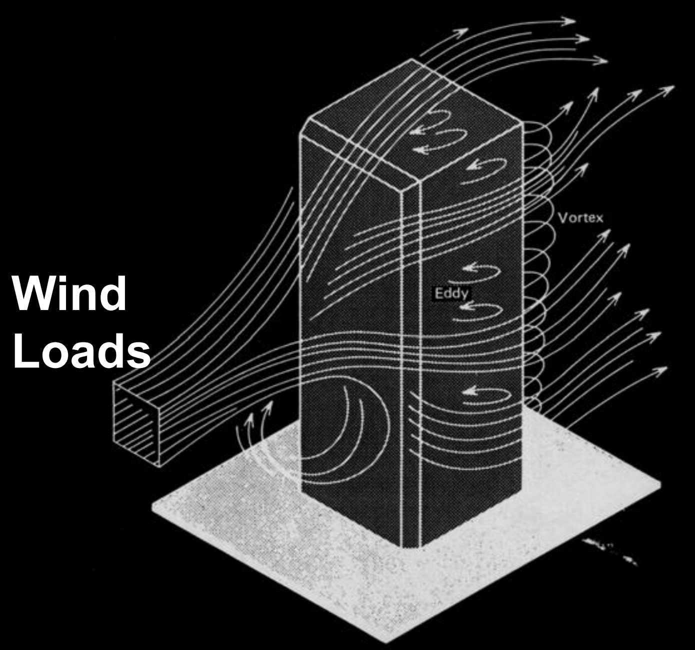
Classification according to structural behavior



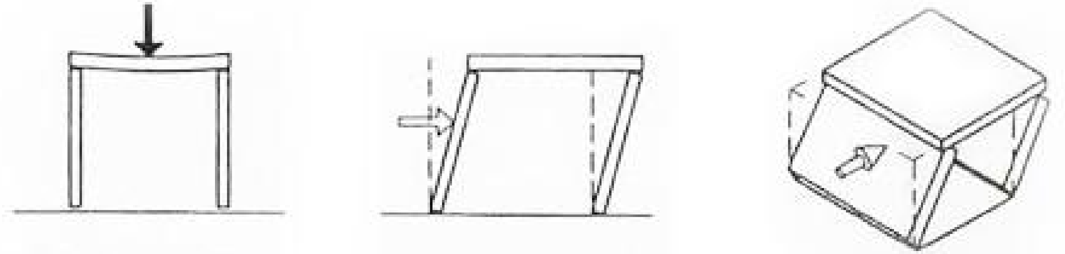
Structural Loads



- Gravity loads
  – Dead loads
  – Live loads
  – Snow loads
- Lateral loads
  – Wind loads
  – Seismic loads
- Special load cases
  – Impact loads
  – Blast loads



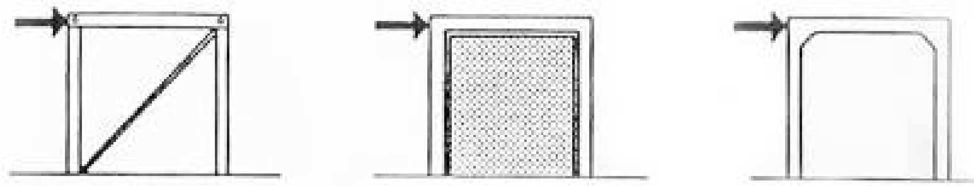
STRUCTURAL CONCERNS



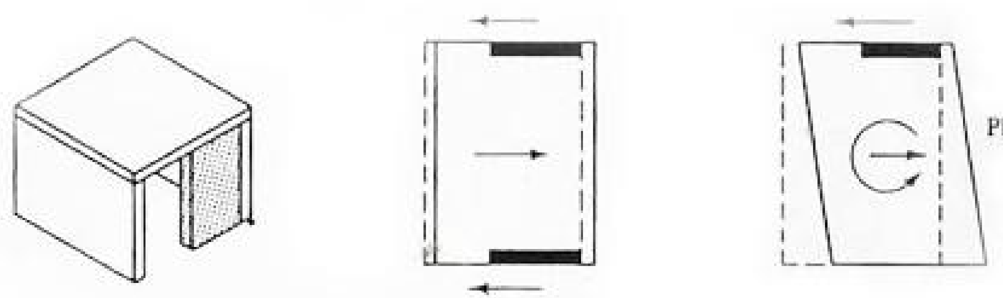
(a) Column-and-beam assembly.

(b) Instability under horizontal loads.

(c) Instability in a wall-and-plate assembly.



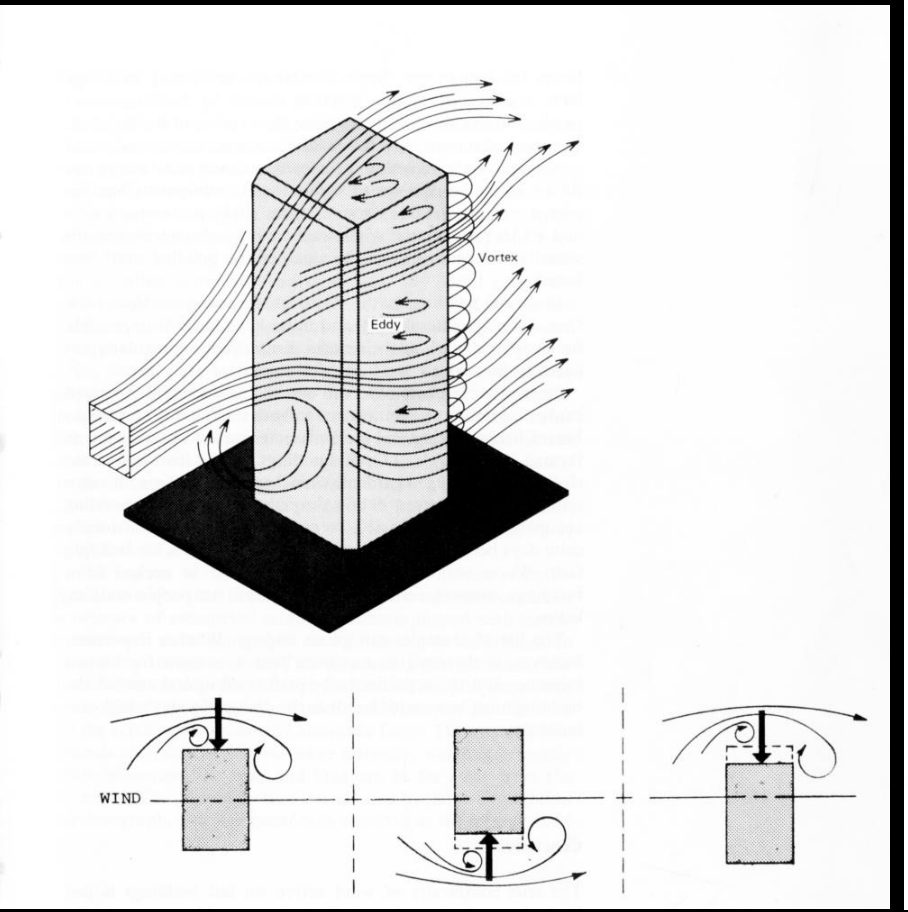
(d) Three basic methods of assuring the lateral stability of simple structural assemblies: diagonal bracing, shear planes, and rigid joints.

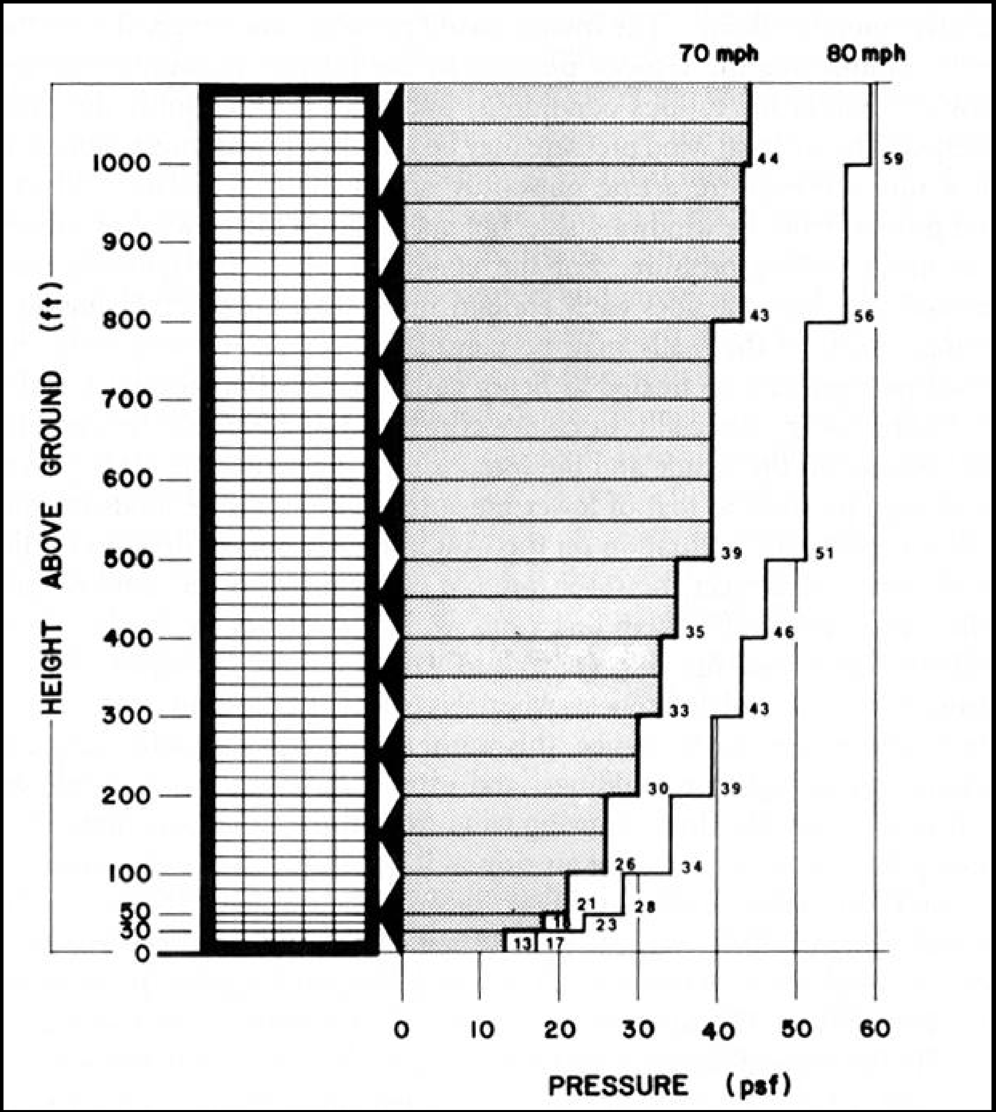


(e) Any method used to assure the lateral stability of a structure should be used symmetrically. Otherwise, undesirable torsional effects might be developed in the structure.

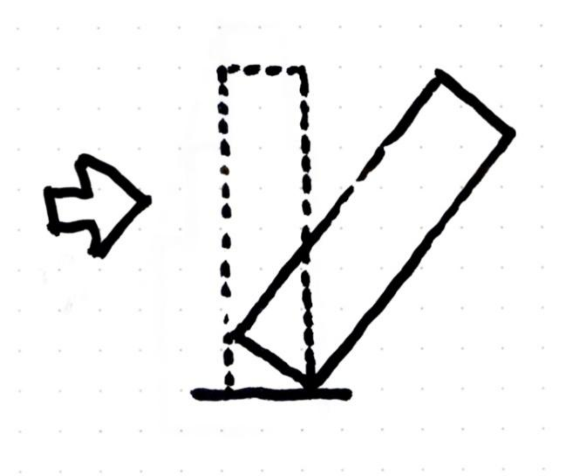
STRUCTURAL CONCERNS

Lateral force system

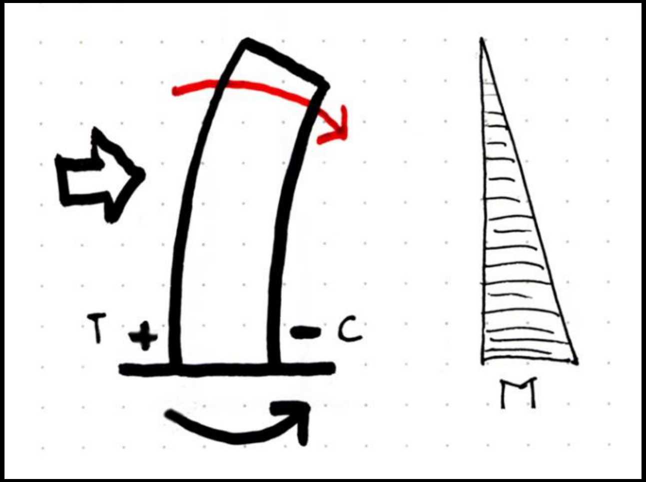




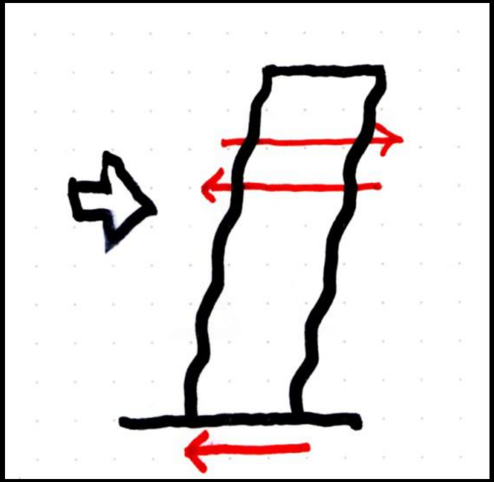
STRUCTURAL CONCERNS



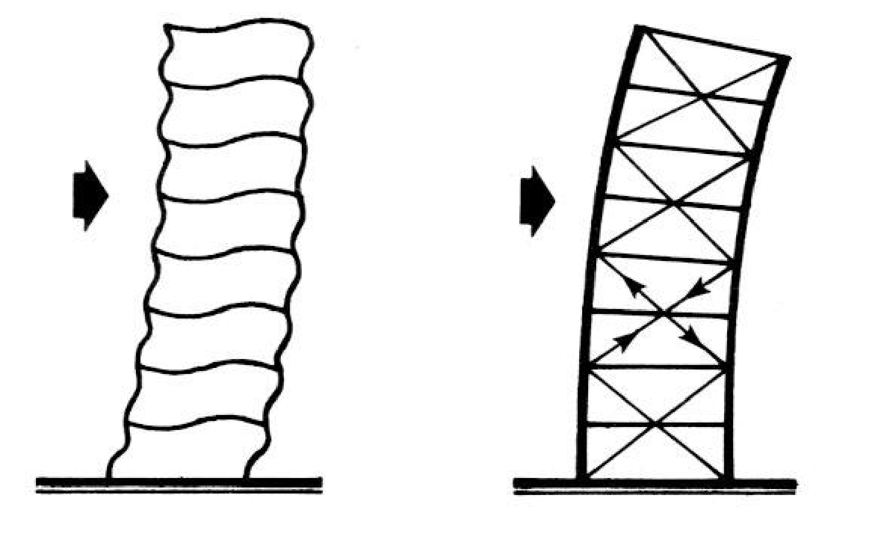
overturning



bending



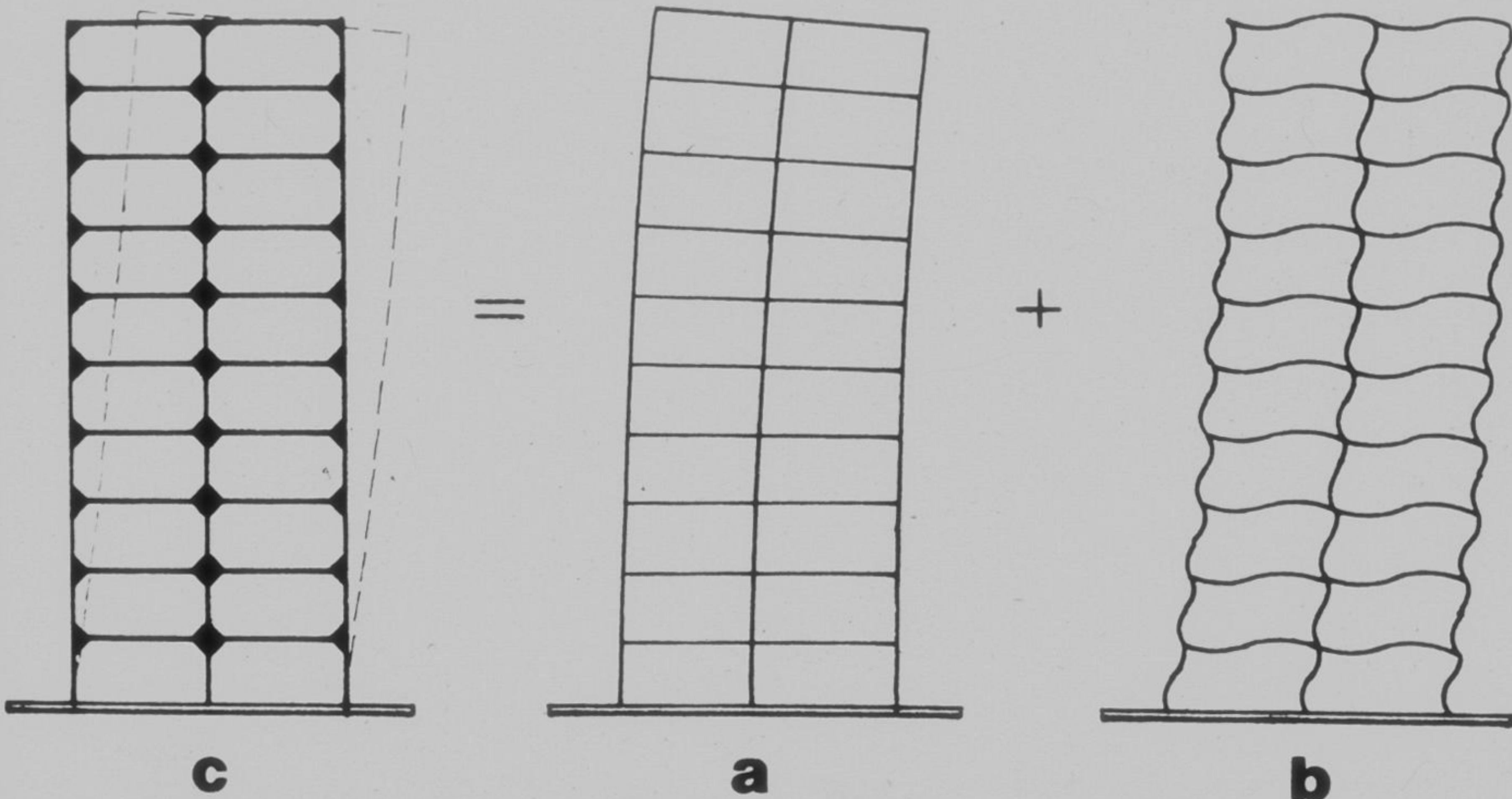
shear racking



Column–Diagonal Trussed Tube

-The primary structural skeleton of a tall building can be visualized as a vertical cantilever beam with its base fixed in the ground. The structure has to carry the vertical gravity loads and the lateral wind and earthquake loads.

-Gravity loads are caused by dead and live loads. Lateral loads tend to snap the building or topple it. The building must therefore have adequate shear and bending resistance and must not lose its vertical load-carrying capability.



-A rigid or semi-rigid frame will deform under lateral loads in two ways: a) cantilever bending and b) shear sway distortion

-The combination of these represents the actual behavior of the frame structure.

-Stiffening the frame with x-bracing, for example, will cause more cantilever bending and less shear sway

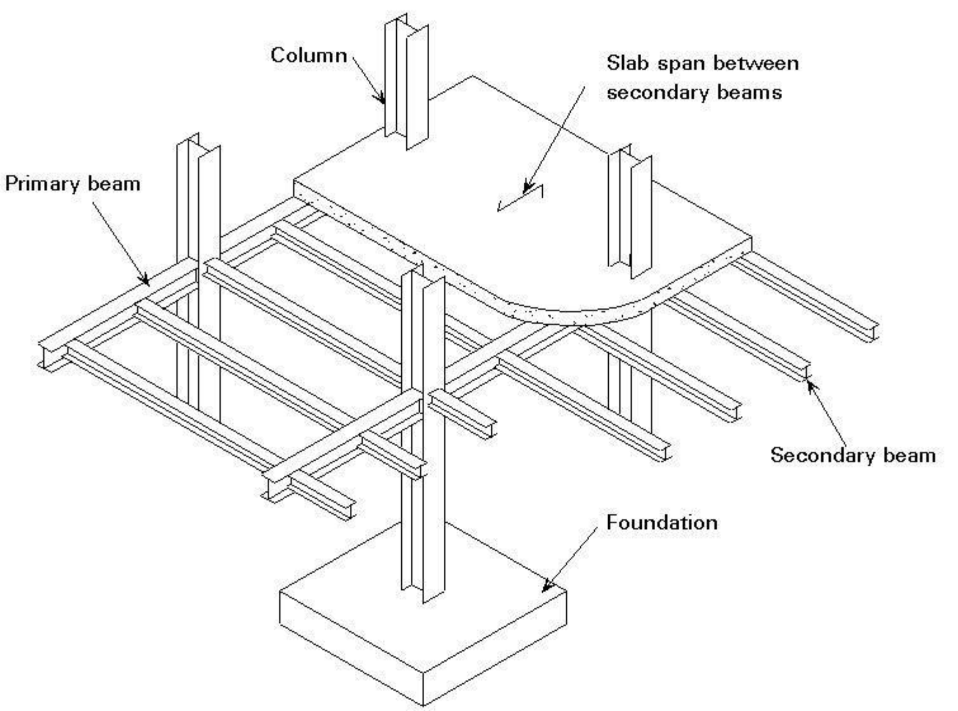
STRUCTURAL CONCERNS

Fighting gravity

-The weight of the building is supported by a group of vertical coloumns

-Each floor is supported by horizontal steel girders running between vertical coloumns.

-Curtain wall made of steel and concrete attaches to the outside



Wind resistance

-Buildings taller than 10 storeys would generally require additional steel for lateral system.

-The most basic method for controlling horizontal sway is to simply tighten up the structure. At the point where the horizontal girders attach to the vertical column, the construction crew bolt: and welds them on the top and bottom. as well as the side. This makes the entire steel super structure move more as one unit, like a pole, as opposed to a flexible skeleton.

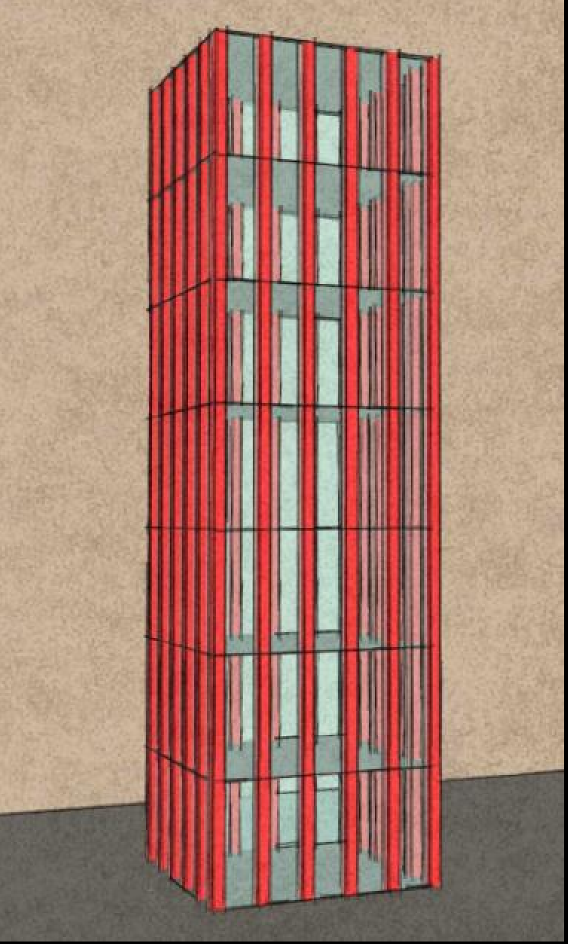
STRUCTURAL CONCERNS

- For taller skyscrapers, tighter connections don't really do the trick To keep these buildings from swaying heavily. Designers have to construct especially **strong cores through the center of the building.**
- The effects of wind can also be minimized by aerodynamic shaping of the building. Wind tunnel testing considers appropriate loading for overall lateral system design and cladding design, and predicts motion perception and pedestrian level effects.
- Use of damping systems

(as the building becomes taller and the building’s sway due to lateral forces becomes critical, there is a greater demand on the girders and columns that make up the rigid-frame system to carry lateral forces.)

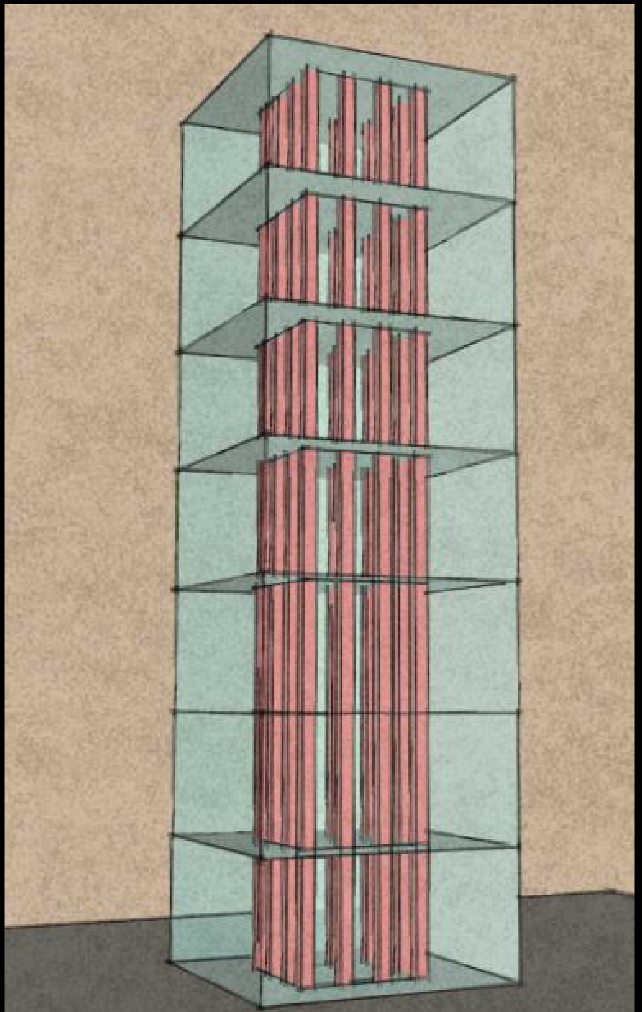
CLASSIFICATION OF TALL BUILDING STRUCTURAL SYSTEMS

- Can be classified based on the structural material used such as concrete or steel
- Structural systems of tall buildings can also be divided into two broad categories:
- 1)INTERIOR STRUCTURES
- 2)EXTERIOR STRUCURES
- This classification is based on the distribution of the components of the primary lateral load-resisting system over the building. A system is categorized as an interior structure when the major part of the *lateral load resisting system is located within the interior of the building*. Likewise, if the major part of the lateral load-resisting system is located at the building perimeter, a system is categorized as an exterior structure. It should be noted, however, that any interior structure is likely to have some minor components of the lateral load-resisting system at the building perimeter, and any exterior structure may have some minor components within the interior of the building.



INTERIOR STRUCTURES

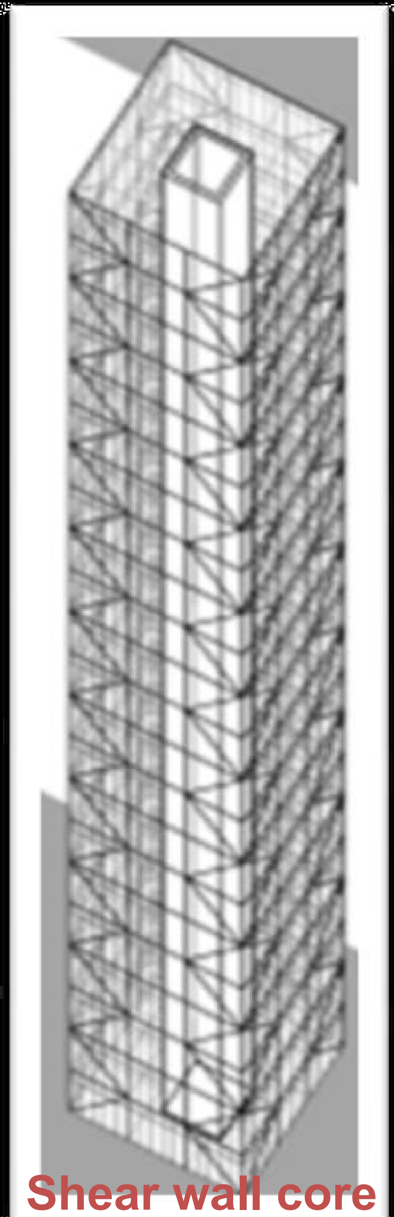
By clustering steel columns and beams in the core, engineers create a stiff backbone that can resist tremendous wind forces. The inner core is used as an elevator shaft , and the design allows lots of open space on each floor



EXTERIOR STRUCTURES

In newer skyscrapers, like the Sears Tower in Chicago, engineers moved the columns and beams from the core to the perimeter, creating a hollow, rigid tube as strong as the core design, but weighing much, much less.

INTERIOR STRUCTURAL SYSTEM



Shear wall core

)RIGID FRAME

\ rigid frame in structural engineering is the load-resisting skeleton constructed with straight or curved members interconnected by mostly rigid connections which resist movements induced at the joints of members. Its members can take bending moment, shear, and axial loads.

:onsist of columns and girders joined by moment resistant connections.

:an build upto 20 to 25 floors

Seagram building

2)SHEAR WALL STRUCTURE

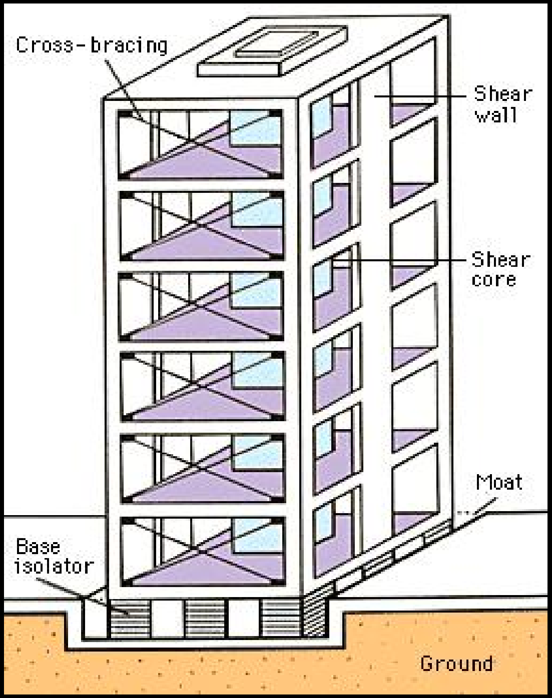
-Concrete or masonry continuous **vertical walls** may serve both architecturally partitions and structurally to carry gravity and lateral loading. Very high in plane stiffness and strength make them ideally suited for bracing tall building

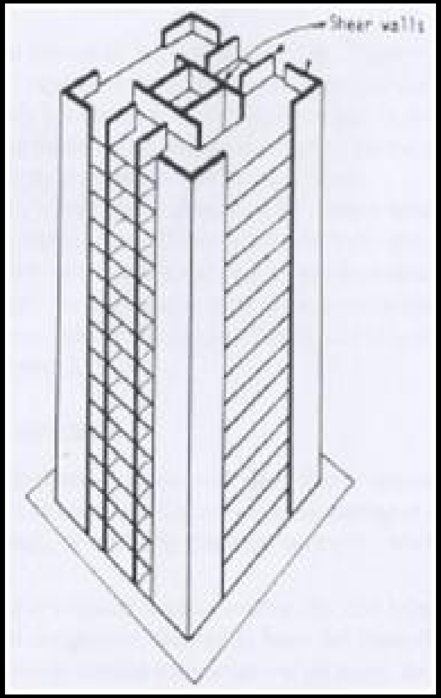
-Usually built as the core of the building

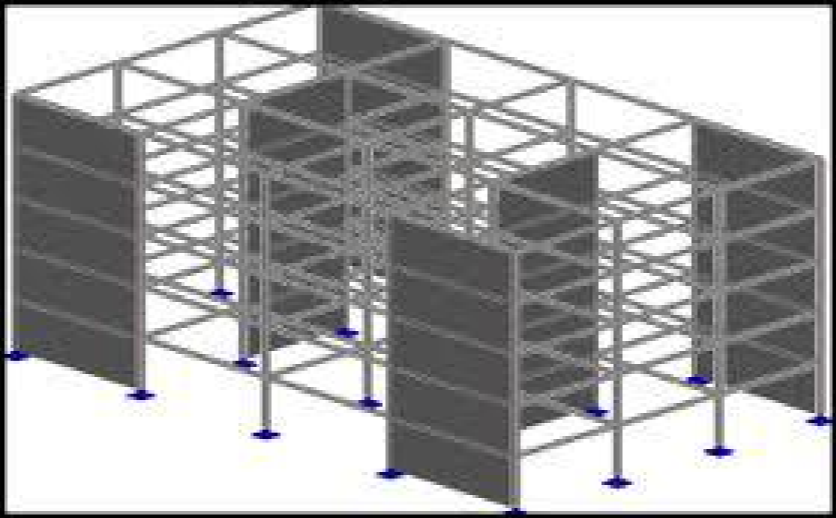
-Can build upto 35 Floors

Shear wall system

- A type of rigid frame construction.
- The shear wall is in steel or concrete to provide greater lateral rigidity. It is a wall where the entire material of the wall is employed in the resistance of both horizontal and vertical loads.
- Is composed of braced panels (or shear panels) to counter the effects of lateral load acting on a structure. Wind & earthquake load are the most common among the loads.
- For skyscrapers, as the size of the structure increases, so does the size of the supporting wall. Shear walls tend to be used only in conjunction with other support systems.



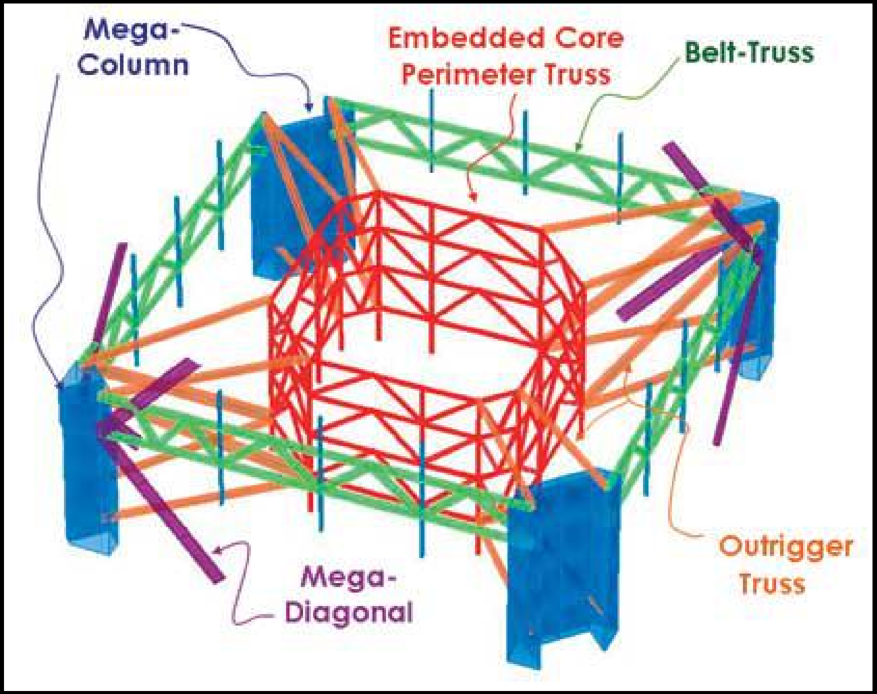


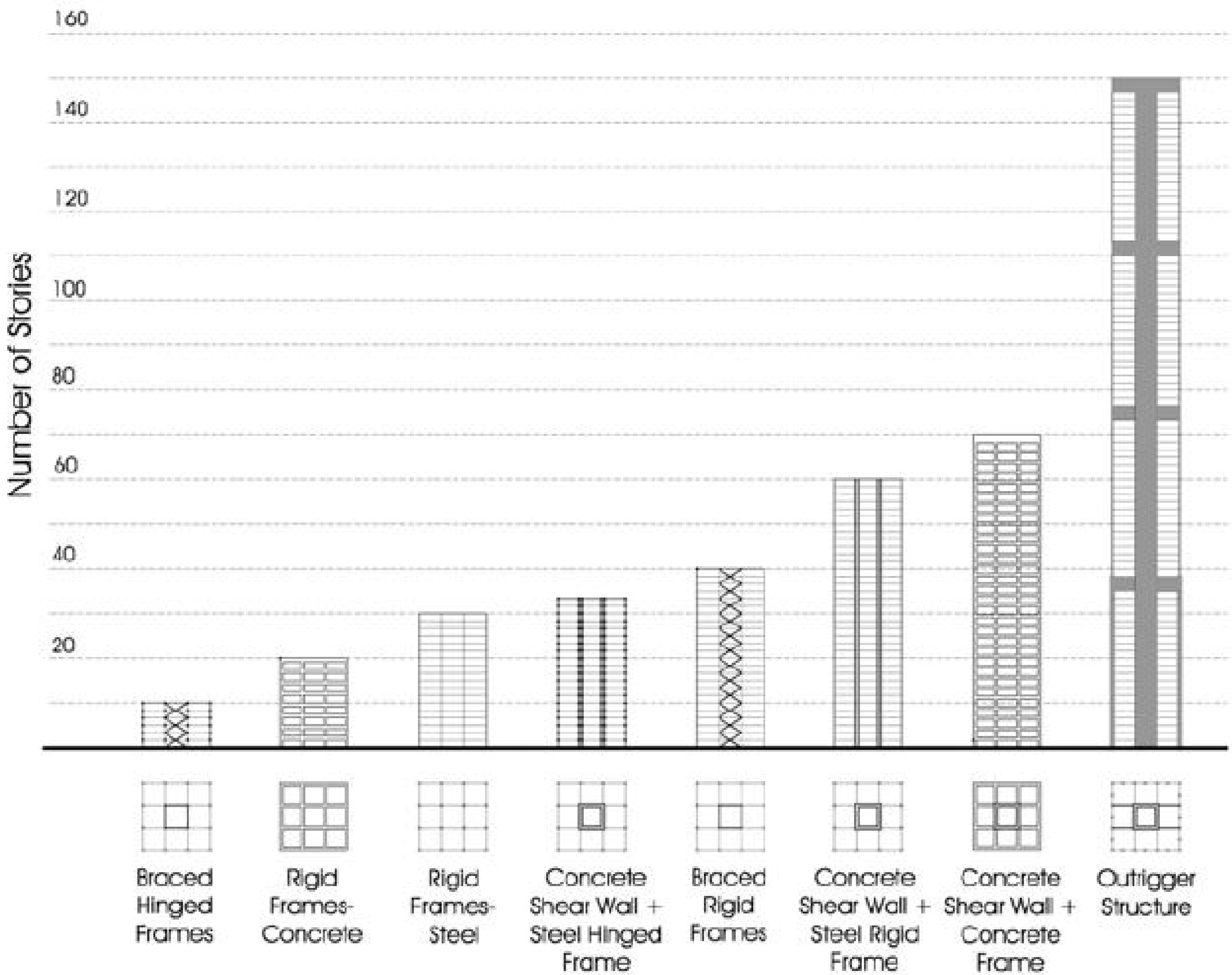


3)OUTRIGGER STRUCTURES

- The **core** may be centrally located with outriggers extending on both sides or in some cases it may be located on one side of the building with outriggers extending to the building columns on the other side
- The o**utriggers are generally in the form of trusses** (1 or 2 story deep) in steel structures, or walls in concrete structures, that effectively act as stiff headers inducing a tension-compression couple in the outer columns.
- **Belt trusses** are often provided to distribute these tensile and compressive forces to a large number of exterior frame columns.
- An build upto 150 floors

Shanghai World financial centre





160
140
120
100
80
60
40
20
Number of Stories
Braced Hinged Frames
Rigid Frames-Concrete
Rigid Frames-Steel
Concrete Shear Wall + Steel Hinged Frame
Braced Rigid Frames
Concrete Shear Wall + Steel Rigid Frame
Concrete Shear Wall + Concrete Frame
Outrigger Structure

EXTERIOR STRUCTURES

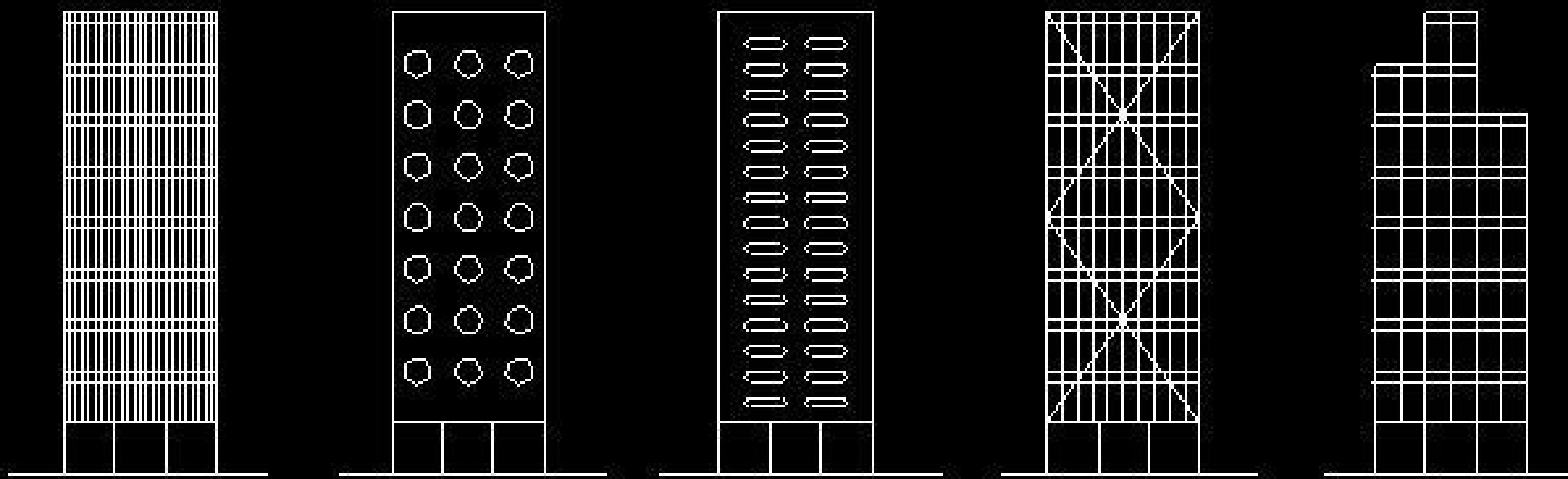
1)Tube system

•The tube system concept is based on the idea that a building can be designed to resist lateral loads by designing it as a **hollow cantilever** perpendicular to the ground. In the simplest incarnation of the tube, the perimeter of the exterior consists of closely spaced columns that are tied together with deep spandrel beams through moment connections. This assembly of columns and beams forms a rigid frame that amounts to a dense and **strong structural wall along the exterior** of the building.

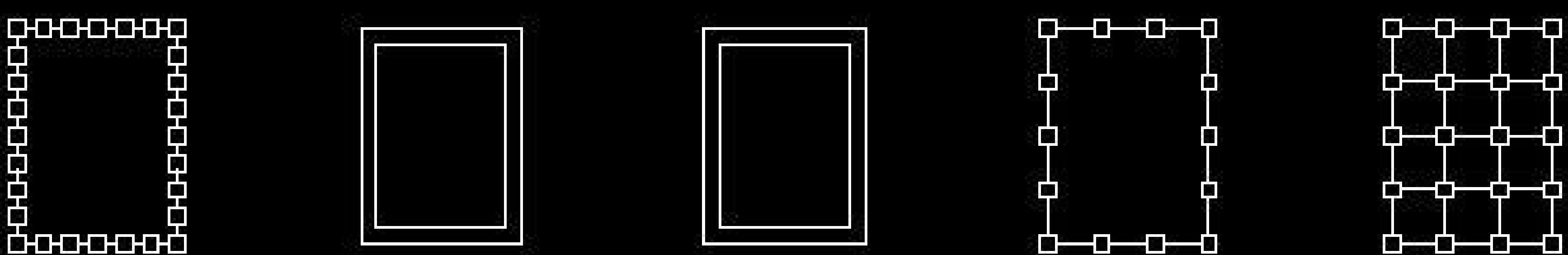
The different tubular systems are-

1)Framed tube 2)Braced tube 3)Bundled tube 4)Tube in tube

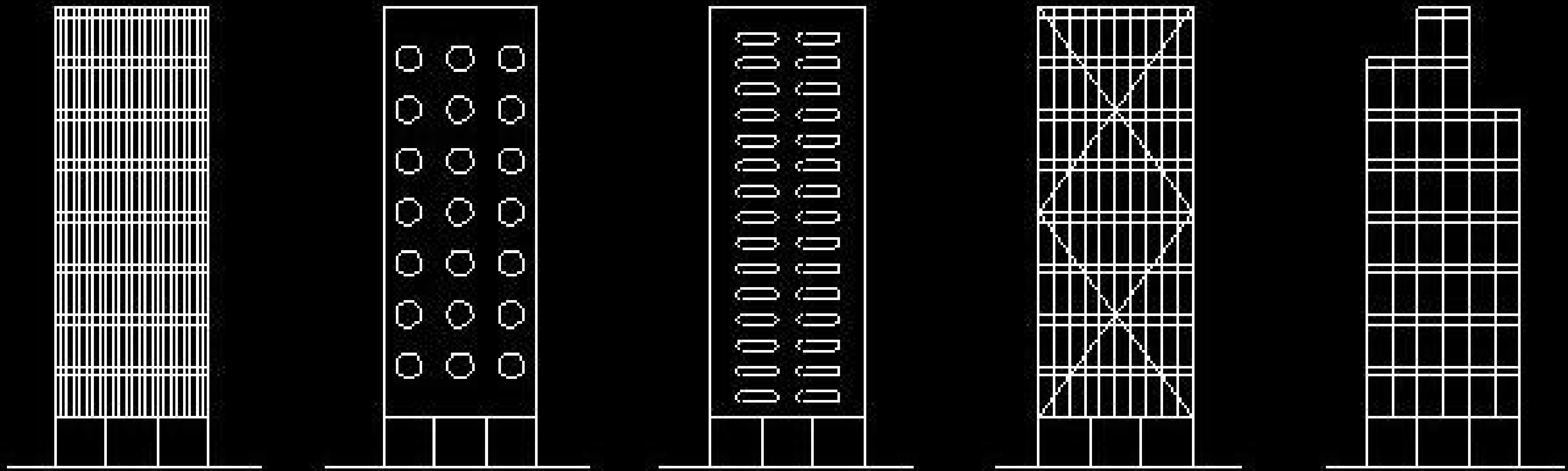
TYPES OF TUBULAR SYSTEMS



Framed tube | Perforated shell tube | Deep spandrel tube | Trussed tube | Bundled tube



TYPES OF TUBULAR SYSTEMS



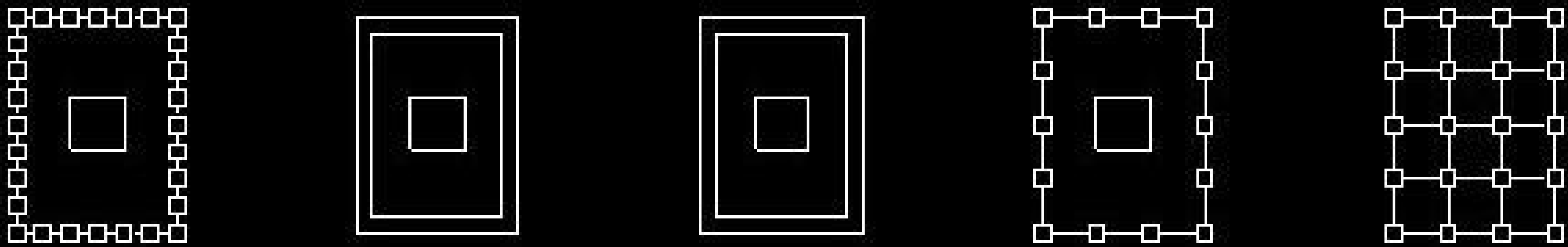
Framed tube-in-tube

Perforated tube-in-tube

Deep spandrel tube with interior columns

Trussed tube-in-tube

Framed tube and hat/belt trusses



2)Diagrid systems

With their structural efficiency as a varied version of the tubular systems, diagrid structures have been emerging as a new aesthetic trend for tall buildings in this era of pluralistic styles.

Early designs of tall buildings recognized the effectiveness of diagonal bracing members in resisting lateral forces.

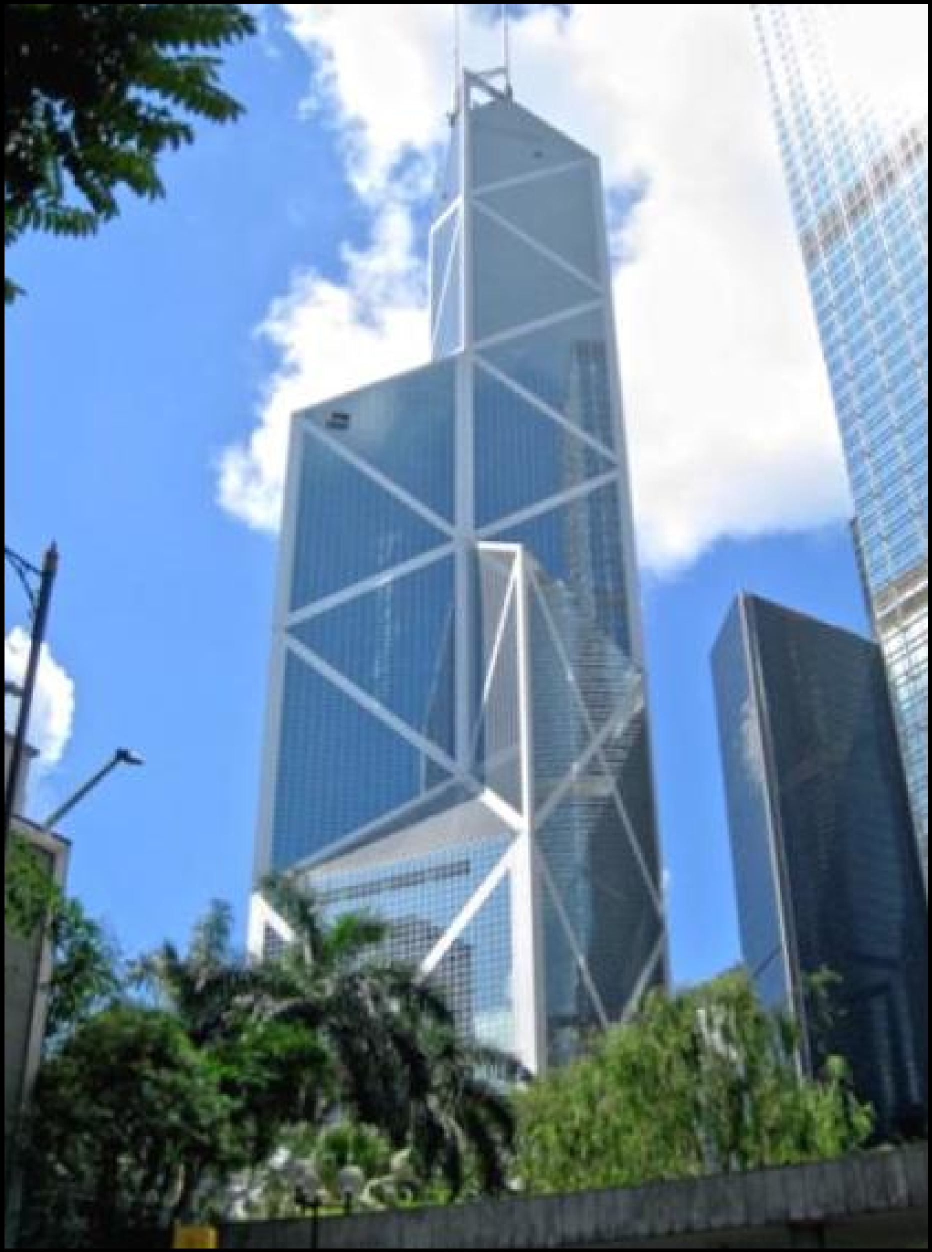
Most of the structural systems deployed for early tall buildings were steel frames with diagonal bracings of various configurations such as X, K, and chevron. However, while the structural importance of diagonals was well recognized, the aesthetic potential of them was not appreciated since they were considered obstructive for viewing the outdoors.

Efficiently resists lateral shear by axial forces in the diagonal members but have Complicated joints

Hearst tower , New York

3)Space truss

Space truss structures are modified braced tubes with diagonals connecting the exterior to interior. In a typical braced tube structure, all the diagonals, which connect the chord members – vertical corner columns in general, are located on the plane parallel to the facades. However, in space trusses, some diagonals penetrate the interior of the building.



Bank of China, Hong Kong

4)Exo skeleton structure

In exoskeleton structures, lateral load-resisting systems are placed outside the building lines away from their facades.

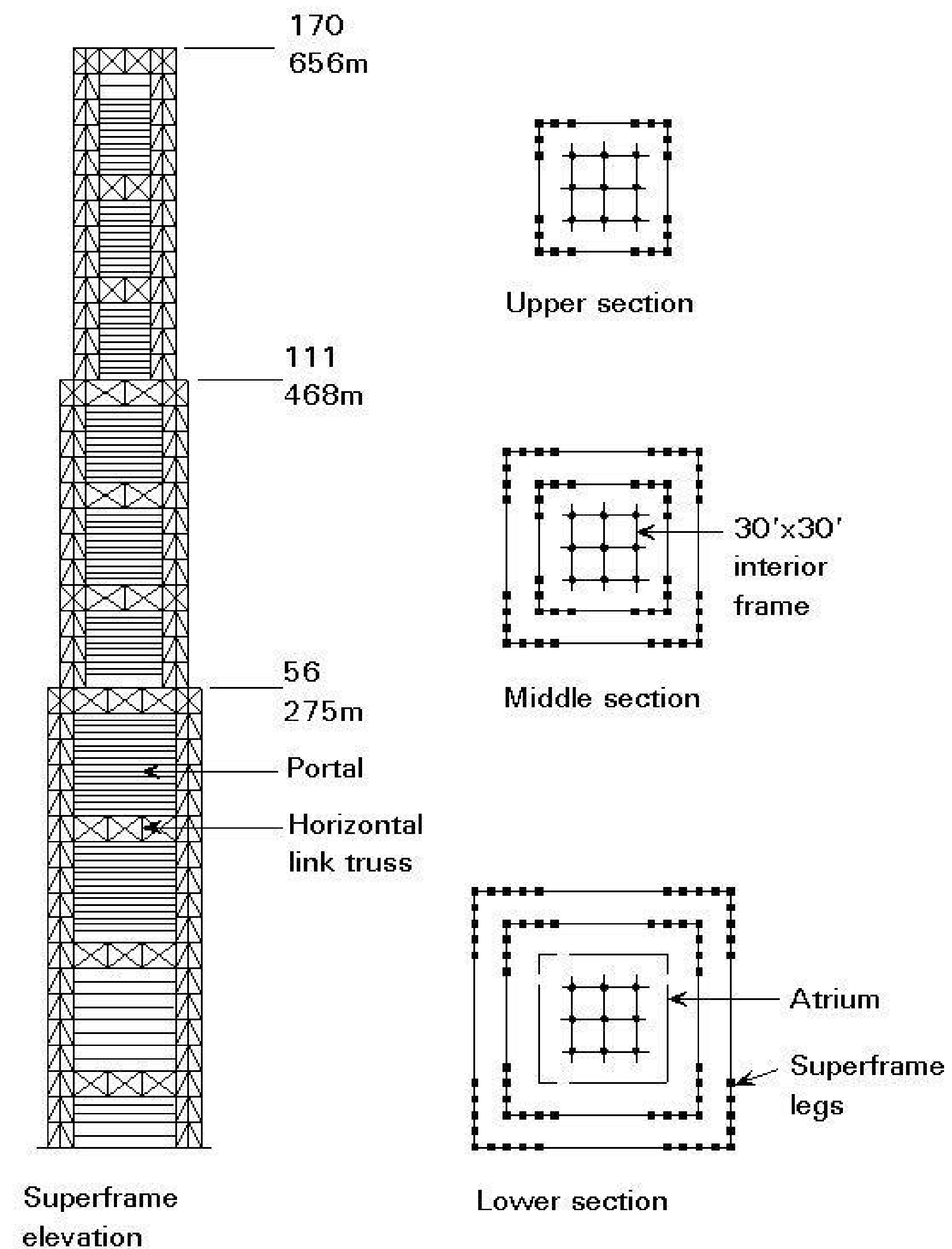
Due to the system's compositional characteristics, it acts as a primary building identifier – one of the major roles of building facades in general cases.

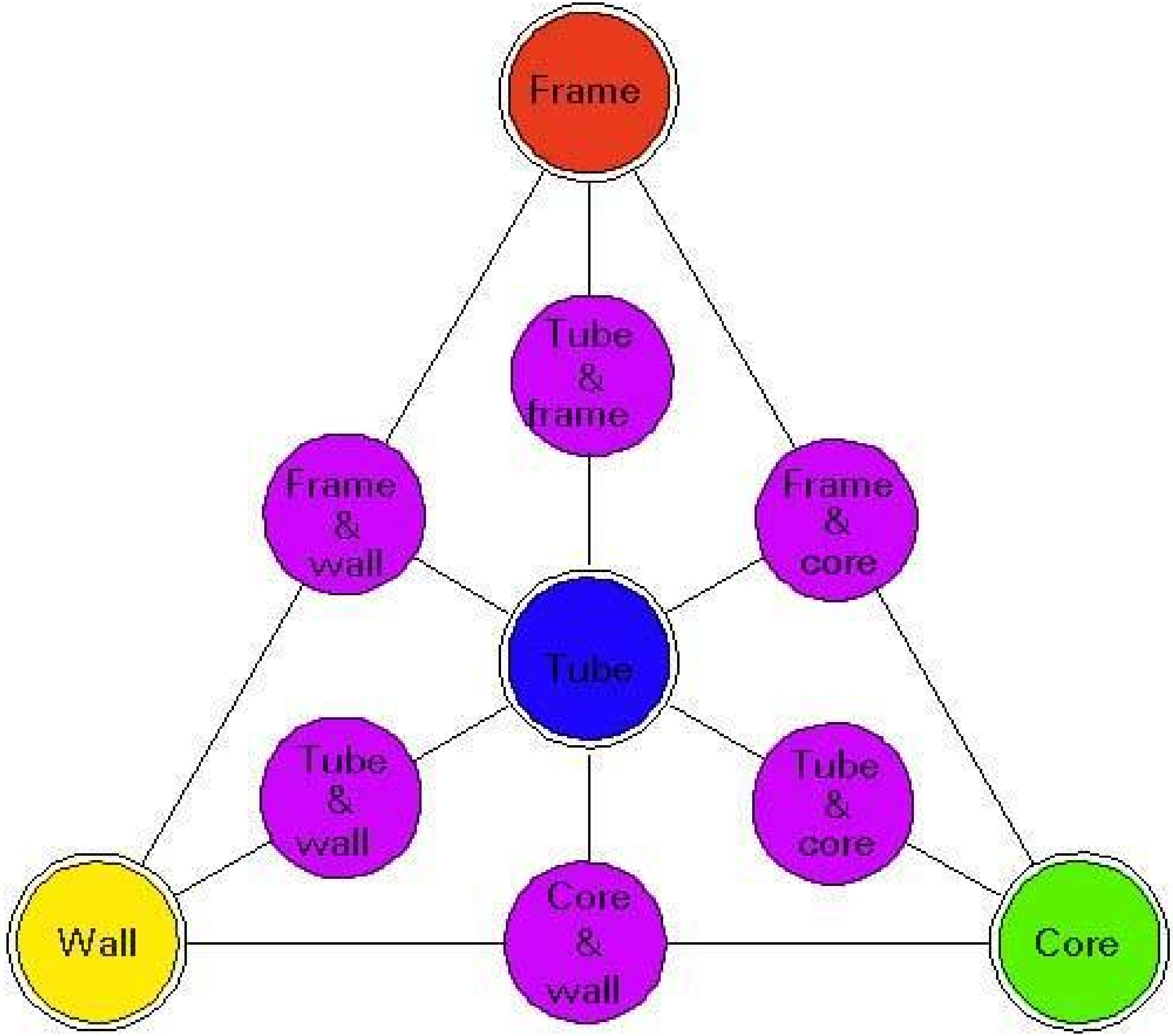
Fire proofing of the system is not a serious issue due to its location outside the building line.

Hotel de las Atres

5)Super frame structures

- Superframe structures can create ultra high-rise buildings upto 160 floors.
- Superframes or Megaframes assume the form of a portal which is provided on the exterior of a building.
- The frames resist all wind forces as an exterior tubular structure. The portal frame of the Superframe is composed of vertical legs in each corner of the building which are linked by horizontal elements at about every 12 to 14 floors.
- Since the vertical elements are concentrated in the corner areas of the building, maximum efficiency is obtained for resisting wind forces.


170
656m
111
468m
56
275m
Portal
Horizontal
link truss
Superframe
elevation
Upper section
30'x30'
interior
frame
Middle section
Atrium
Superframe
legs
Lower section


Frame
Tube & frame
Frame & wall
Frame & core
Tube
Tube & wall
Tube & core
Wall
Core & wall
Core

FRAMED-TUBE STRUCTURES

The lateral resistant of the framed-tube structures is provided by very stiff moment-resistant frames that form a "tube" around the perimeter of the building.

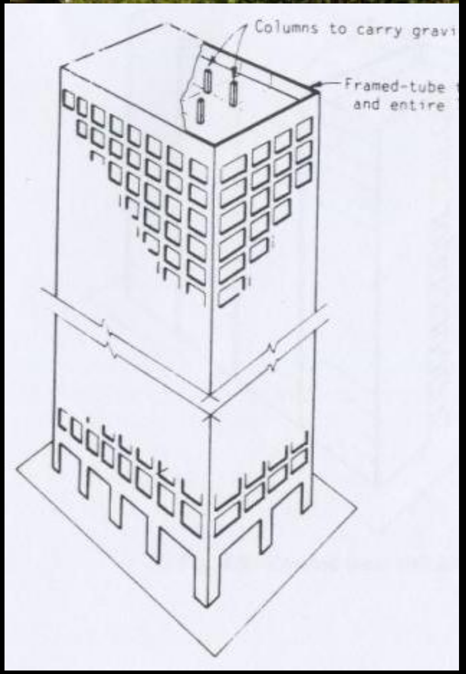
The basic inefficiency of the frame system for reinforced concrete buildings of more than 15 stories resulted in member proportions of prohibitive size and structural material cost premium, and thus such system were economically not viable.

The frames consist of 6-12 ft (2-4m) between centers, joined by deep spandrel girders.

Gravity loading is shared between the tube and interior column or walls.

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

The tube form was developed originally for building of rectangular plan, and probably it's most efficient use in that shape.



THE TRUSSED TUBE

Recently the use of perimeter diagonals – thus the term "DIAGRID" - for structural effectiveness and lattice-like aesthetics has generated renewed interest in architectural and structural designers of tall buildings.

The trussed tube system represents a classic solution for a tube uniquely suited to the qualities and character of structural steel.

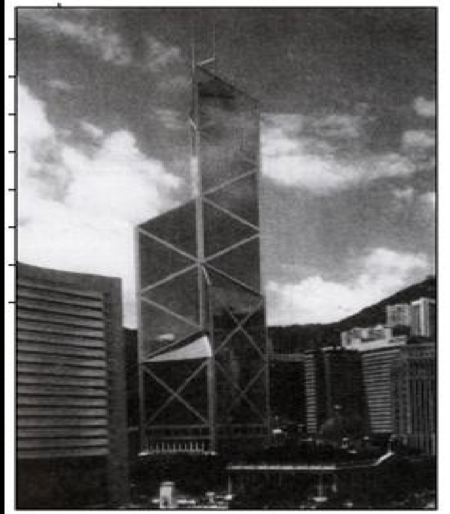
Interconnect all exterior columns to form a rigid box, which can resist lateral shears by axial in its members rather than through flexure.

Introducing a minimum number of diagonals on each façade and making the diagonal intersect at the same point at the corner column.

The system is tubular in that the fascia diagonals not only form a truss in the plane, but also interact with the trusses on the perpendicular faces to affect the tubular behavior. This creates the x form between corner columns on each façade.

Relatively broad column spacing can resulted large clear spaces for windows, a particular characteristic of steel buildings.

The façade diagonalization serves to equalize the gravity loads of the exterior columns that give a significant impact on the exterior architecture.



Example of trussed tube structure; Bank of China, Hong Kong

Introducing a minimum number of diagonals on each façade and making the diagonal intersect at the same point at the corner column

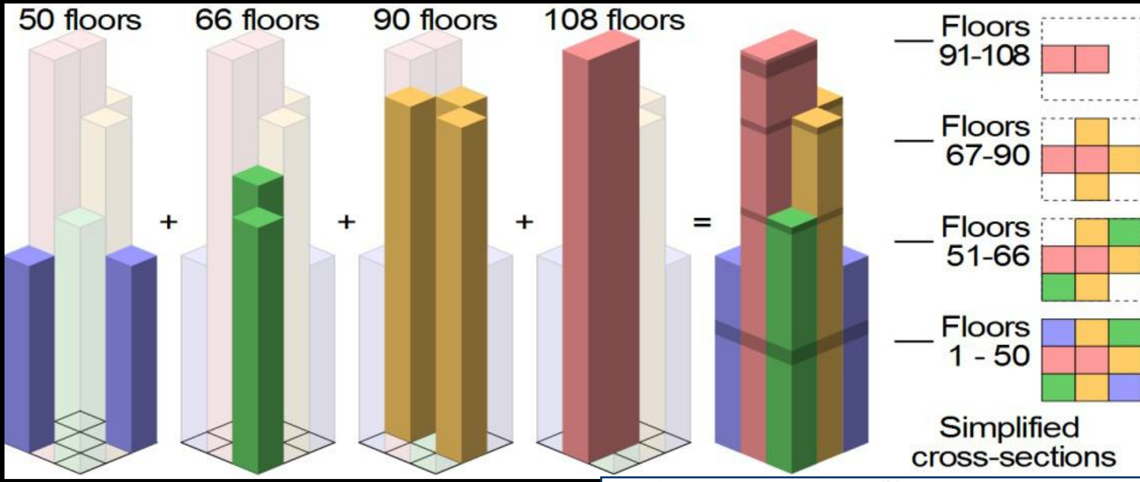
John Hancock Center introduced trussed tube design.

BUNDLED TUBE SYSTEM

The concept allows for wider column spacing in the tubular walls than would be possible with only the exterior frame tube form.

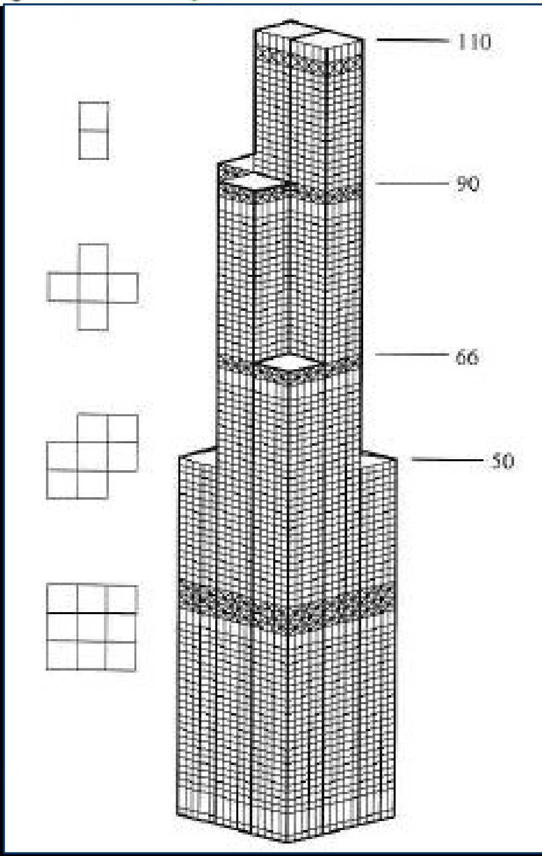
The spacing which make it possible to place interior frame lines without seriously compromising interior space planning.

The ability to modulate the cells vertically can create a powerful vocabulary for a variety of dynamic shapes therefore offers great latitude in architectural planning of at all building.



Sears Tower, Chicago.

Burj Khalifa, Dubai.



TUBE-IN-TUBE SYSTEM

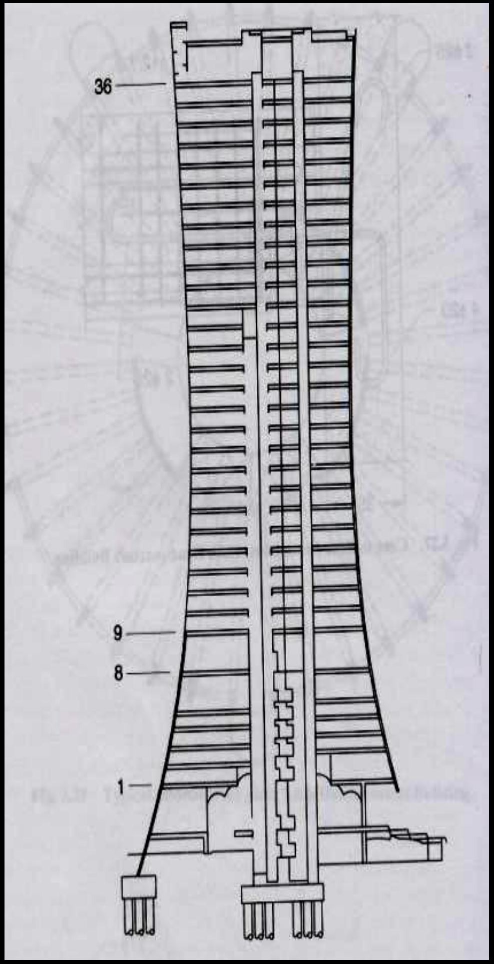
This variation of the framed tube consists of an outer frame tube, the "Hull," together
with an internal elevator and service core.

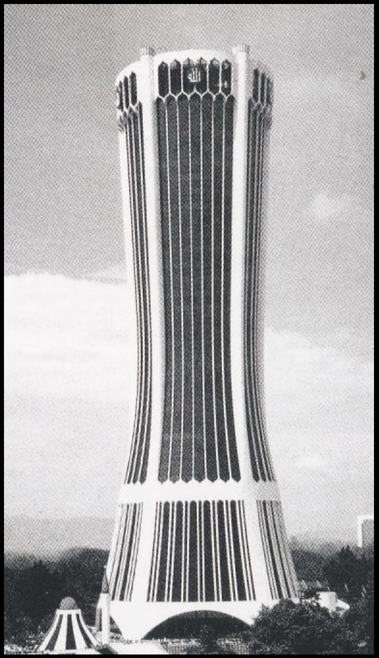
The Hull and core act jointly in resisting both gravity and lateral loading.

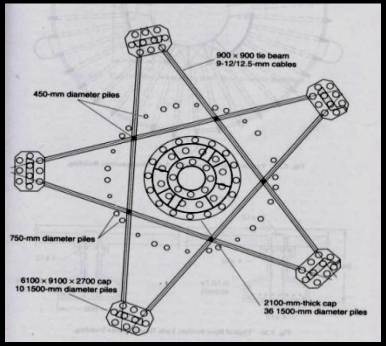
The outer framed tube and the inner core interact horizontally as the shear and flexural components of a wall-frame structure, with the benefit of increased lateral stiffness.

The structural tube usually adopts a highly dominant role because of its much greater structural depth.

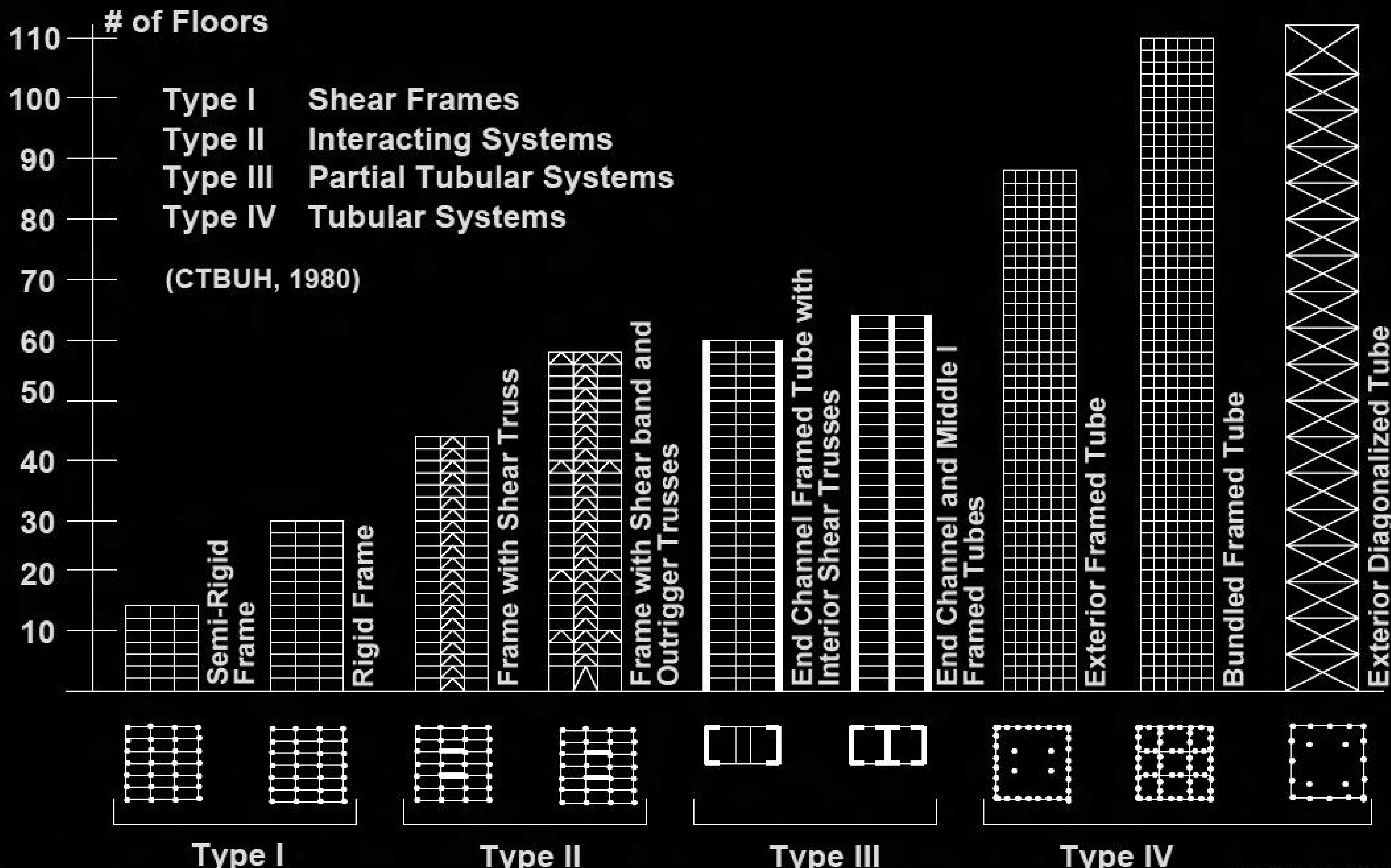
Lumbago Tatung Haji Building, Kuala Lumpur



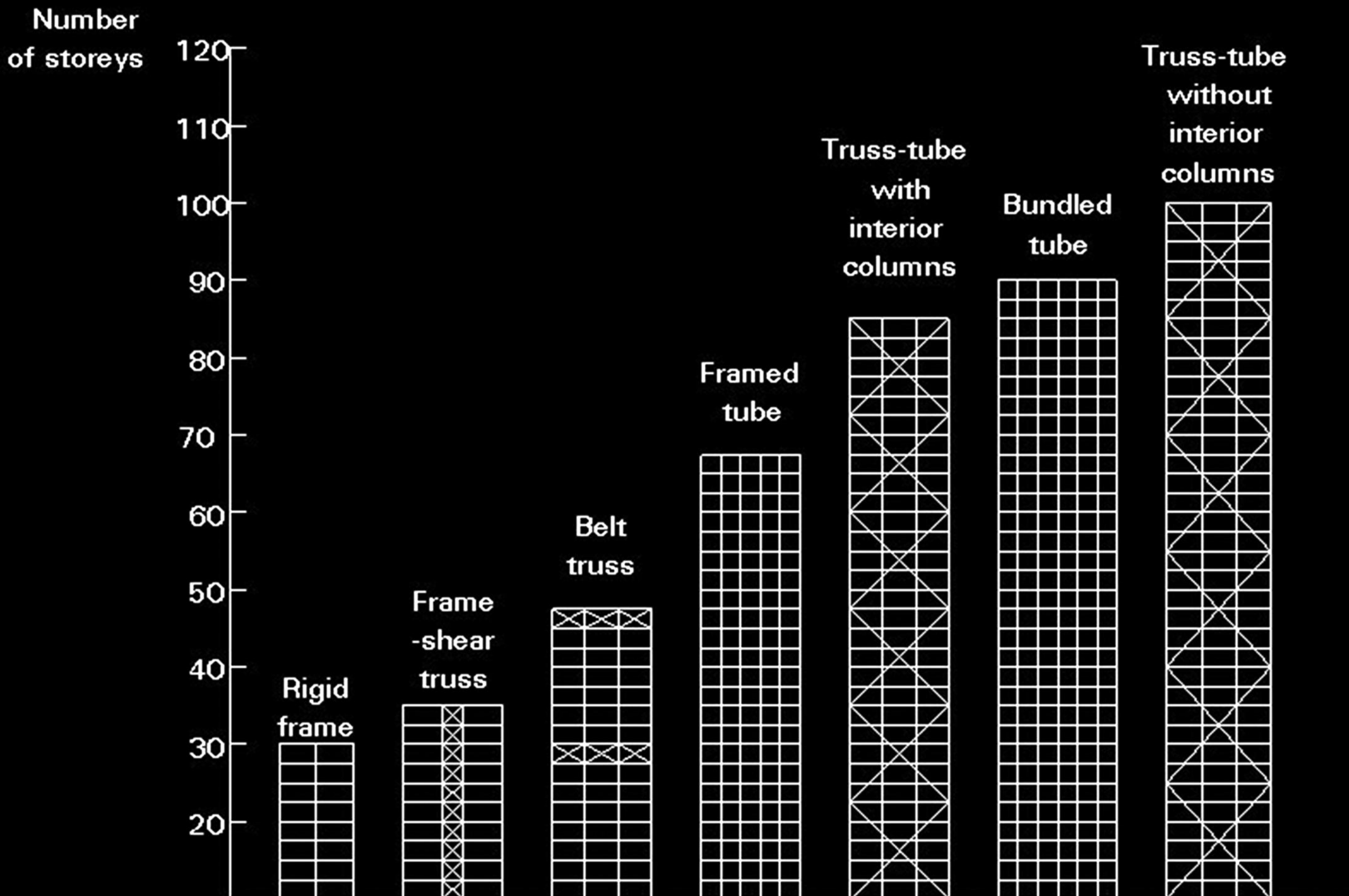




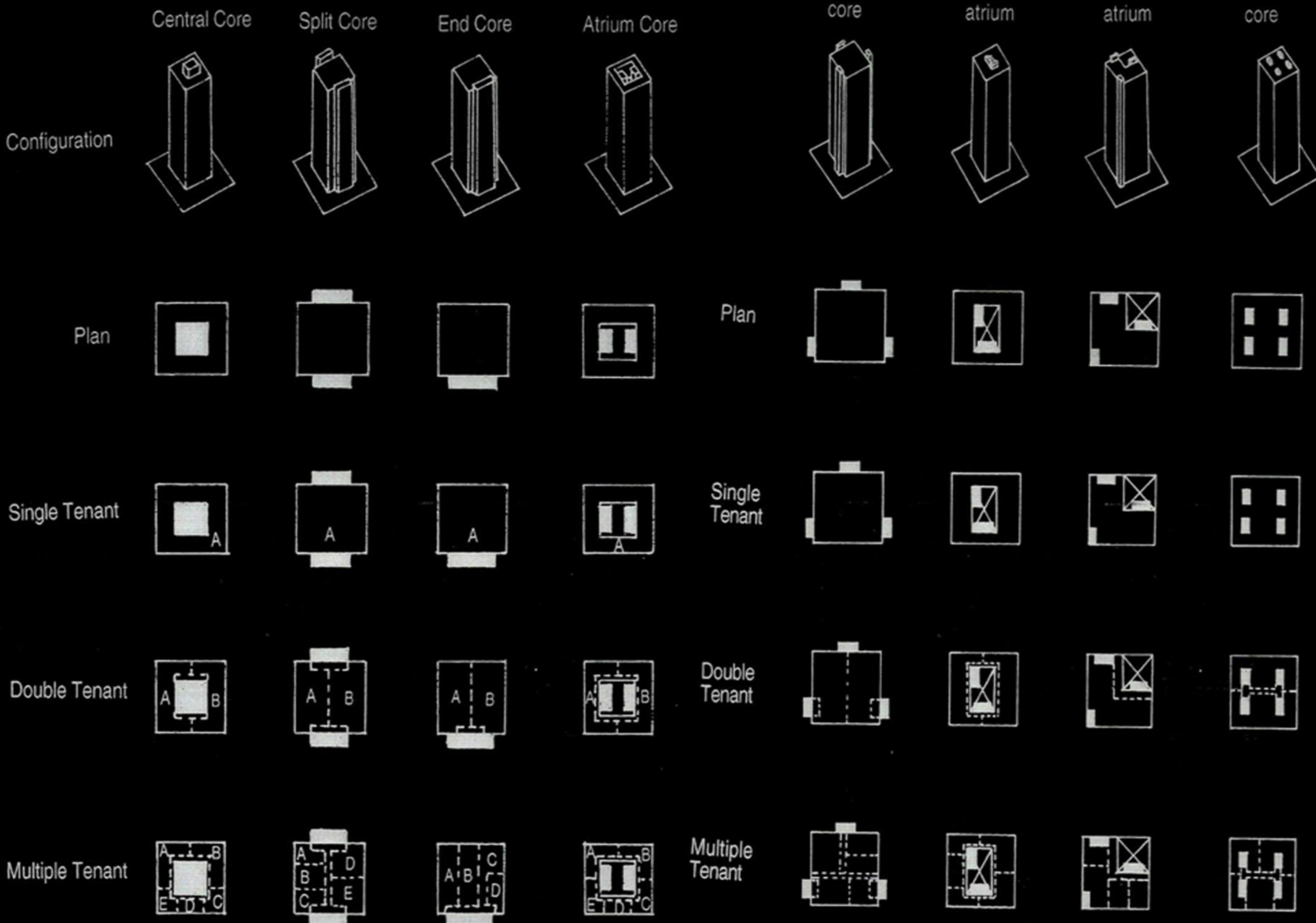
Evolution of Structural Systems

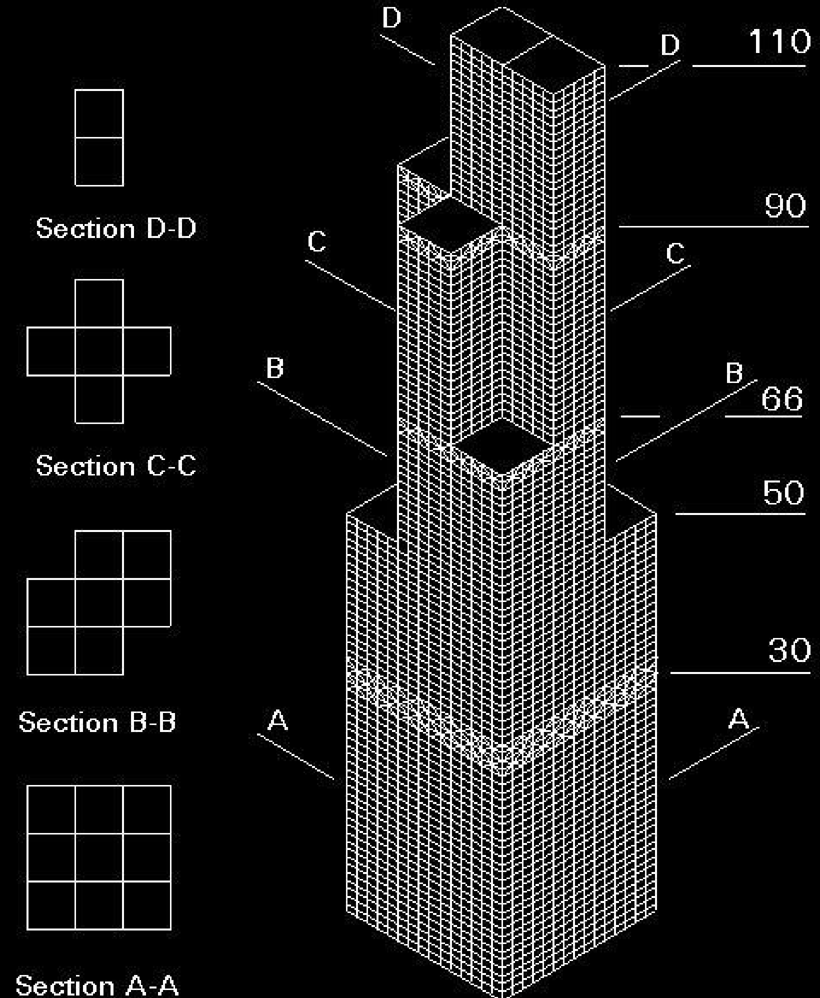


STEEL STRUCTURAL SYSTEMS AND THE NO. OF STOREYS

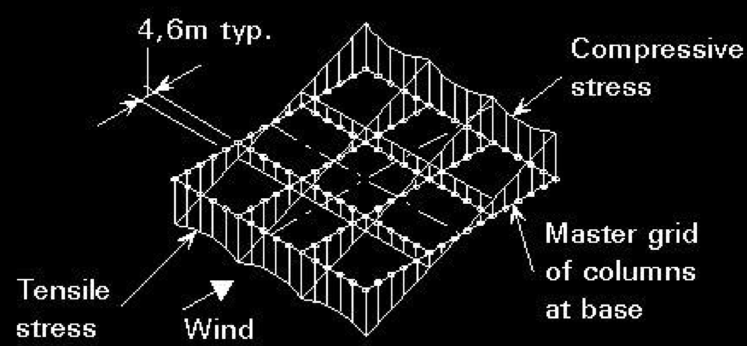


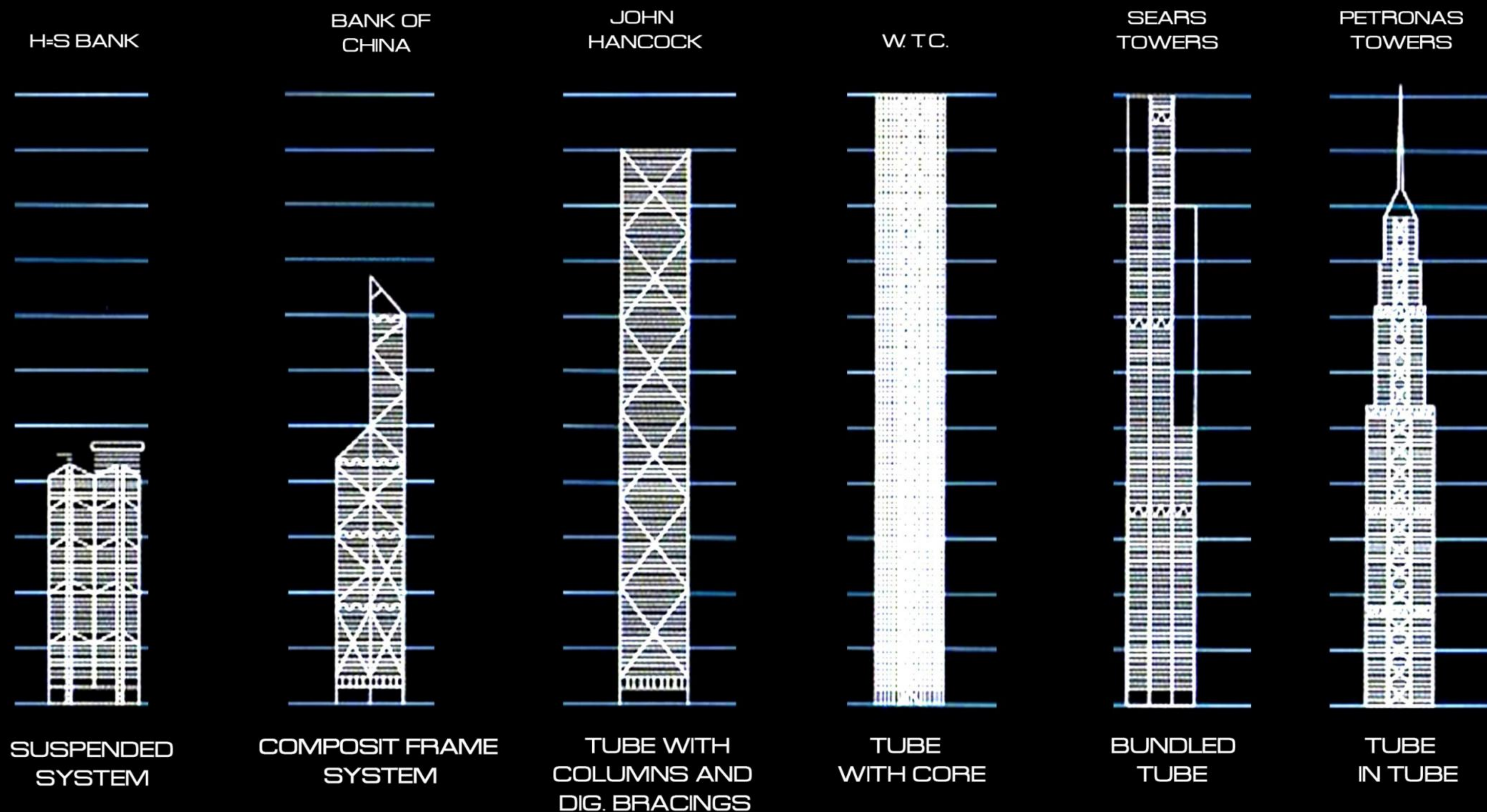
TYPES OF CORE SYSTEMS





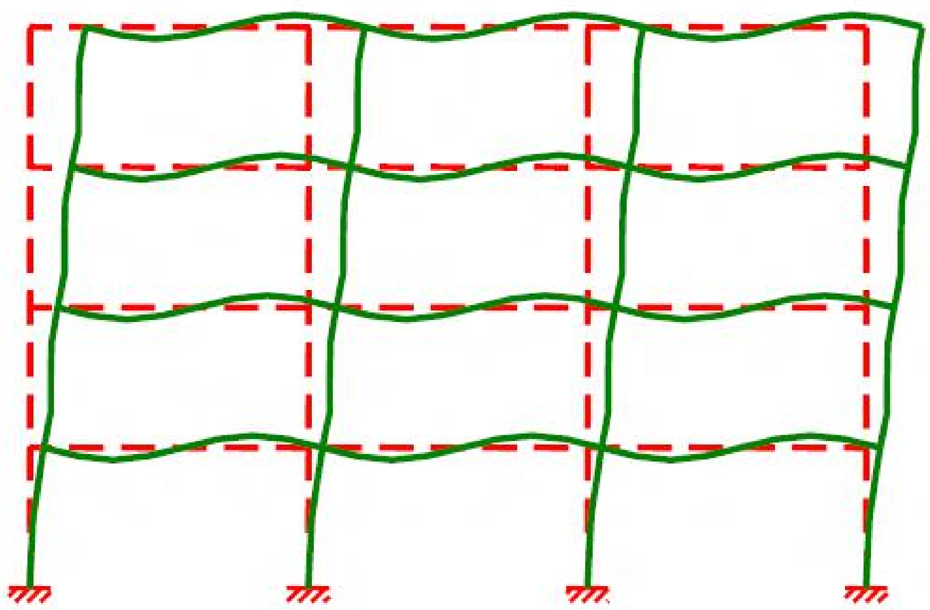
(a) Modular floor configurations




H=S BANK
BANK OF CHINA
JOHN HANCOCK
W. T.C.
SEARS TOWERS
PETRONAS TOWERS
SUSPENDED SYSTEM
COMPOSIT FRAME SYSTEM
TUBE WITH COLUMNS AND DIG. BRACINGS
TUBE WITH CORE
BUNDLED TUBE
TUBE IN TUBE

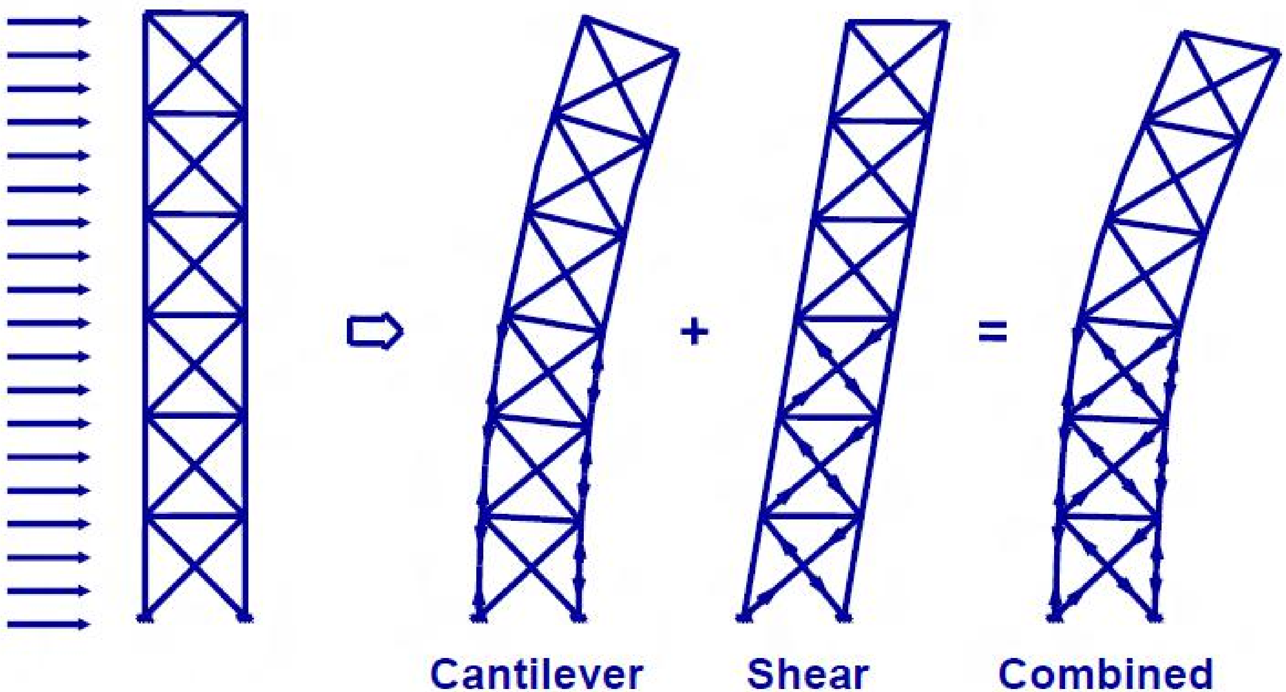
Shear Frame System

- Resists lateral deformation by joint rotation
- Requires high bending stiffness of columns and beams
- Rigid joints are essential for stability
- Not effective for heights over 30 stories



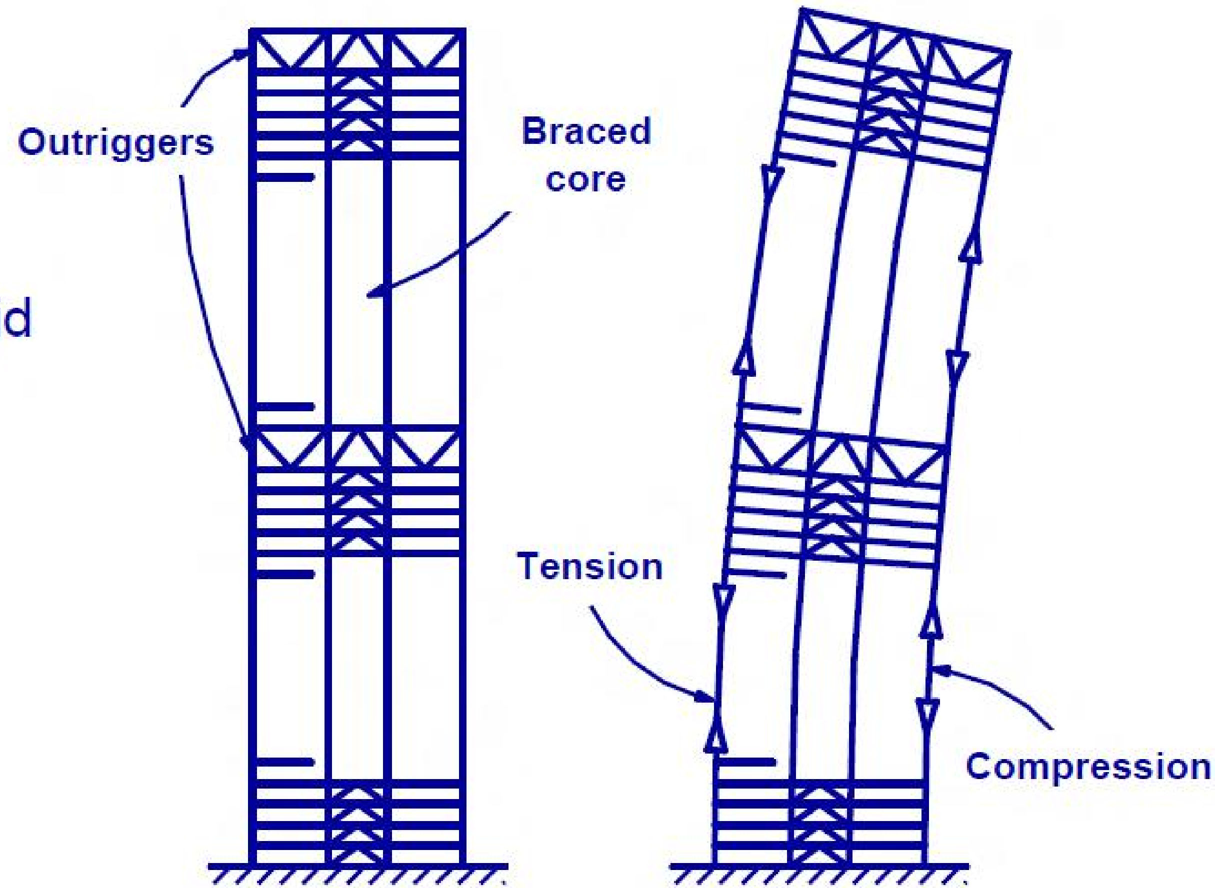
Braced Frame System

- Lateral forces are resisted by axial actions of bracing and columns
- Steel bracing members or filled-in bays
- More efficient than a rigid frame



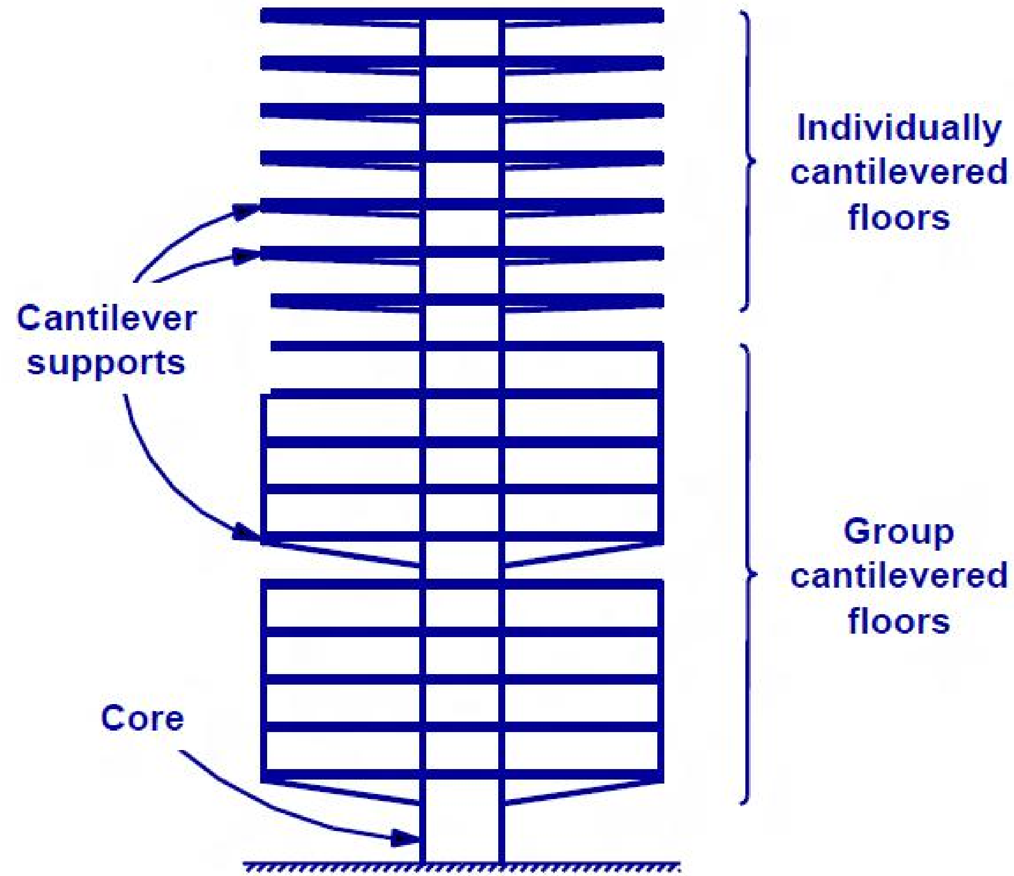
Outrigger Braced Structure System

- 1- or 2-story deep truss connects core to perimeter columns
- Increases the bending rigidity
- Dependent of rigid core for shear resistance



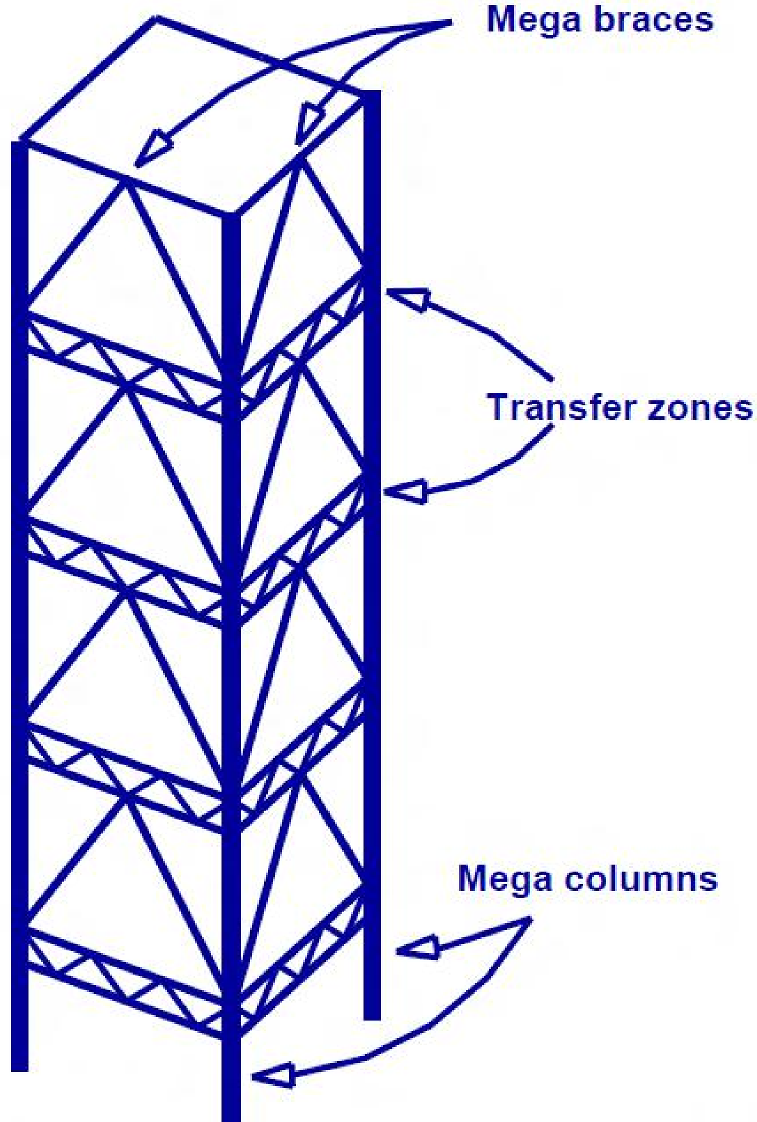
Core Structure System

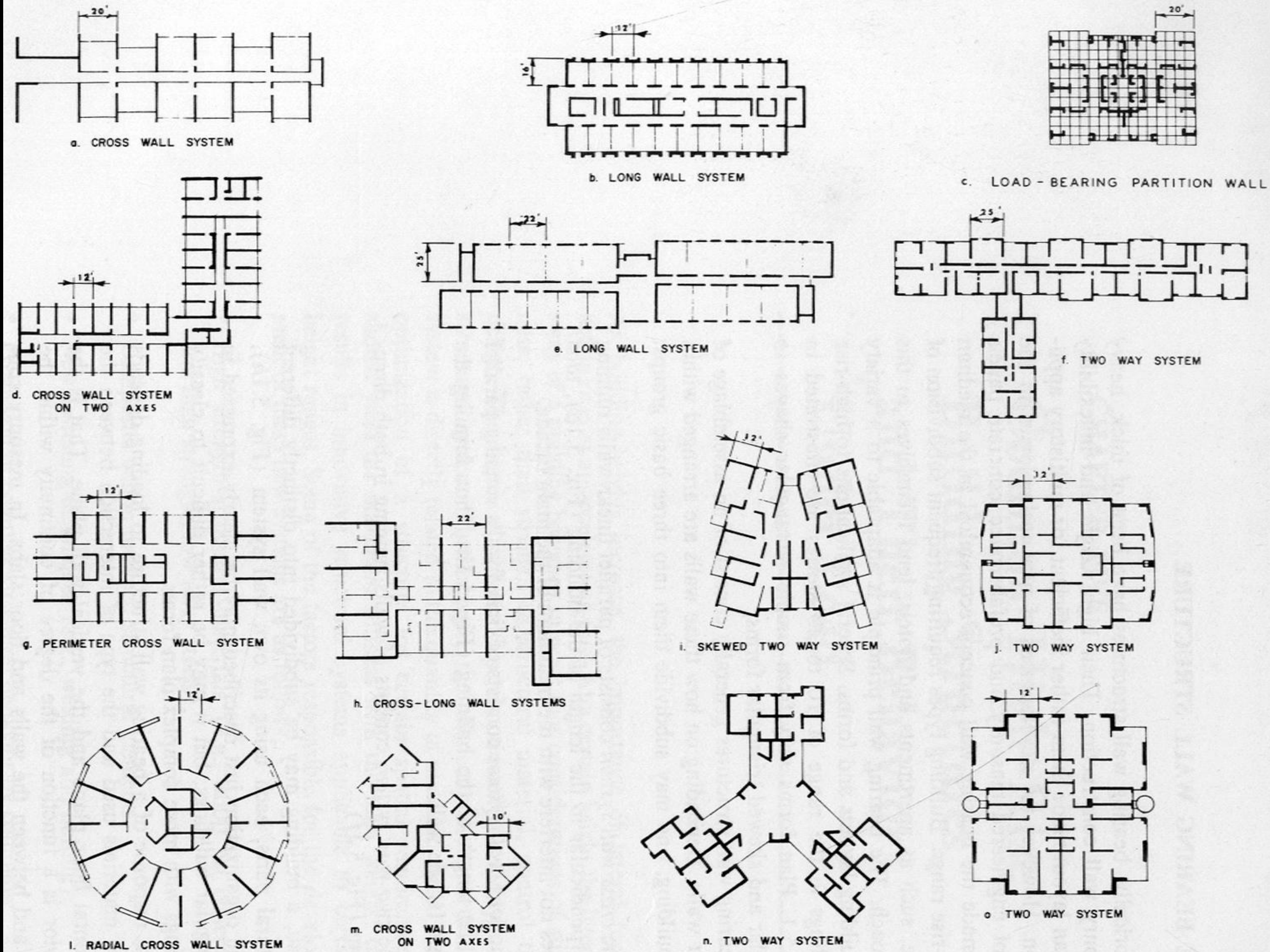
- Lateral and gravity loads supported by central core
- Eliminates columns and bracing elements
- Core is inefficient because it is not deep in respect to bending
- Moment supported floors are inefficient



High-Efficiency Mega-Braced Frame System

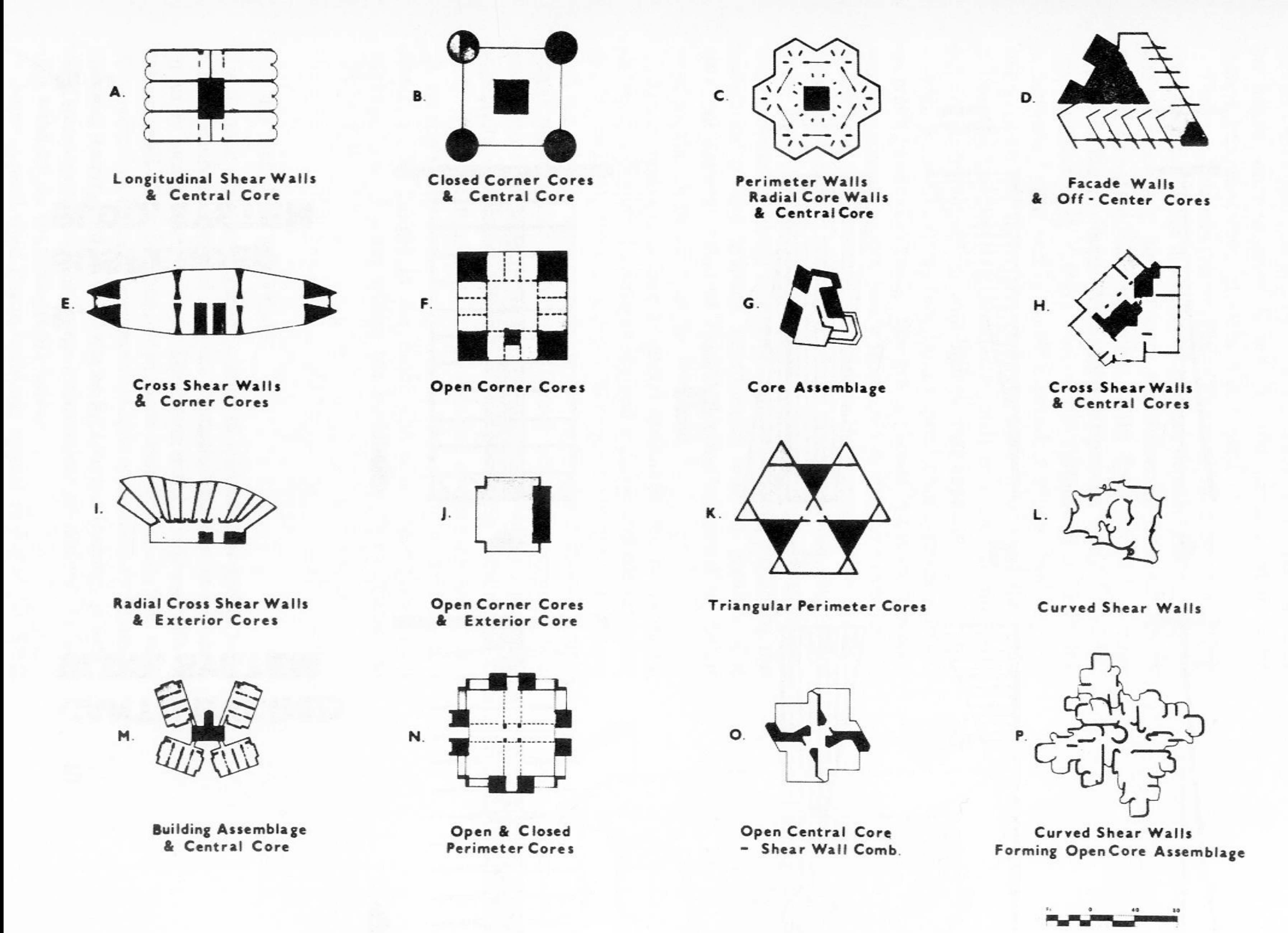
- Very large columns and bracing
- Small number of columns
- Bracing extends over multiple floors
- Stiff transfer floors allow for internal flexiblity



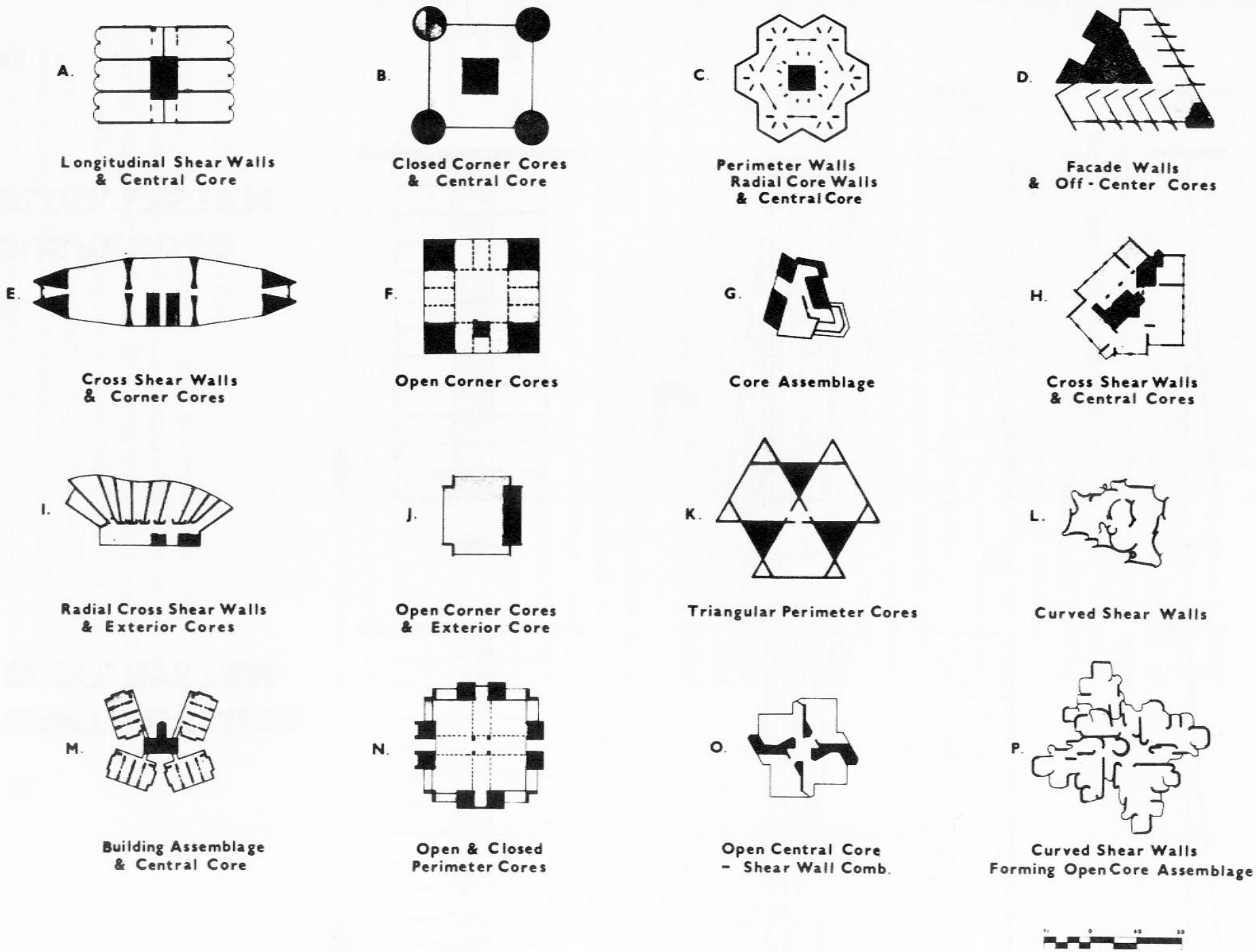


1 Bearing wall system

Three types: *cross wall system, long wall system and two-way system.*



2 Wall-core system Lateral force resistance is shared between load bearing wall structure and service core structures.



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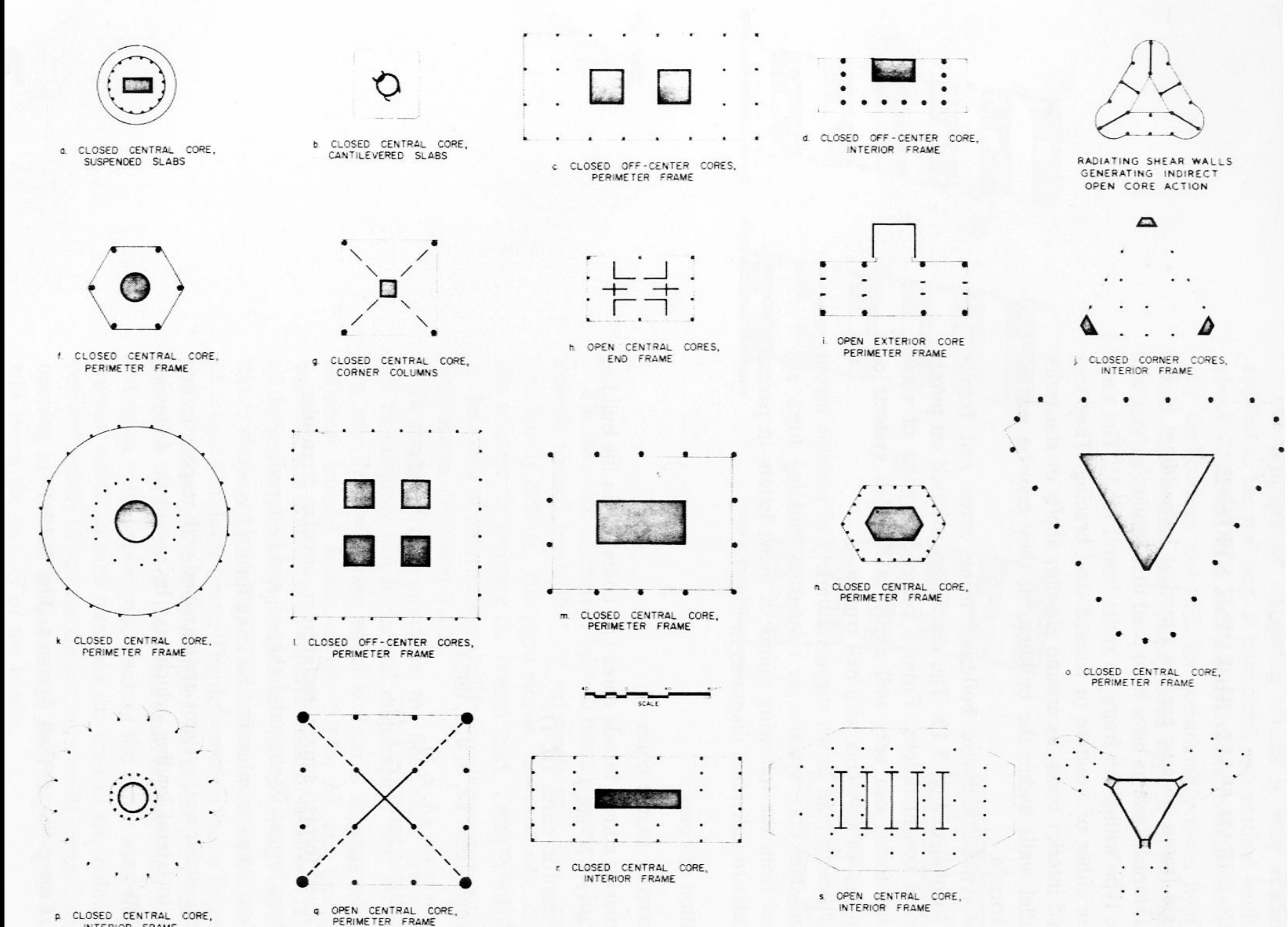

3 Core-frame system

The structural core acts as a shear wall. The frame may contribute also to the lateral stiffness, depending on the type of frame. A hinged frame contributes nothing and only carries vertical loads. A rigid frame contributes significantly.

Core and frame systems provide adequate stiffness up to 30-40 stories. Generally cores are at the center of the building, both for practical reasons (daylight) and to resist shear forces more effectively. If not centered, they are usually symmetrically located.

Construction materials

Materials used for high rise buildings: concrete, steel, glass, cladding material, high alumina cement used for roofs & floors. It contains bauxite instead of clay, cement, Portland cement of lime stone, silica.

Advantages are:

- Plasticity
- Easily availability
- Easy in casting
- Non corrosive
- Can be cast in situ

Disadvantages are:

- Cost of form
- Dead weight
- Difficulty in pouring

CONCRETE:- cellular concrete of clay-gypsum & invention of light weight concrete.

FERRO CONCRETE:-it is layer of fine mesh saturated with cement.

GUNITE:- it is also known as shot Crete.

compressed air to shoot concrete onto (or into) a frame or structure. Shot Crete is frequently used against vertical soil or rock surfaces, as it eliminates the need for

formwork.

GLASS:- float glass with double glass is used in tall buildings .

Tempered glass is used in tall buildings instead of plain glass, as that would shatter at such height.

CONSTUCTION METHODS AND TECHNIQUES

Slip forming, **continuous poured**, **continuously formed**, or **slip form construction** is a construction method in which concrete is poured into a continuously moving form. Slip forming is used for tall structures (such as bridges, towers, buildings, and dams), as well as horizontal structures, such as roadways. Slip forming enables continuous, non-interrupted, cast-in-place "flawless" (i.e. no joints) concrete structures which have superior performance characteristics to piecewise construction using discrete form elements. Slip forming relies on the quick-setting properties of concrete, and requires a balance between quick-setting capacity and workability. Concrete needs to be workable enough to be placed into the form and consolidated (via vibration), yet quick-setting enough to emerge from the form with strength. This strength is needed because the freshly set concrete must not only permit the form to "slip" upwards but also support the freshly poured concrete above it.

In **vertical slip forming** the concrete form may be surrounded by a platform on which workers stand, placing steel reinforcing rods into the concrete and ensuring a smooth pour. Together, the concrete form and working platform are raised by means of hydraulic jacks. Generally, the slipform rises at a rate which permits the concrete to harden by the time it emerges from the bottom of the form

Slipforming is an economical, rapid and accurate method of constructing reinforced concrete. At its most basic level, slipforming is a type of movable formwork which is slowly raised, allowing the continuous extrusion of concrete.

TABLE FORM/FLYING FORM

A table form/flying form is a large pre-assembled formwork and falsework unit, often forming a complete bay of suspended floor slab. It offers mobility and quick installation for construction projects with regular plan layouts or long repetitive structures, so is highly suitable for flat slab, and beam and slab layouts. It is routinely used for residential flats, hotels, hostels, offices and commercial buildings.

SYSTEM COLUMN FORMWORK

-The column formwork systems now available are normally modular in nature and allow quick assembly and erection on-site while minimising labour and crane time. They are available in steel, aluminium and even cardboard (not reusable but recycled) and have a variety of internal face surfaces depending on the concrete finish required.

-Innovations have led to adjustable, reusable column forms which can be clamped on-site to give different column sizes.

VERTICAL PANEL SYSTEMS

Crane-lifted panel systems are commonly used on building sites to form vertical elements and usually consist of a steel frame with plywood, steel, plastic or composite facing material.
The systems are normally modular in nature, assembly times and labour costs are considerably lower than traditional formwork methods with far fewer components required.

They offer greater opportunities for reuse for different applications on site. Panel systems are extremely flexible and the larger crane-lifted versions can be used for constructing standard concrete walls, perimeter basement walls, columns and in conjunction with jump form climbing systems.

JUMP FORM SYSTEMS

Generally, jump form systems comprise the formwork and working platforms for cleaning/fixing of the formwork, steel fixing and concreting. The formwork supports itself on the concrete cast earlier so does not rely on support or access from other parts of the building or permanent works.

Jump form, here taken to include systems often described as climbing form, is suitable for construction of multi-storey vertical concrete elements in high-rise structures, such as shear walls, core walls, lift shafts, stair shafts and bridge pylons. These are constructed in a staged process. It is a highly productive system designed to increase speed and efficiency while minimising labour and crane time.

Systems are normally modular and can be joined to form long lengths to suit varying construction geometries.

Three types of jump form are in general use:

TYPES OF JUMP FORM

Normal jump/climbing form – units are individually lifted off the structure and relocated at the next construction level using a crane.

Guided-climbing jump form – also uses a crane but offers greater safety and control during lifting as units remain anchored/guided by the structure.

Self-climbing jump form – does not require a crane as it climbs on rails up the building by means of hydraulic jacks, or by jacking the platforms off internal recesses in the structure. It is possible to link the hydraulic jacks and lift multiple units in a single operation.

TUNNEL FORM

Tunnel form is used to form repetitive cellular structures, and is widely recognised as a modern innovation that enables the construction of horizontal and vertical elements (walls and floors) together.

Significant productivity benefits have been achieved by using tunnel form to construct cellular buildings such as hotels, low- and high-rise housing, hostels, student accommodation, prison and barracks accommodation.

THANKS………………….