

Technology 3

INTRODUCTION TO HIGH-RISE FRAMED BUILDING STRUCTURES

TECHNICAL



Learning Outcomes

Aim

To introduce the subject area of high-rise framed building structures with a brief consideration of the functional requirements, materials and methods of construction used.

Learning objectives

Understand the principles of framed building structures and choice of technologies available in their construction.

Learning Outcomes

- To provide designers with guidance on the prime factors to be considered, the options available and the implications of a given choice of structure.

The Importance of Structure

- Previous lecture series may have focussed mainly on loadbearing masonry wall construction where the loads applied to the building are transferred via the walls (supporting and enclosing element) to the foundations.
- In framed or skeletal buildings there is a distinction between the supporting element (structural system) and the enclosing element (enclosure system). The latter can be made relatively light and thin and is not fixed in its position relative to the skeletal frame.



FRAMED BUILDINGS/ SKELETAL STRUCTURES

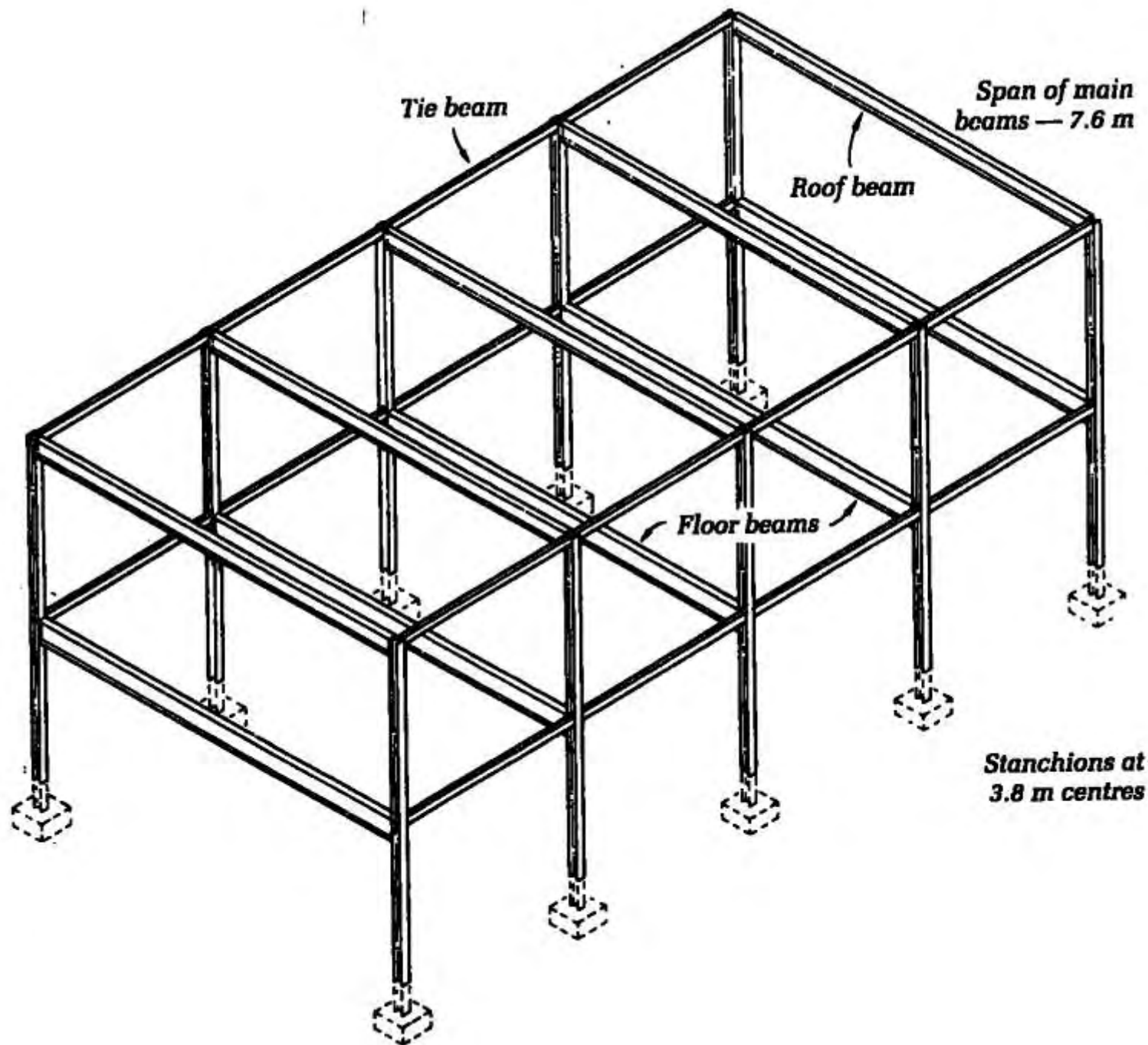
● **Concept of skeletal structures**

- Consists essentially of a skeleton or framework which supports all the loads and resists all the forces acting on the building and through which all loads are transferred to the soil on which the building rests.
- By its nature the skeleton frame cannot enclose space within it as an environmental envelope. Other enclosing elements such as roofs and walls, must be associated with it, which can be relatively light and thin.
- Skeletal structures are suitable for high- and low-rise, and for long- and short-span buildings.

FRAMED BUILDINGS

FRAMED BUILDINGS/ SKELETAL STRUCTURES

- Certain forms of framed buildings consist essentially of pairs of columns with members spanning between them, spaced apart in a grid formation to enclose the building.
- They are classified as:
- Building Frame- comprising columns and horizontal beams for single and multi-story buildings
- Shed Frame- of columns and roof truss for single storey buildings
- Portal or rigid frame of columns and horizontal or pitched beam for single storey buildings.







FRAMED BUILDINGS/ SKELETAL STRUCTURES

● Advantages of framed structures to the designer:

- Saving in floor space – removes the need for internal loadbearing structure required in loadbearing masonry methods.
- This allows flexibility in the plan arrangement and building operations.
- Reduces the dead weight of the construction.

FRAMED BUILDINGS/ SKELETAL STRUCTURES

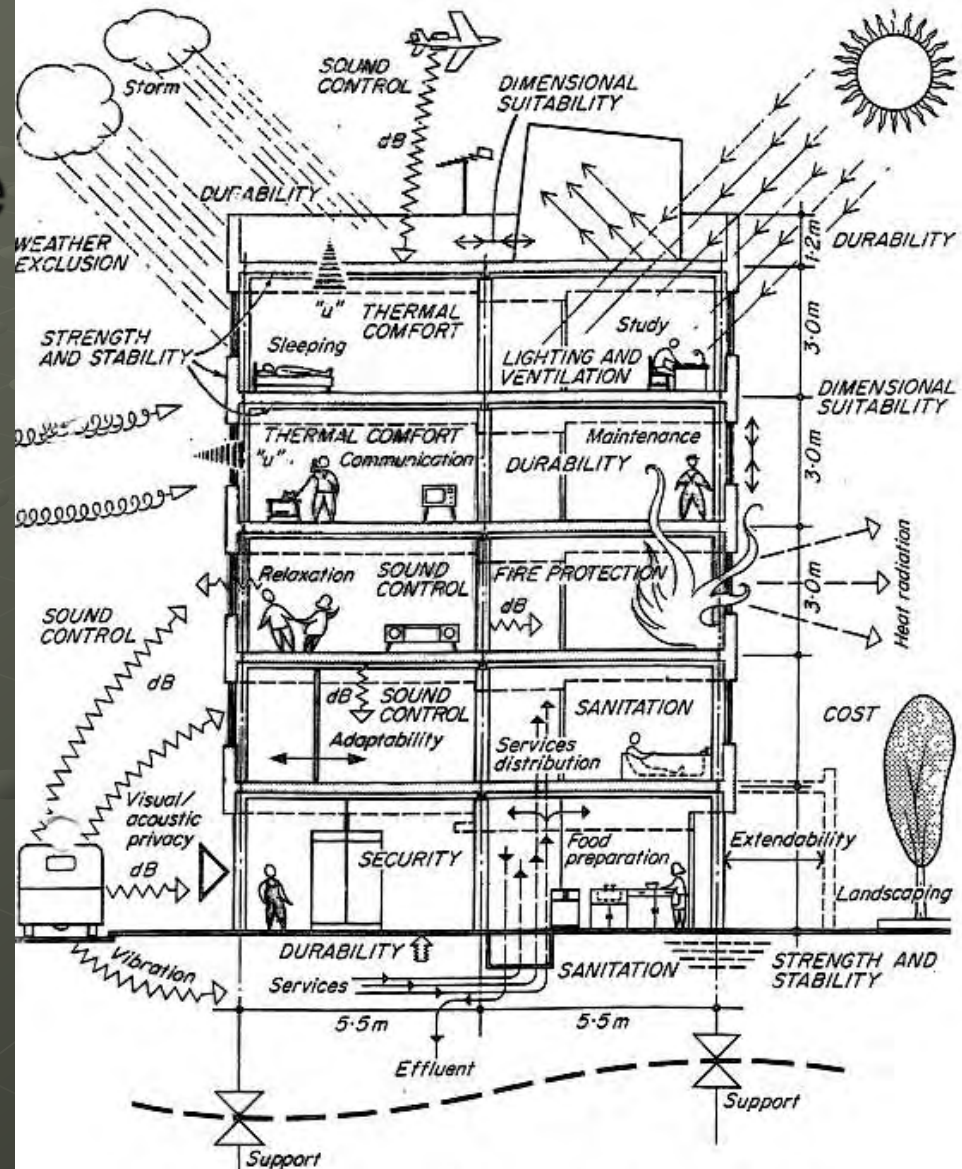
- The economic advantages of using a framed building will have to be considered depending on the circumstances in each project.
- Economies are derived from large-scale production using prefabricated components with reduced erection time and savings in site labour costs.

The background of the slide features a 3D grid of small, light gray spheres. These spheres are arranged in a perspective view, receding into the distance. The grid lines are faint and light gray, creating a sense of depth and structure. The overall color palette is dark gray, providing a high-contrast background for the red text.

FUNCTIONAL / PERFORMANCE REQUIREMENTS

Functional / Performance Requirements

What do we mean by functional / performance requirements?

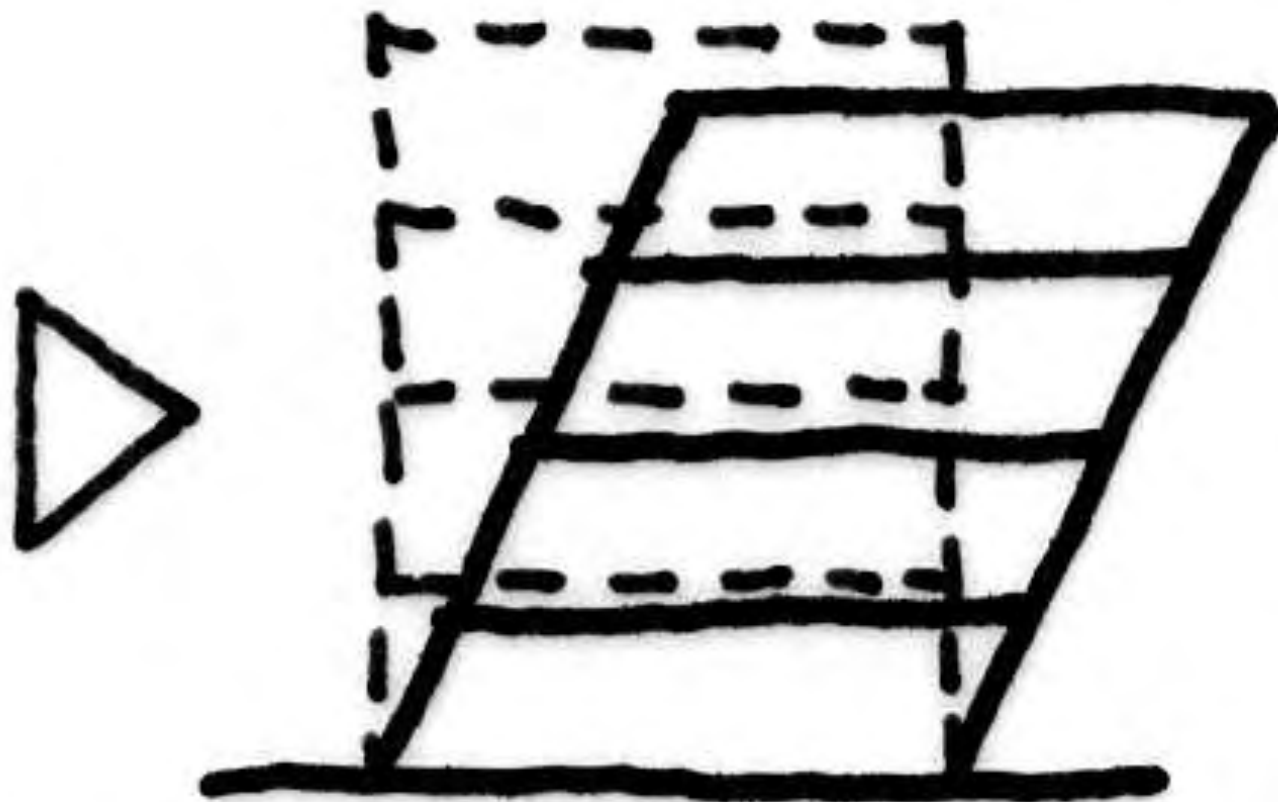


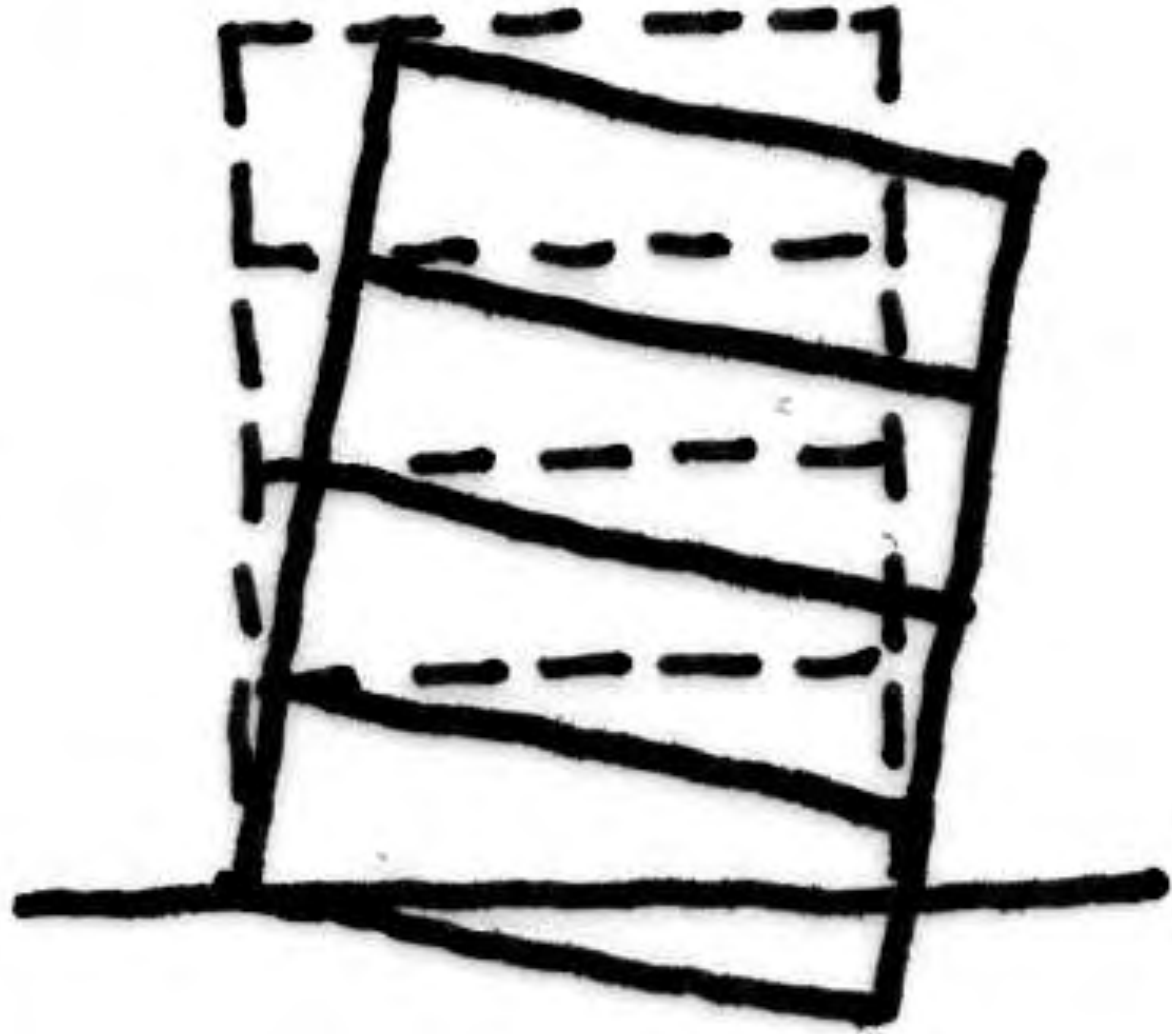
Performance Requirements of a Building

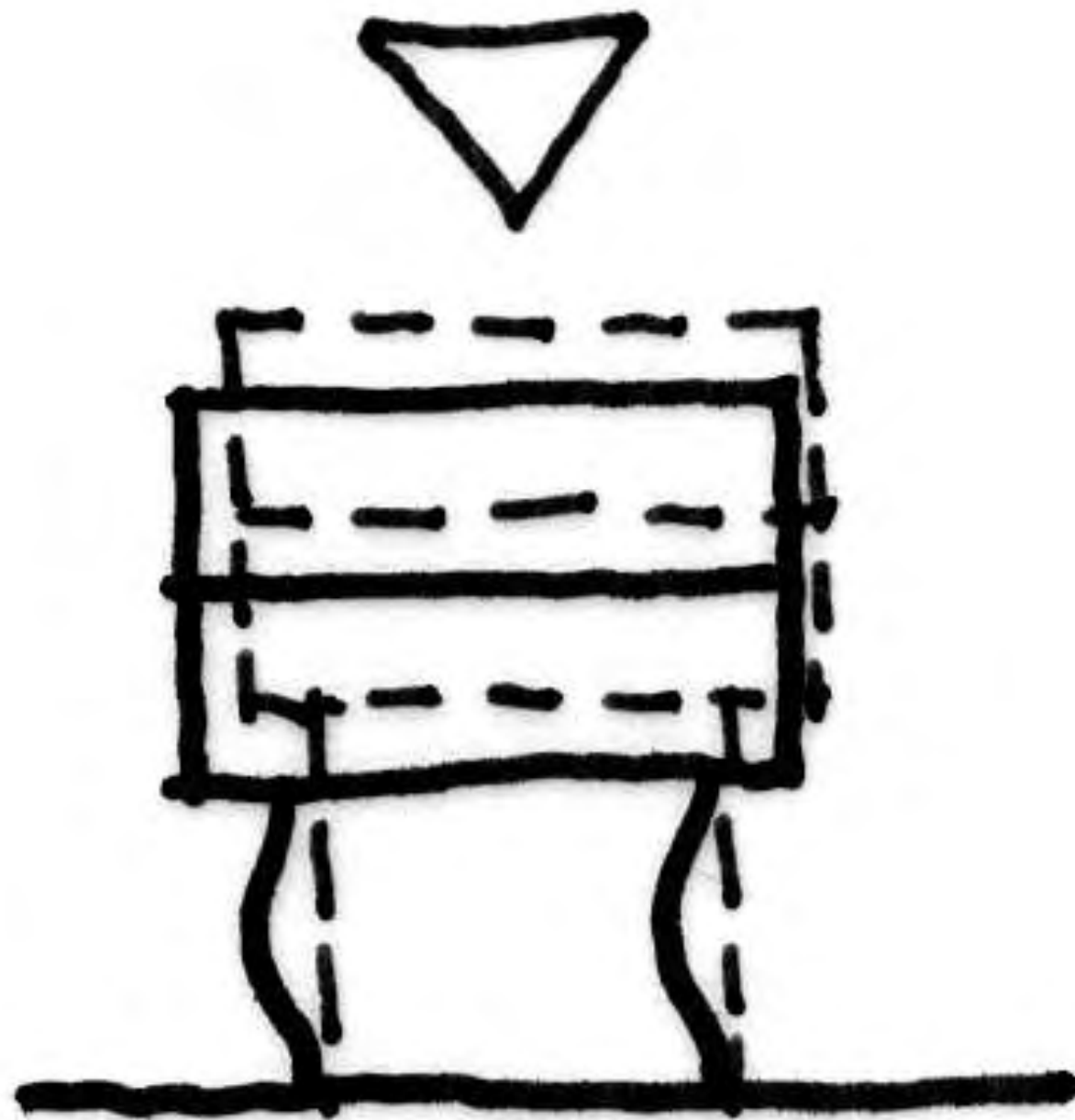
FRAMED BUILDINGS/ SKELETAL STRUCTURES

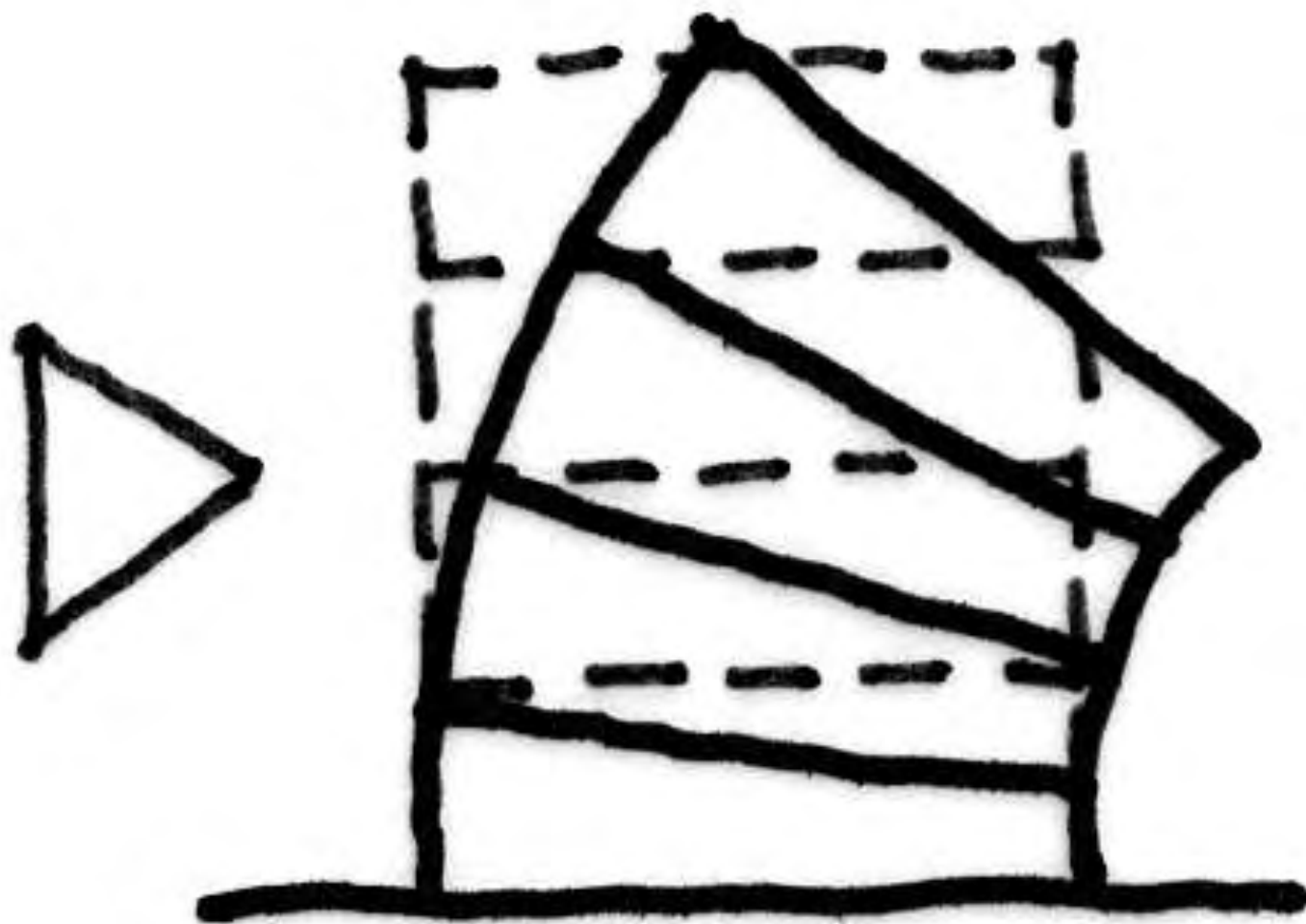
● Functional Requirements

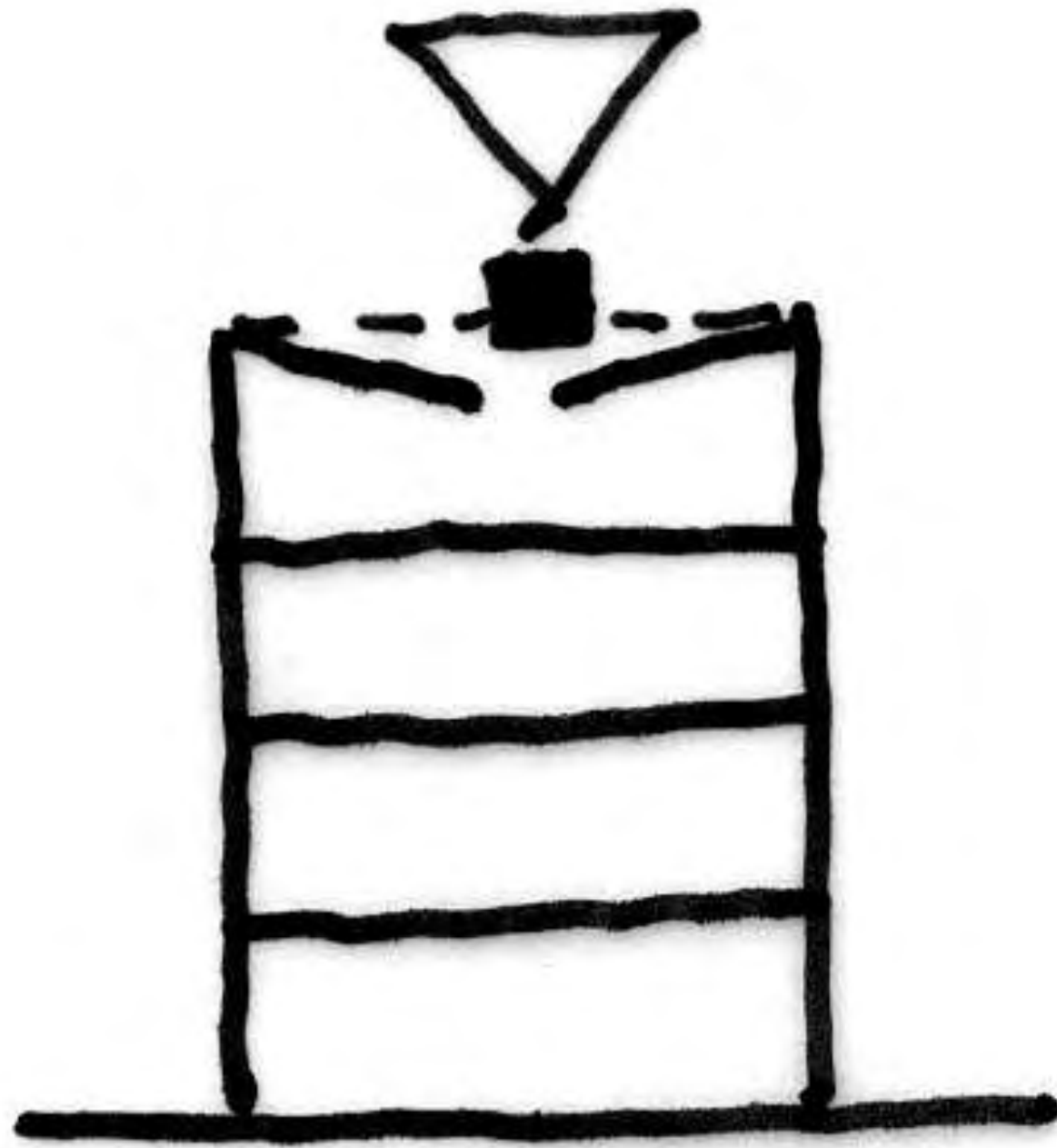
- **Strength and Stability**- Ensured by use of appropriate materials in suitable forms related to manner in which the structure behaves under load.
- Building frames are classified according to the stiffness or rigidity of the joints between the members especially column to beam.
- Rigidity is achieved by inclusion of stiffening elements in the structure i.e. triangulating members.
- Span /depth ratio
- Dead/live load ratio

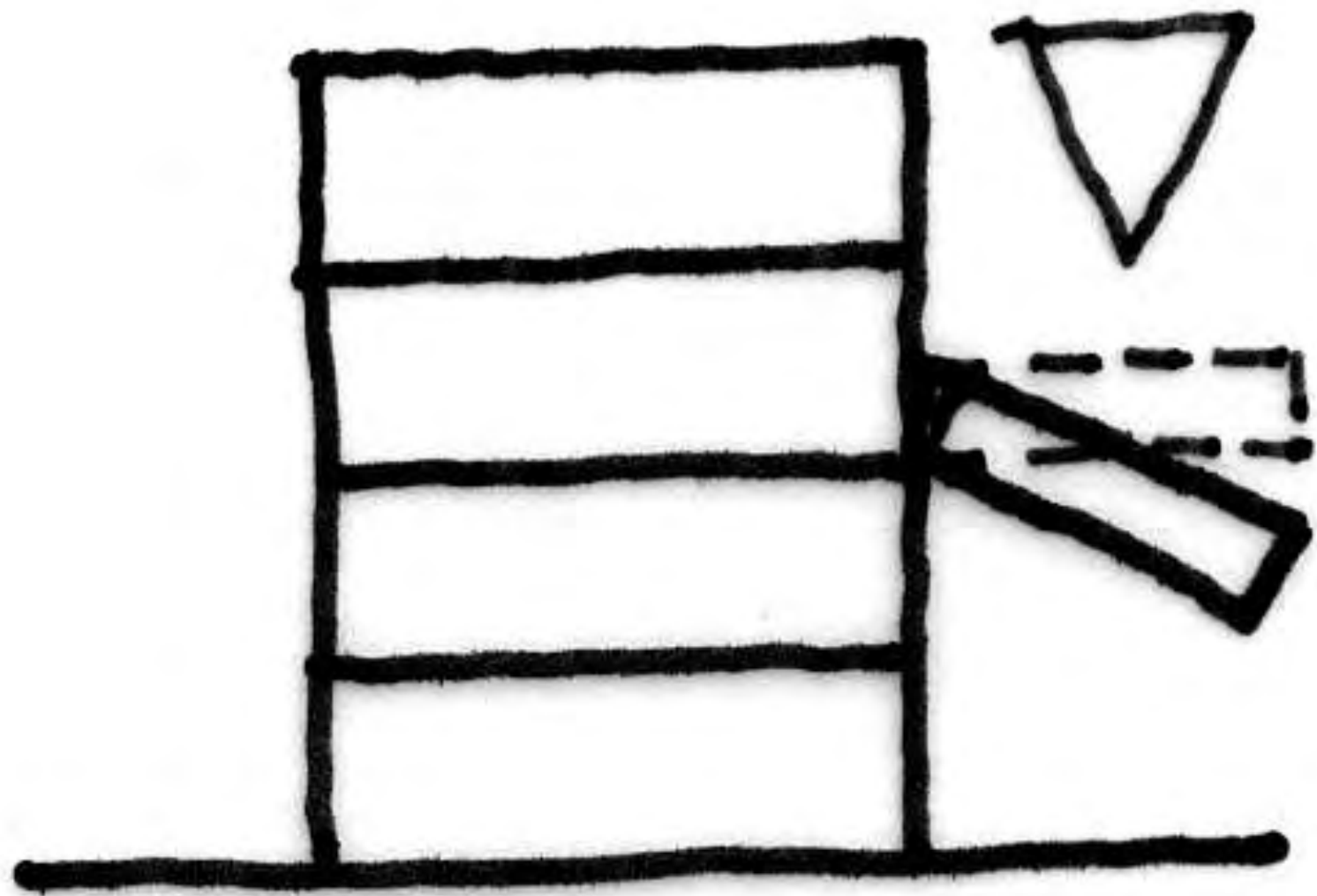






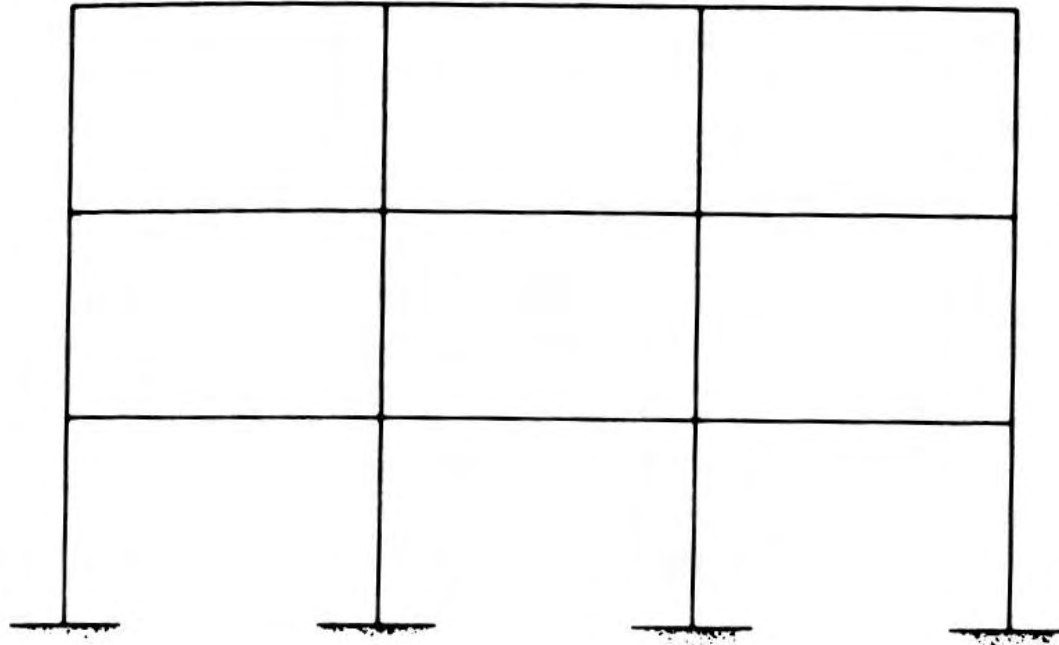






FRAMED BUILDINGS/ SKELETAL STRUCTURES

- FULLY RIGID- All the joints are rigid



(a) Normal multistory frame

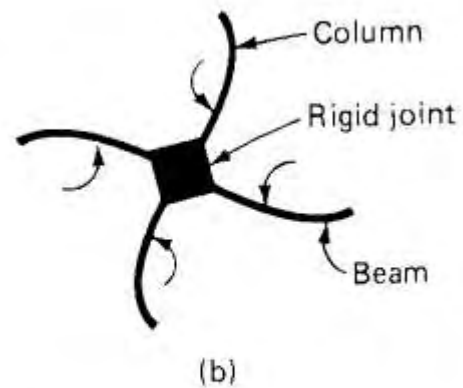
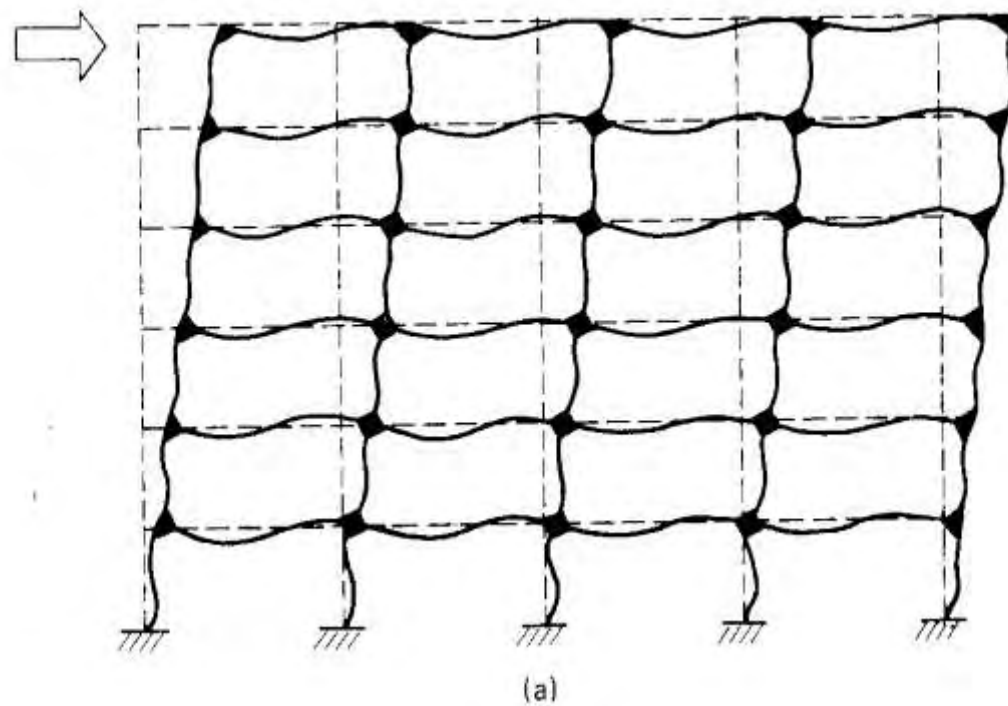


Figure 4.15 (a) Response of rigid frame to lateral loads; (b) flexural deformation of beams and columns due to nondeformability of connection.

FRAMED BUILDINGS/ SKELETAL STRUCTURES

● SEMI-RIGID and NON RIGID FRAMES

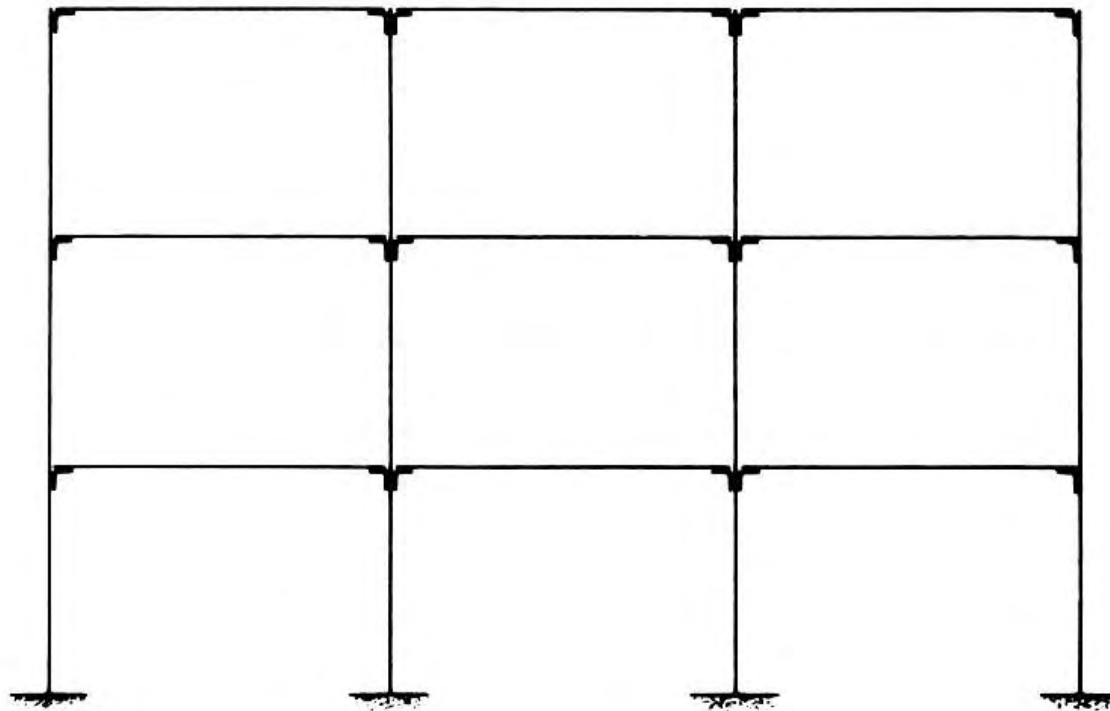
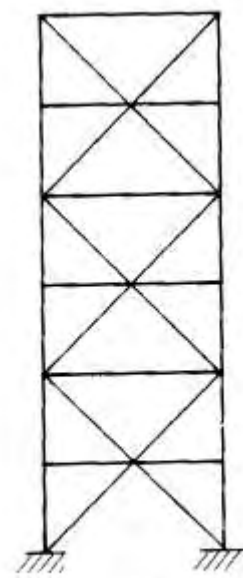
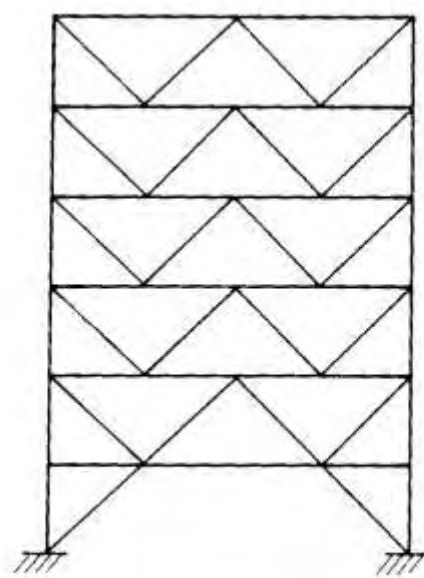


Fig. 1.45.

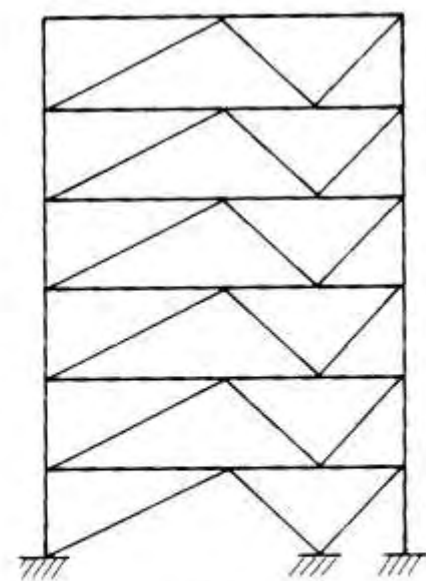
Nonrigid multistory frame, built with beams simply supported on beam connectors.



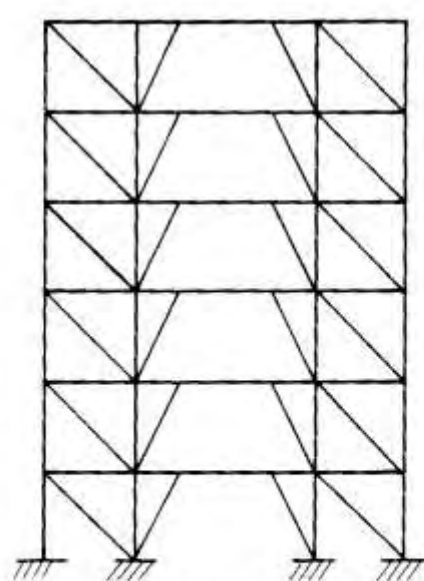
(a)



(b)



(c)



(d)

Figure 4.17 Common types of braced frames.

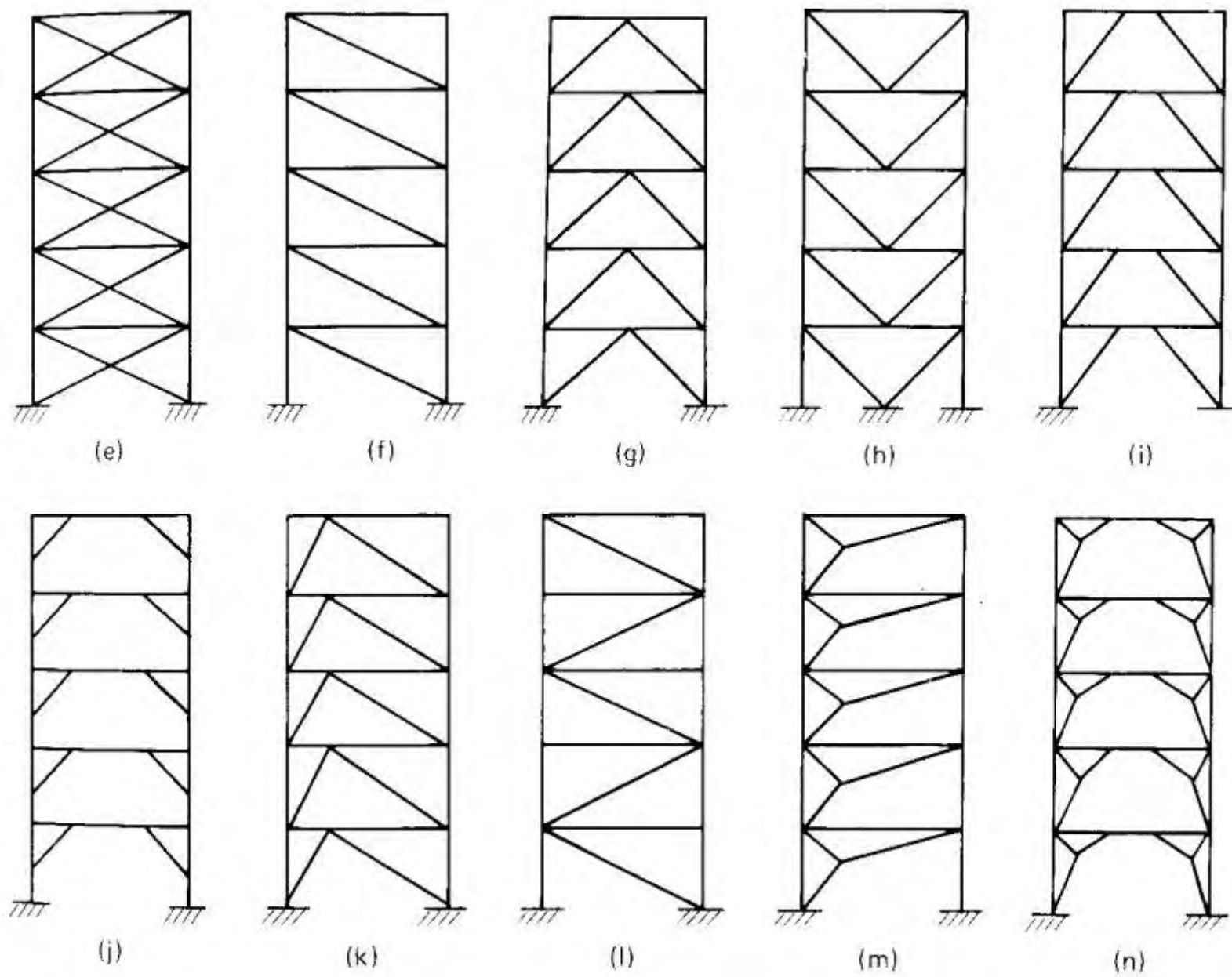


Figure 4.17

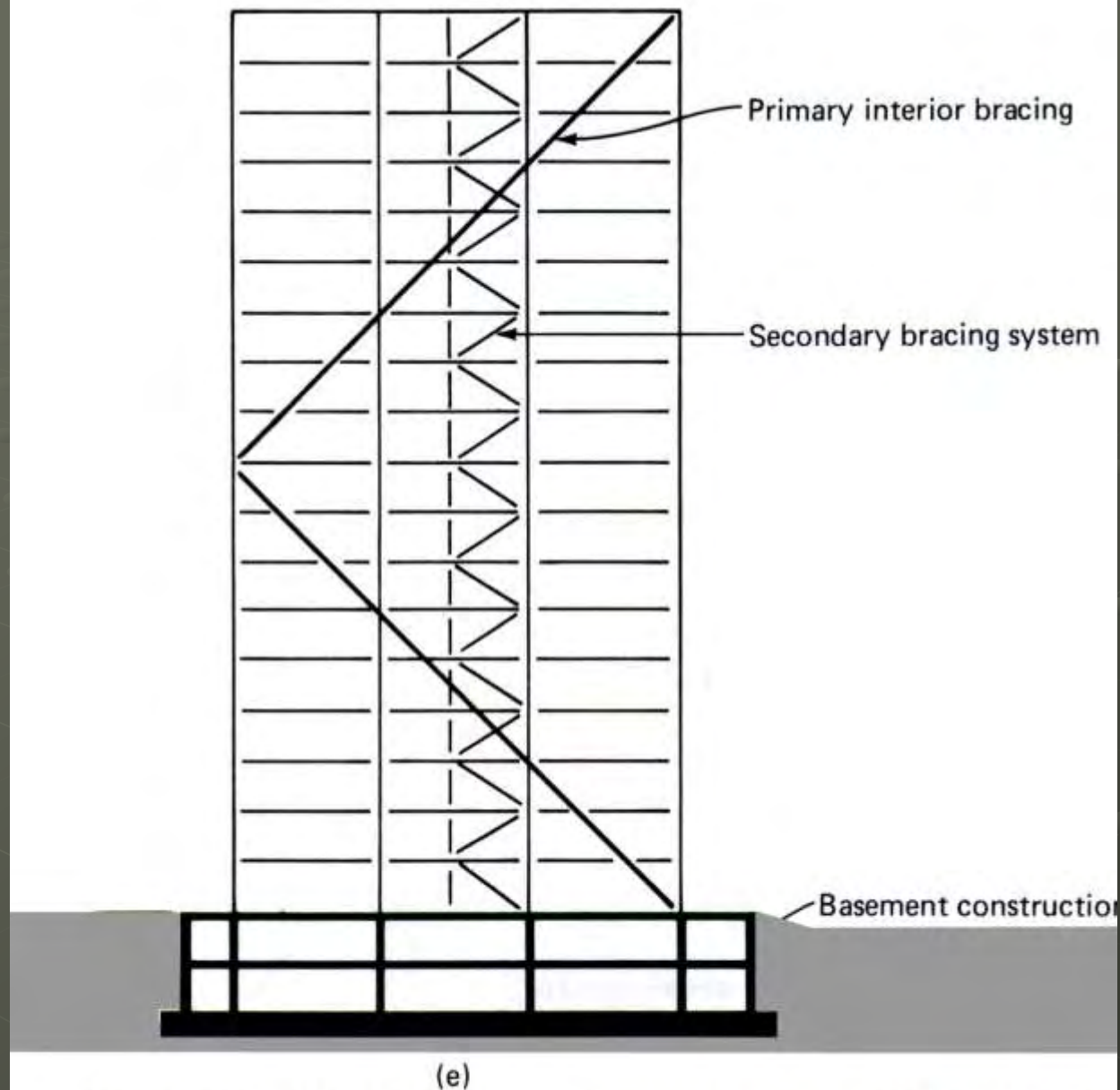
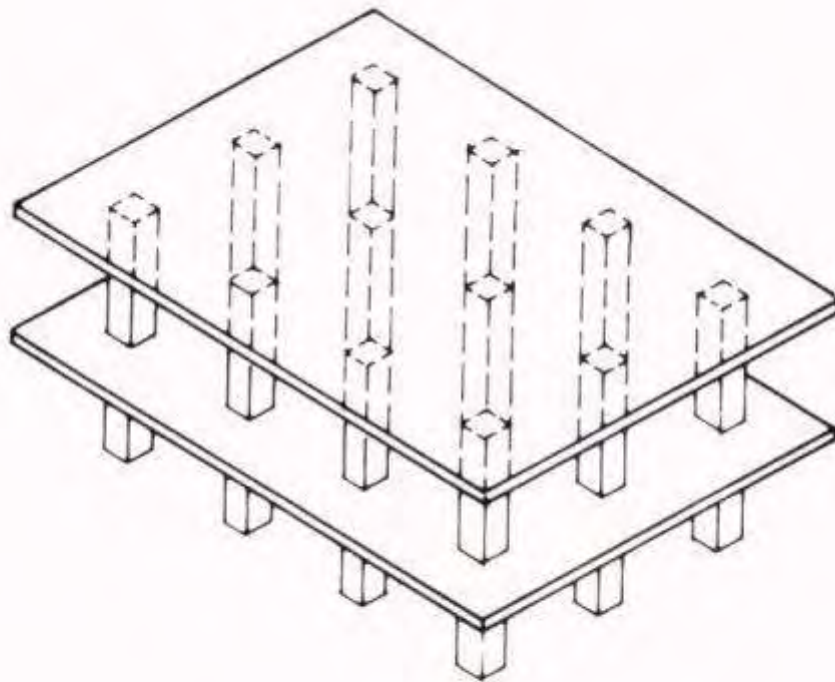


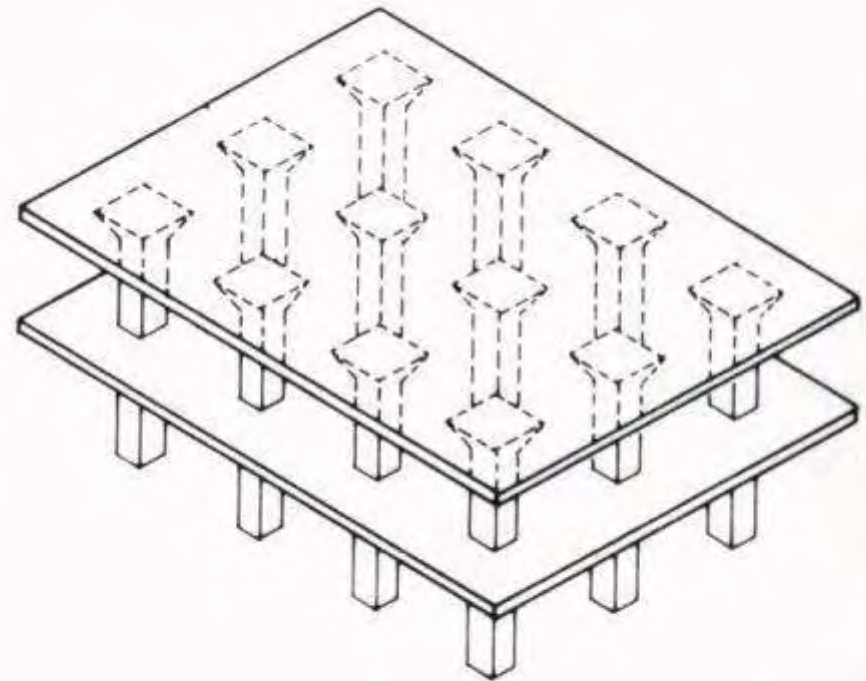
Figure 4.24 (Continued) (e) Transverse cross section showing primary interior bracing, secondary bracing, and basement construction.

FRAMED BUILDINGS/ SKELETAL STRUCTURES

- FULLY RIGID- All the joints are rigid



(a) Flat plate



(b) Flat slab

FRAMED BUILDINGS/ SKELETAL STRUCTURES

- **Fire Resistance-** An adequate degree of fire resistance in the frame is essential in order that its structural integrity is maintained in the event of a fire.

NON-LOADBEARING WALLS

- Buildings with external non-loadbearing walls rely on a building structure to support the walls, floors and roof
- The enclosure system -the building envelope provide the weather protection, thermal and sound insulation and fire protection.
- A number of different structural systems can be used with a selection of cladding and infill systems and materials

Grid Size

- The choice of grid size (column spacing) is important because although steel is popular due to its ability to span further than simple reinforced concrete for the same structural depth, costs per sq m rise as the column spacing increases.
- However, these additional costs may be small in comparison with the economic and functional benefits realised from greater areas of uninterrupted useable floor space.
- Internal columns are very unwelcome in high-rise schemes, for example, as they become so large in plan area due to high loading.

Grid Size

- Column grids for many office developments are in the 6-9 m range with a 1.5m common module space planning
- longer spans, particularly in steel can be achieved for only a modest premium, 2 to 3 per cent of the overall building cost.
- A 9 m grid is more common today.
- Users and developers are constantly demanding more column-free space and 12-18 m spans are becoming increasingly popular. Agents are finding column-free spaces easier to let, especially in the current market; they may well command a premium.

Environmental Conditions

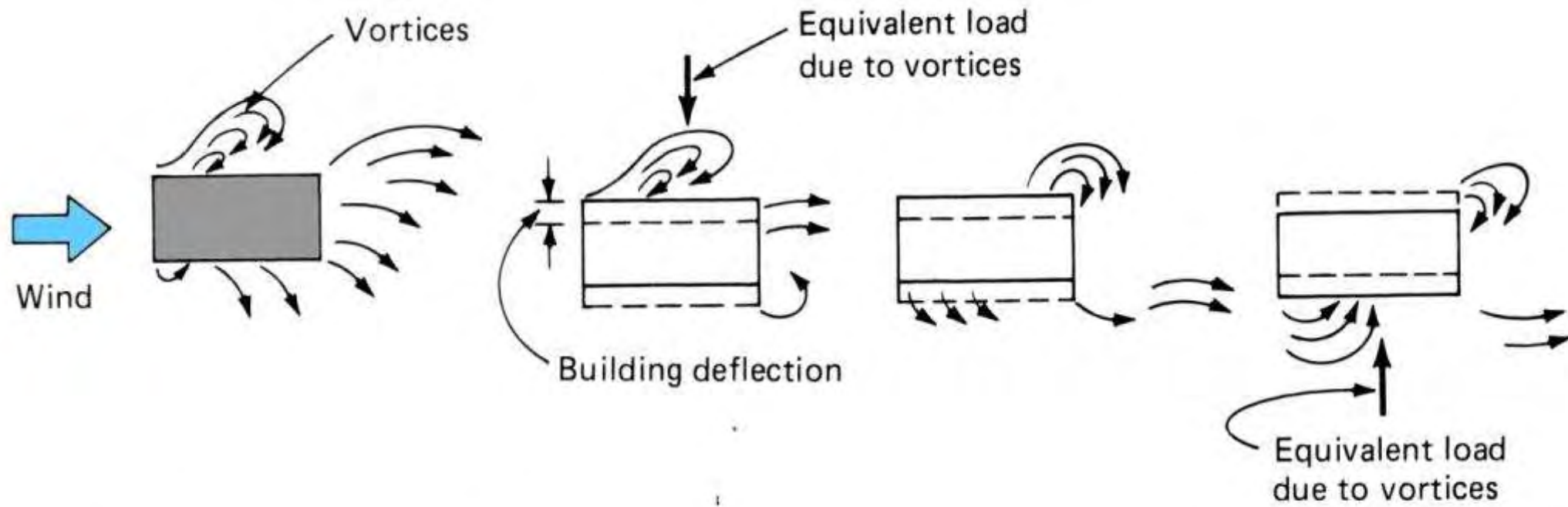
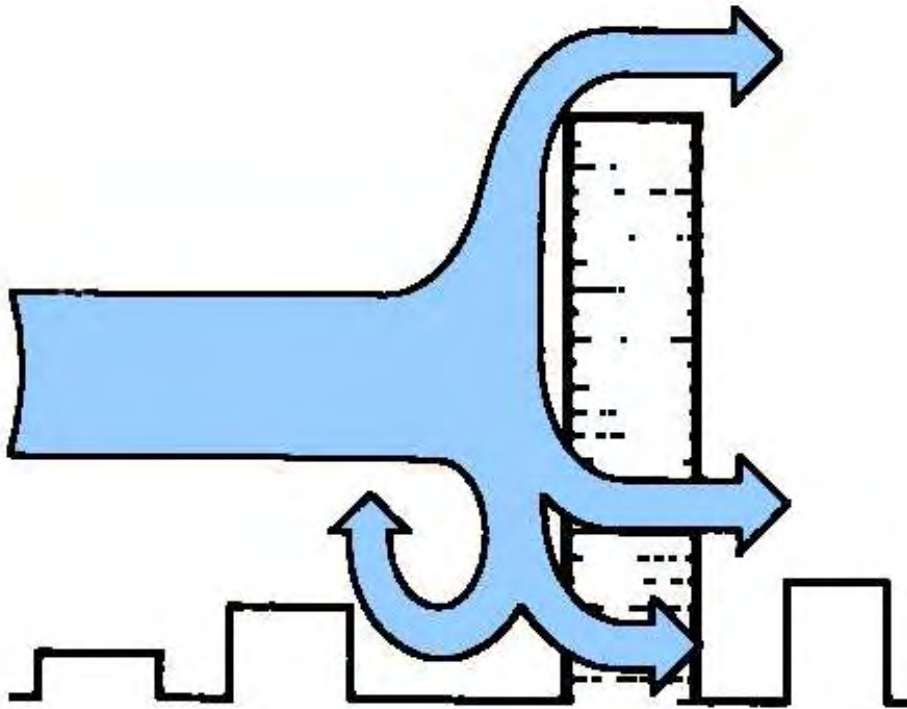
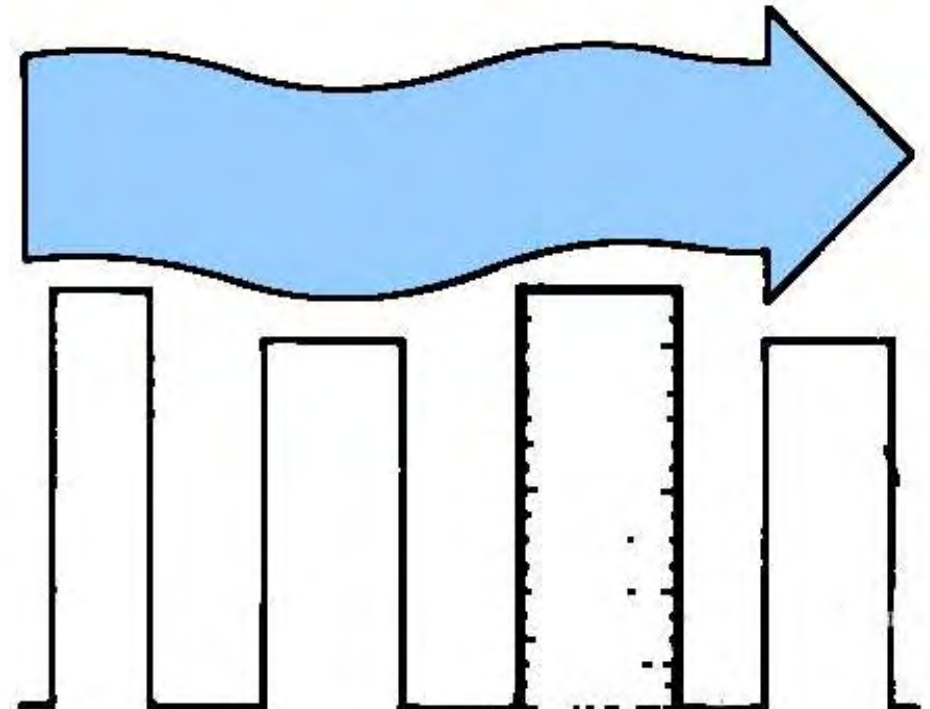


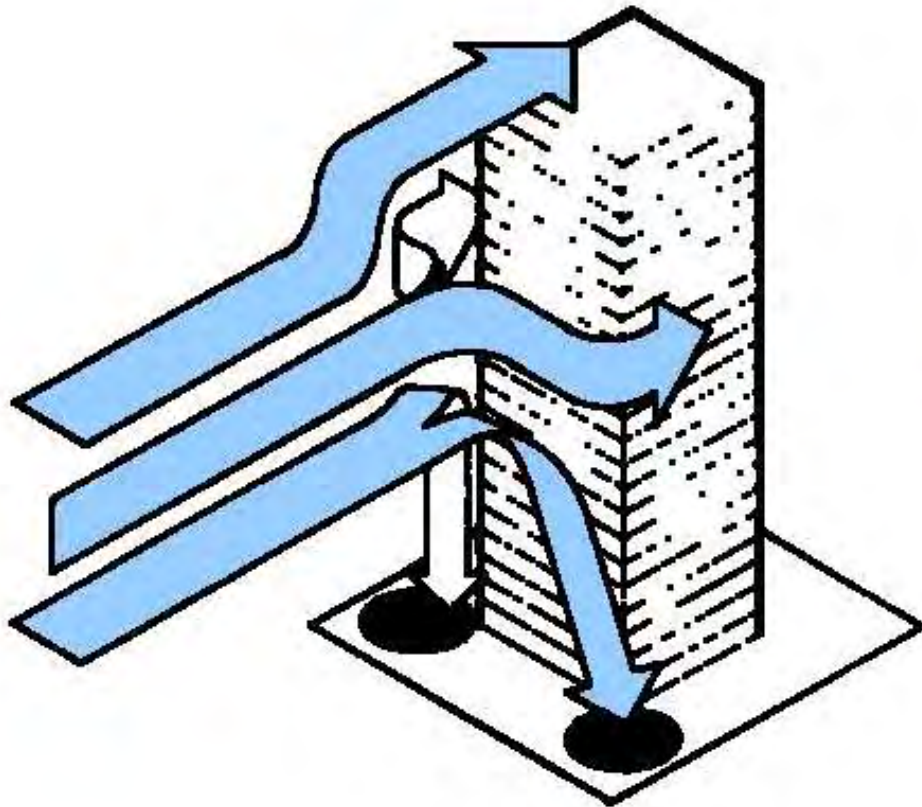
Figure 2.7 Vortex shedding phenomenon.



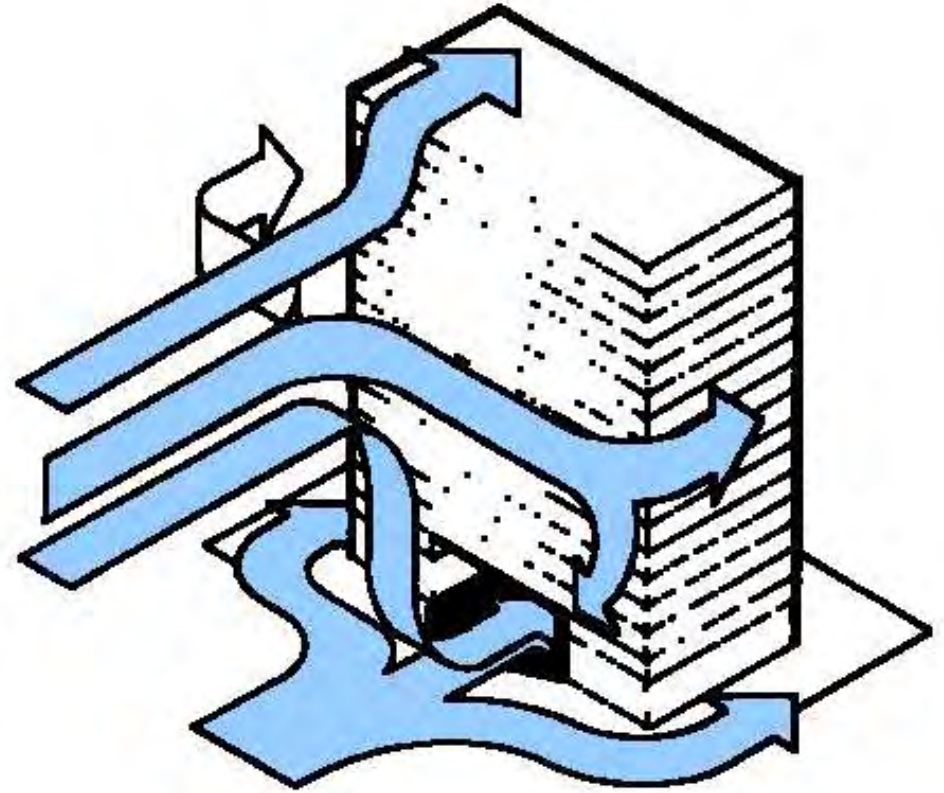
A building significantly taller than its surroundings can experience high wind loads and concentrate pedestrian level winds



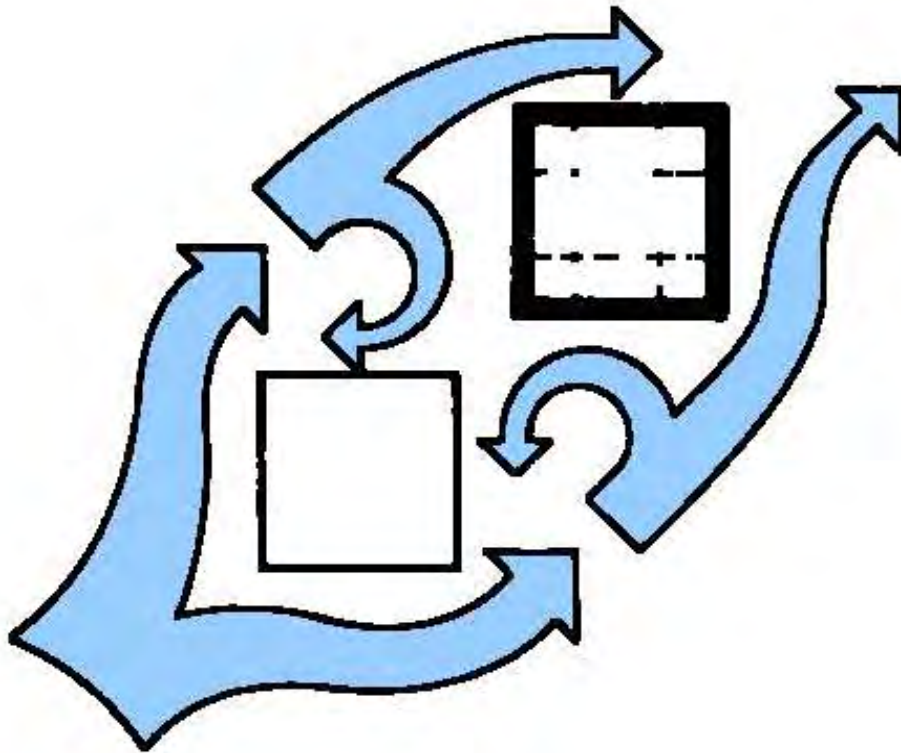
A building of similar height to its surroundings may be protected from large wind loads and concentrated pedestrian winds



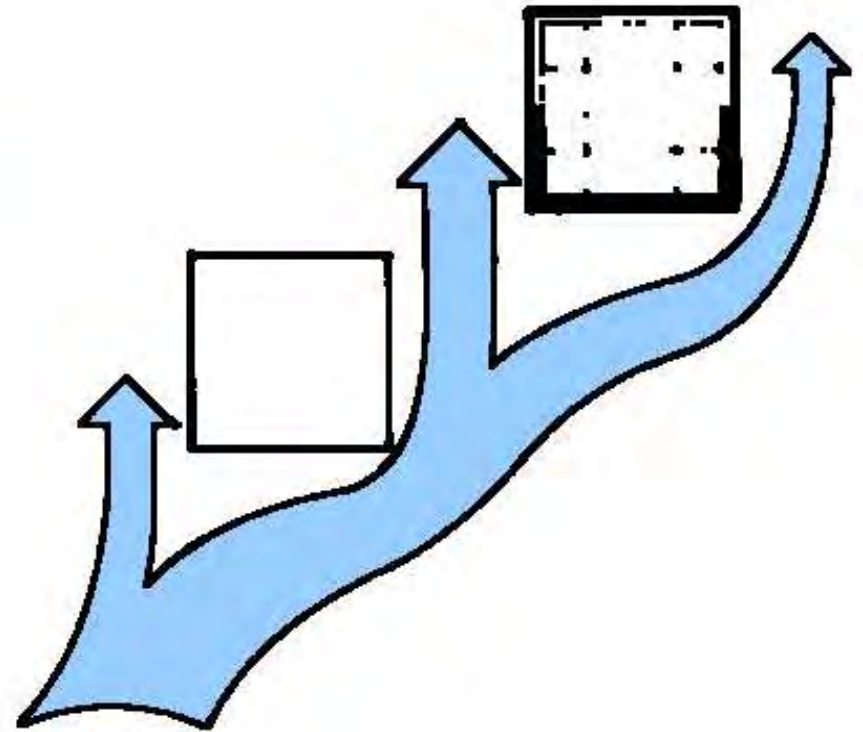
A tall building concentrates wind at its base



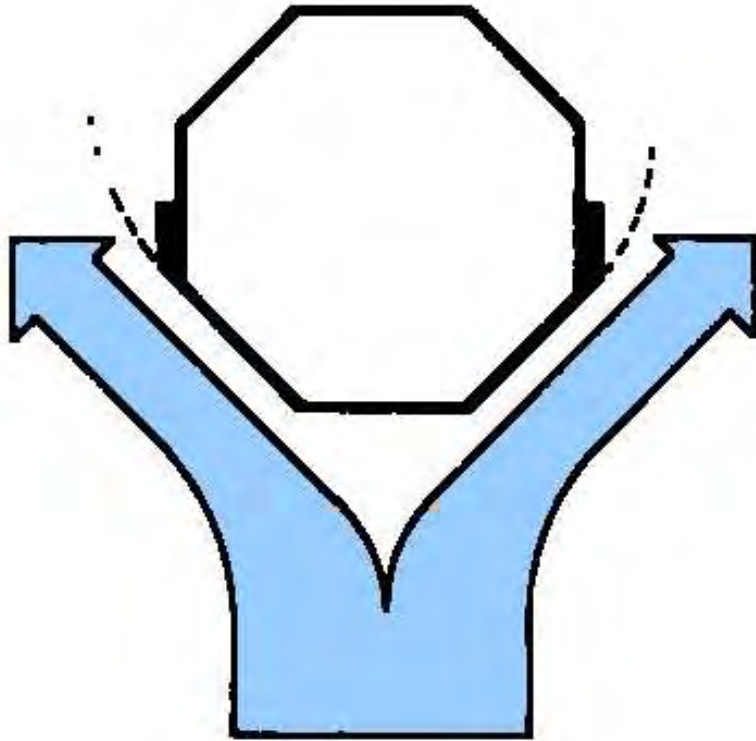
Openings through a building at the base may induce high velocities in the opening



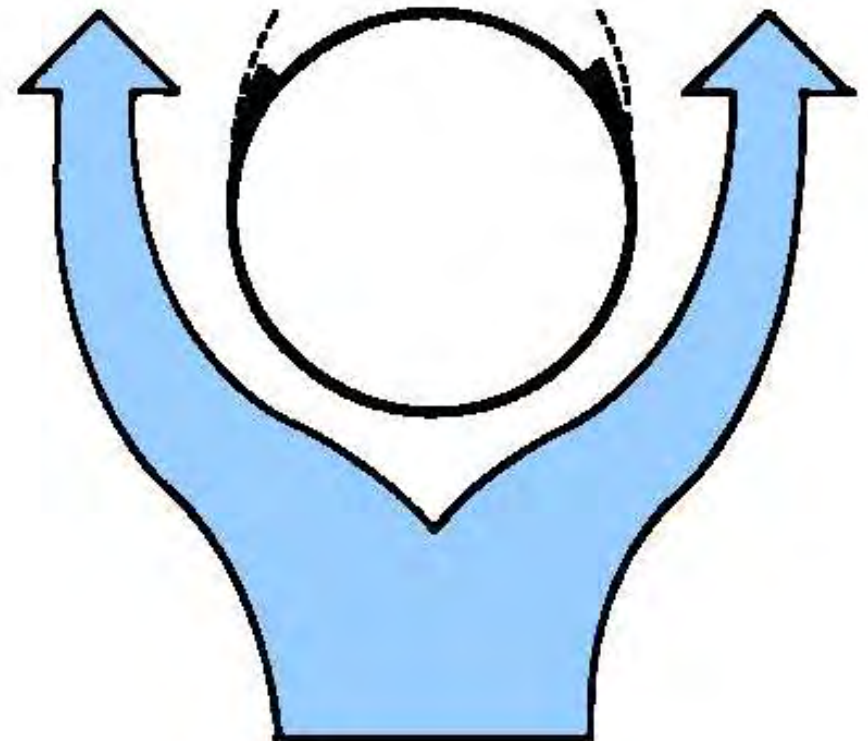
Adjacent building placement may protect from high winds reducing wind loads and pedestrian level winds



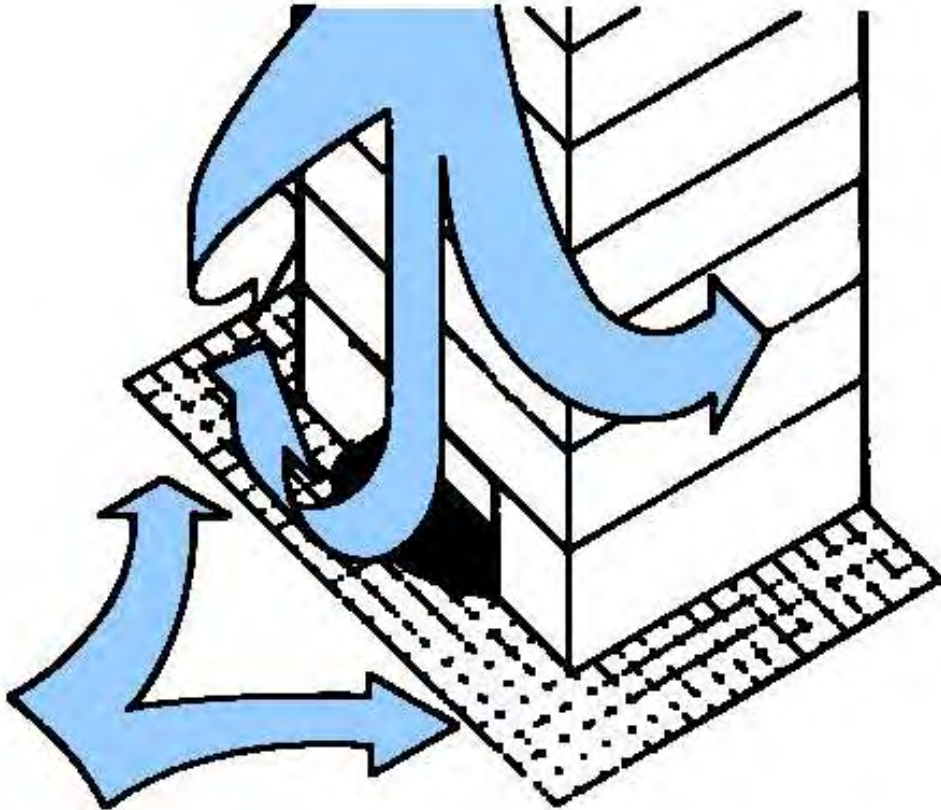
Adjacent building placement may deflect wind resulting in higher wind loads and pedestrian level winds



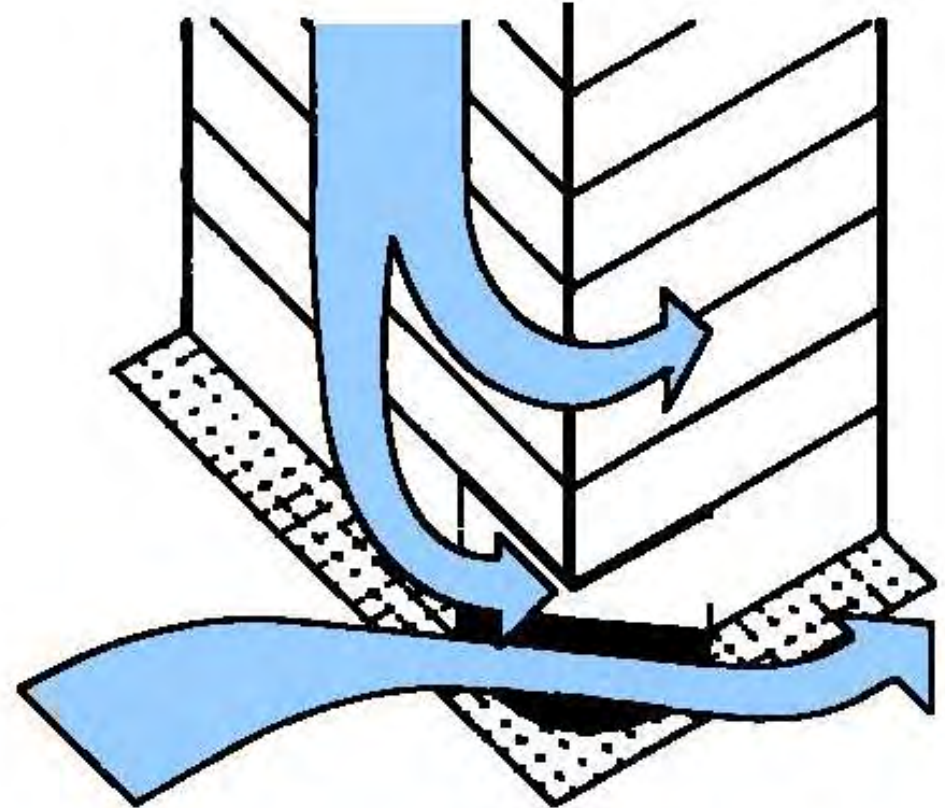
Multi-sided buildings may not permit full development of local pressures, frame loads or pedestrian level winds



Circular buildings may reduce frame loads and pedestrian level winds but increase local cladded loads at the point where the wind separates from the building



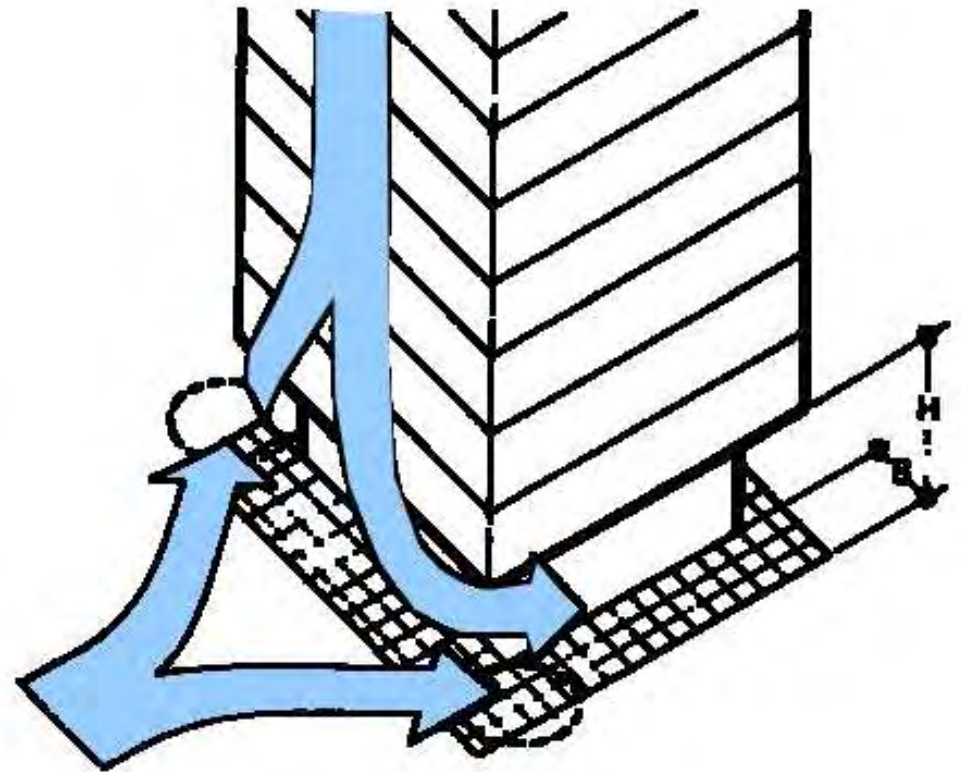
Recessed entry provides low winds at door locations



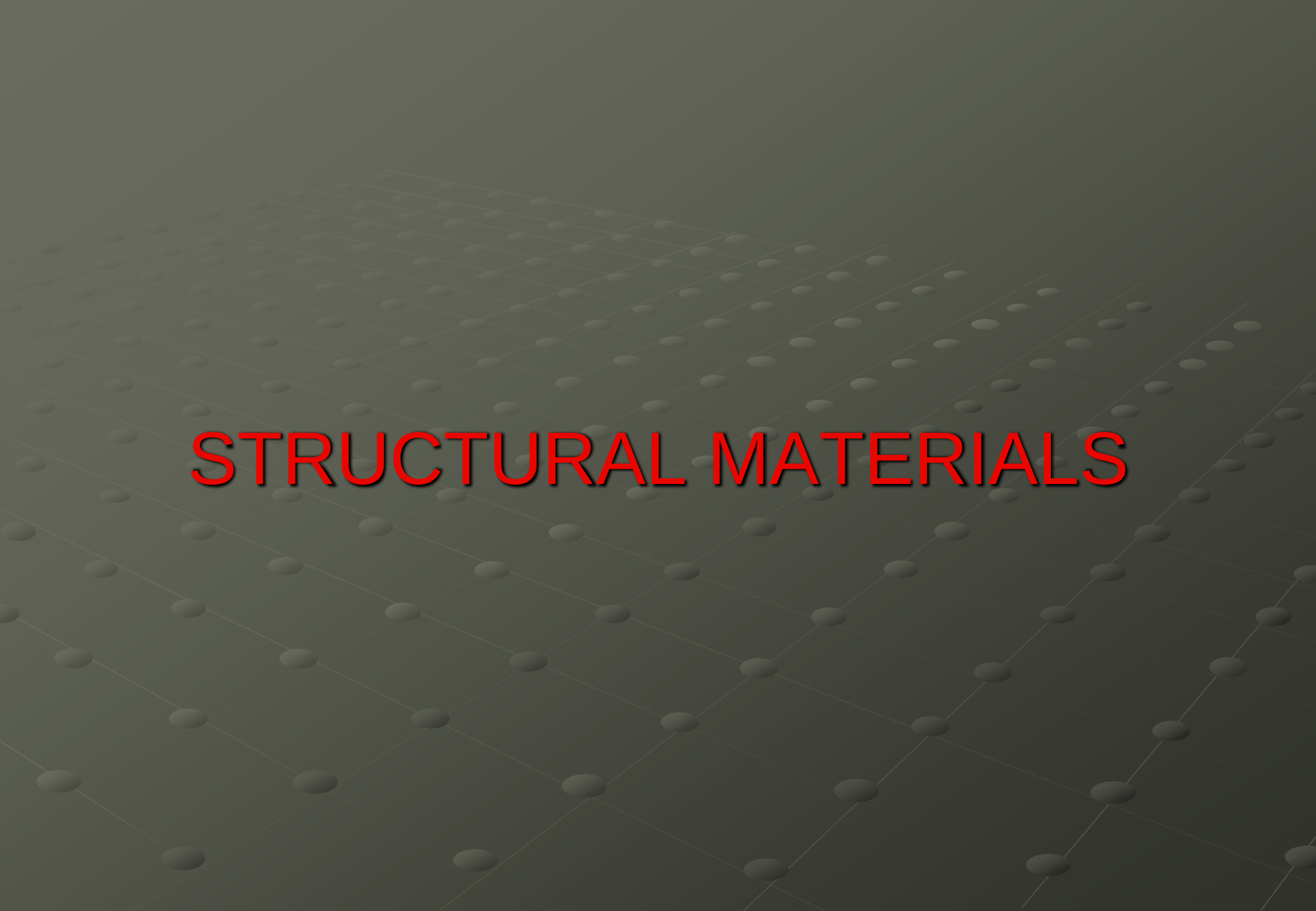
Corner entry may accentuate wind concentration at building corner



A low pedestal building concentrates wind on the roof not at the base



Setback (S) all around the building may improve or worsen wind concentration depending on S or H (height)



STRUCTURAL MATERIALS

STRUCTURAL FRAMES

● MATERIALS

- There are three main materials used for structural frames plus a number of alternatives



STEEL

STRUCTURAL FRAMES

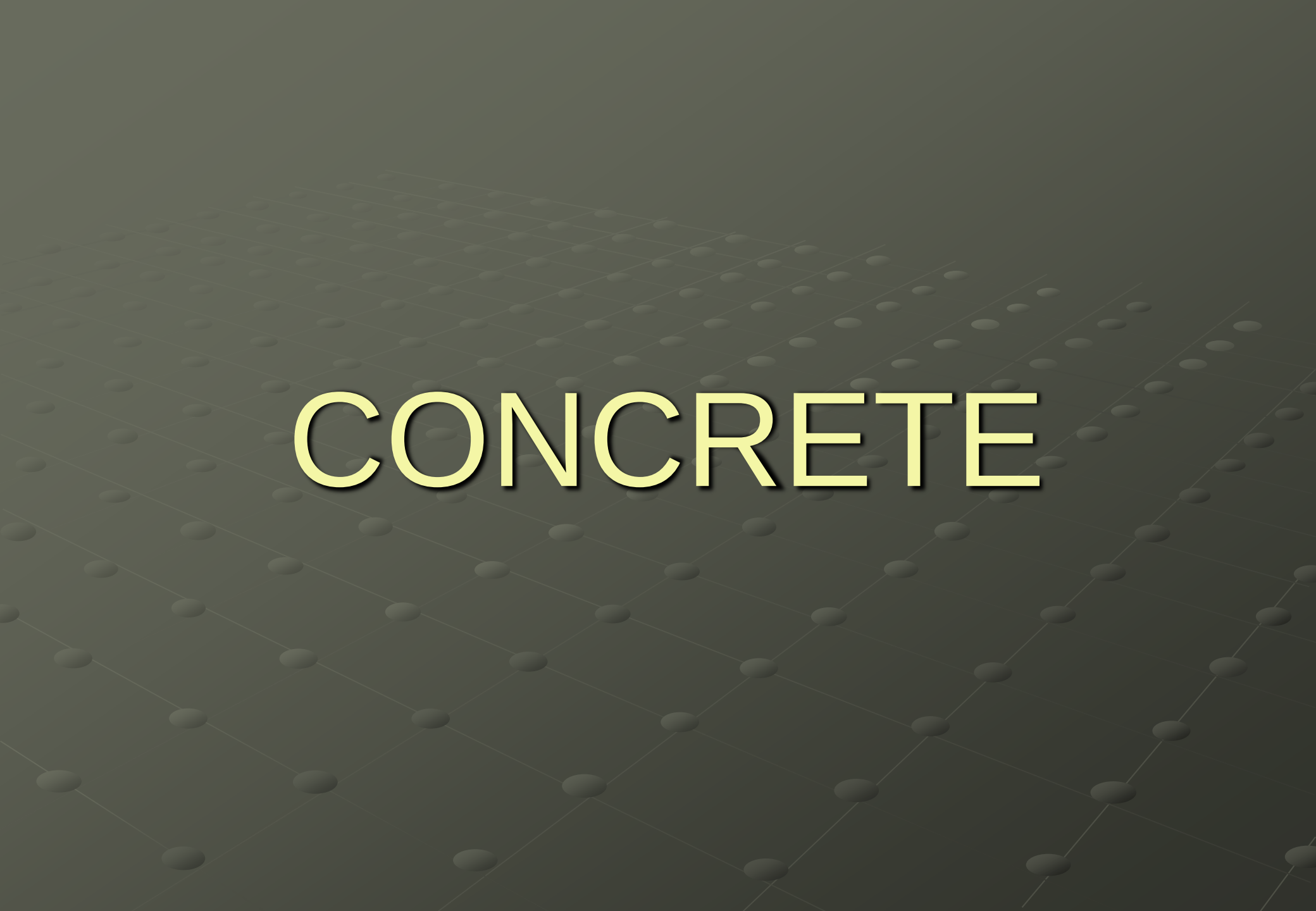
● STEEL – Advantages

- Flexible interiors possible
- Can be dismantled
- Can include a high level of recycled material
- Quick to erect
- Strong structural material
- Appropriate for large structures, spans
- Connected by welding or bolting
- Can be left exposed or treated if required
- Can be encased

STRUCTURAL FRAMES

● STEEL – Disadvantages

- Higher embodied energy
- Requires heavy duty site machinery
- Associated with pollution during production
- Requires the provision of fire protection in many instances



CONCRETE

STRUCTURAL FRAMES

● CONCRETE- Advantages

- Flexible interiors
- High thermal mass
- Concrete frames can be prefabricated or insitu
- Appropriate for large structures
- Good fire resistance properties.

STRUCTURAL FRAMES

● CONCRETE- Disadvantages

- Cement is high CO₂ emitter
- Difficult to recycle to same level of use (not downcycling)
- Varies in strength according to mix; stiffness is low; strength weight ratio low. To overcome these weaknesses it requires steel reinforcement.
- Heavy weight - an economic consideration in high-rise buildings due to implications on structure/foundation design

STRUCTURAL FRAMES

TIMBER - Advantages

- Flexible interior space
- Can be dismantled
- Quick to erect- connections between beam and columns are made with nails, bolts, dowels and cleats.
- Natural, can be supplied from sustainable managed forests
- Low embodied energy with good strength to weight ratio

The image features a dark gray background with a 3D grid of small, dark gray spheres. The spheres are arranged in a perspective view, creating a sense of depth. The word "TIMBER" is centered in the image in a bright green, bold, sans-serif font. The spheres are arranged in a grid that recedes into the distance, with the word "TIMBER" positioned in the middle ground.

TIMBER

STRUCTURAL FRAMES

TIMBER – Disadvantages

- Low thermal mass
- Limited to short spans, longer spans require composite beams e.g. glulam or masonite
- Timber will burn easily in the form of thin boards. However burns less readily in thicknesses greater than 150mm. Combustibility reduced by fire retardants.
- Wind bracing / resistance to racking distortion of the frame must be considered/ infill panels may be required.

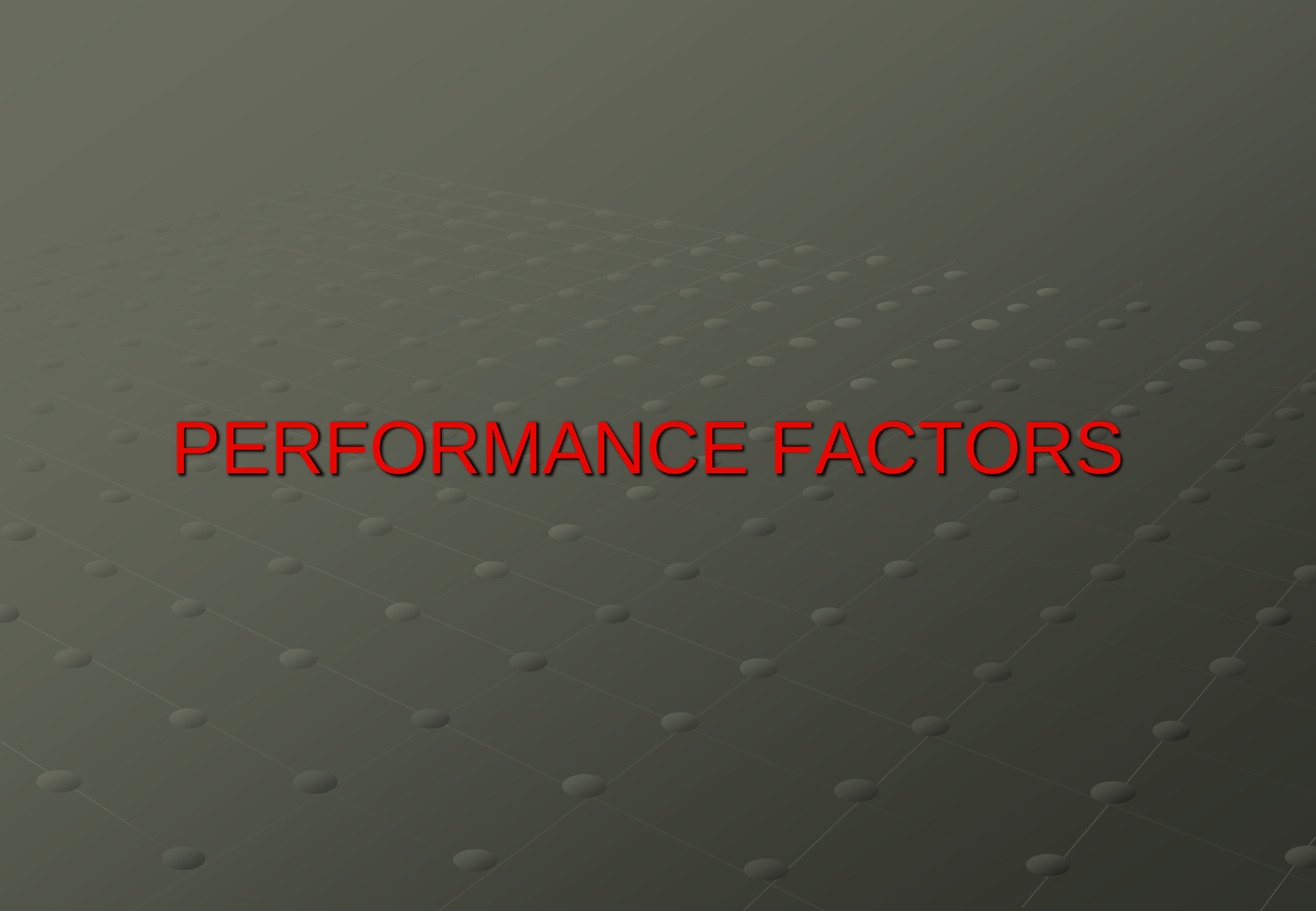
Glulam beams

Timber laminations glued together vertically or horizontally to form square or rectangular sections: more expensive; designed for larger spans and increased loads.



Reading List & further info

- **Architecture: Form, Space and Order**, Francis Ching 1995
- **Steel Buildings** BCSA publication 2003
- **Tall Building Structures: Analysis and Design** by Bryan Stafford-Smith and Amy Mina-Coull 1991
- **Materials, Structures and Standards: All Details Architects Need to Know But Can Never Find** by Julia McMorrough 2006

The background features a dark gray, isometric grid of small, light gray spheres. The spheres are arranged in a 3D perspective, receding into the distance, creating a sense of depth. The grid lines are faint and light gray, intersecting at the centers of the spheres.

PERFORMANCE FACTORS

DESIGNING A STRUCTURE

● Aesthetics

- Structure affects the design of a building and consequently its aesthetics
- The building design may want to make the structural system visually explicit (the structure can be more than just a response to technical problems)

● Feasibility

- The choice of structure will depend on the ability to use the system within the constructional and economic constraints

STRUCTURAL LOADS

- Dead loads- the constant load of the material and structure itself (dead loads are generally directed downwards due to gravity) and of other materials permanent in contact with the structure (e.g. soil pressure on foundation walls).
- Imposed loads- the 'live' or temporary loads of people and equipment as well as snow or wind loads. The loads attributed to users and equipment will vary according to the use of the building: how many people and machinery are anticipated. (E.g. residential loading can be taken as 1.5KN/sq m and office storage areas 5KN/sq m).

STRUCTURAL LOADS

- Thermal loads – the loads due to expansion and contraction of elements as a result of temperature changes.
- Dynamic load – cyclical loads that may cause the structure to oscillate or vibrate. (e.g. vibrations from trains etc., gusts of wind).

What are the effects of structural loads on structures?

- The main task of a structure is to transfer loads safely to the ground without affecting the structure itself. If the structure is not designed adequately a number of problems can occur. Some of these are described below.