Structural Mechanics (1)

Week No-01

What is this class?

- Introduction to Structural Analysis
- Loads on Structures
- Deflection in Determinate Structures
- Indeterminate Structures (Force Method)

Introduction to Structural Analysis

- Structural analysis is the prediction of the performance of a given structure under prescribed loads and/or other external effects, such as support movements, temperature changes and fabrication errors.
- The structure performance is measured by:
  - Displacements (deflections & rotations) & strains, and
  - Stresses & stress resultants (internal forces)
- The objective of the course is to present the methods for the analysis of structures in static equilibrium.

Historical Background

- In 1650s "engineers" began applying the knowledge of Mechanics (Math & Phy) in designing structures.
- Earlier structures were designed by trial and error and using past experience.

During his lifetime Leonardo was valued as an engineer. When he fled to Venice in 1499 he found employment as an engineer and devised a system of moveable barricades to protect the city from attack. He also had a scheme for diverting the flow of the Arno River.
In 1502, Leonardo produced a drawing of a single span 720-foot (220 m) bridge as part of a civil engineering project for Ottoman Sultan Beyazid II of Constantinople. The bridge was intended to span an inlet at the mouth of the Bosporus known as the Golden Horn. Beyazid did not pursue the project because he believed that such a construction was impossible. Leonardo's vision was resurrected in 2001 when a smaller bridge based on his design was constructed in Norway.

Historical Background

Galileo Galilei (1564–1642) is generally considered to be the originator of the theory of structures. In his book entitled Two New Sciences, which was published in 1638, Galileo analyzed the failure of some simple structures, including cantilever beams. Although Galileo's predictions of strengths of beams were only approximate, his work laid the foundation for future developments in the theory of structures and ushered in a new era of structural engineering, in which the analytical principles of mechanics and strength of materials would have a major influence on the design of structures.

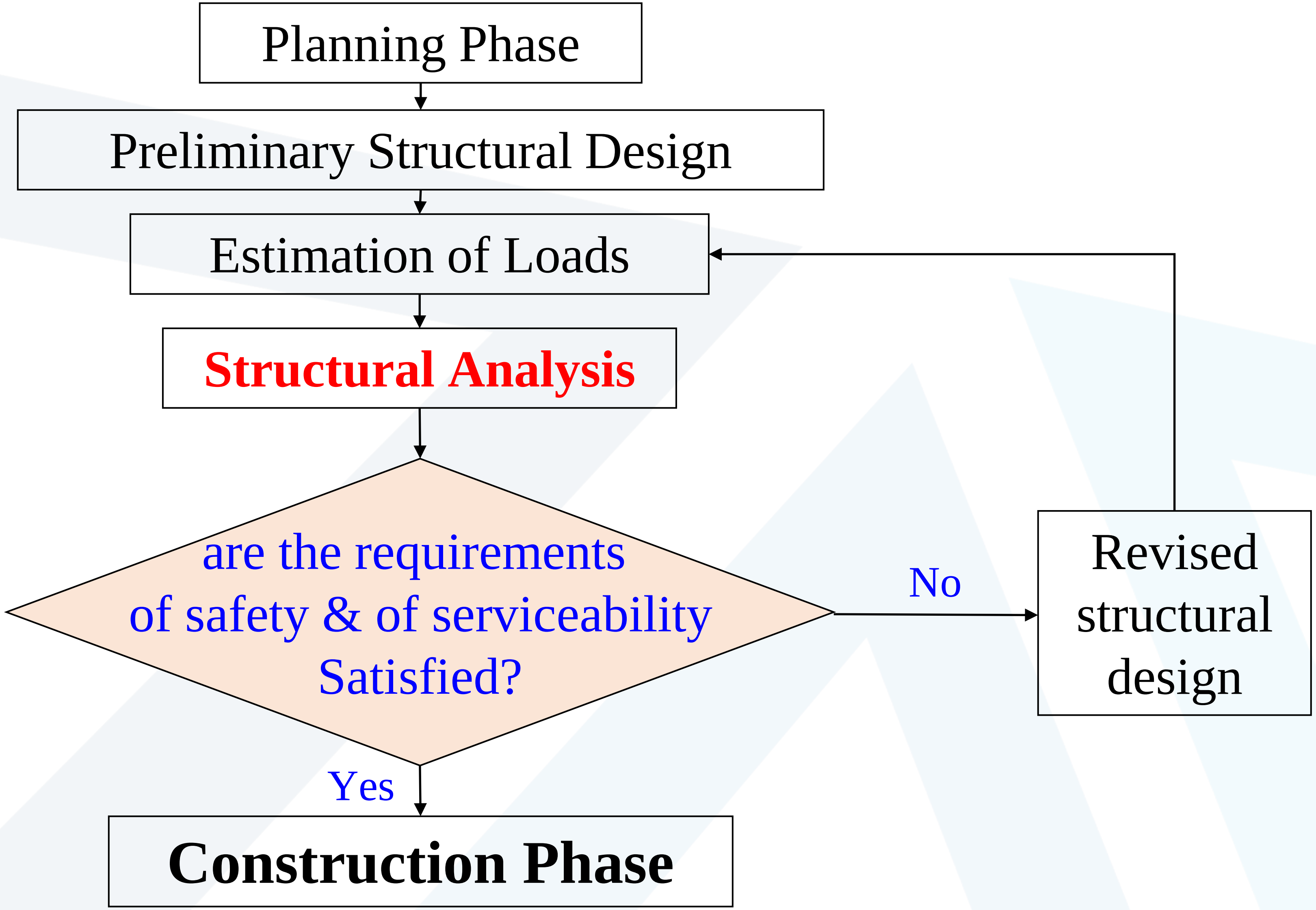
Among the notable investigators of that period were Robert Hooke (1635–1703), who developed the law of linear relationships between the force and deformation of materials (Hooke's law); Sir Isaac Newton (1642–1727), who formulated the laws of motion and developed calculus; John Bernoulli (1667–1748), who formulated the principle of virtual work; Leonhard Euler (1707–1783), who developed the theory of buckling of columns.

Historical Background

C.A. de Coulomb (1736–1806), who presented the analysis of bending of elastic beams.
In 1826 L. M. Navier (1785–1836) published a treatise on elastic behavior of structures, which is considered to be the first textbook on the modern theory of strength of materials. B. P. Clapeyron (1799–1864), who formulated the three-moment equation for the analysis of continuous beams; J. C. Maxwell (1831–1879), who presented the method of consistent deformations and the law of reciprocal deflections; Otto Mohr (1835–1918), who developed the conjugate-beam method for calculation of deflections and Mohr's circles of stress and strain; Alberto Castigliano (1847–1884), who formulated the theorem of least work; C. E. Greene (1842–1903), who developed the moment-area method; H. Muller-Breslau (1851–1925), who presented a principle for constructing influence lines; G. A. Maney (1888–1947), who developed the slope-deflection method, which is considered to be the precursor of the matrix stiffness method; and Hardy Cross (1885–1959), who developed the moment-distribution method in 1924.

John Smeaton (1724–1792) is the first to described himself as a 'civil engineer' in 1768. In doing so, he identified a new profession that was distinct from that of the military engineers.

Role of Structural Analysis in Structural Engineering Project



Classification Of Structures

Classification is not unique and not perfect

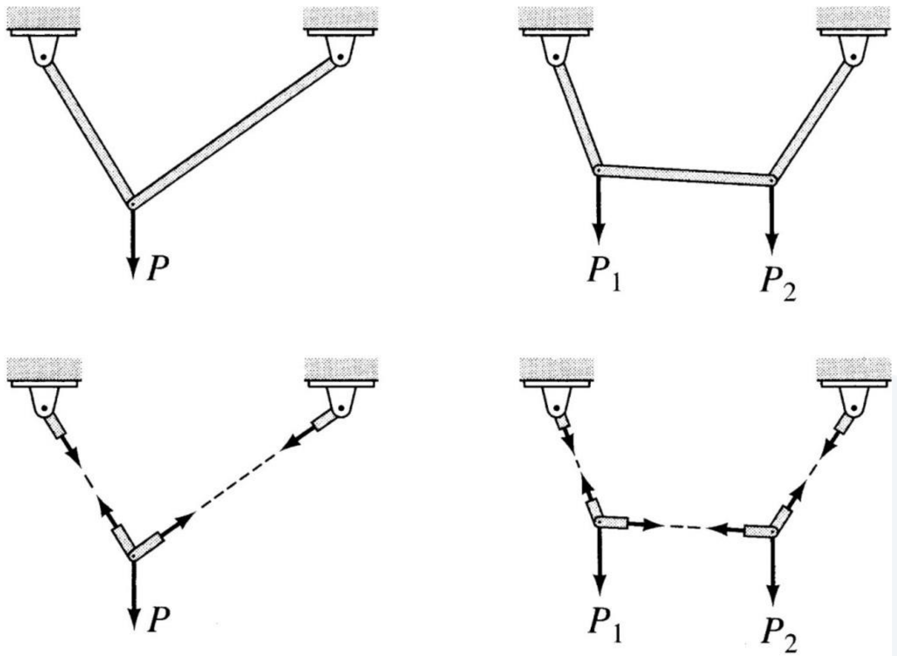
Classification of Structures According to State of Stress

1. Tension Structures

Classification Of Structures

Classification is not unique and not perfect

1-Tension Structures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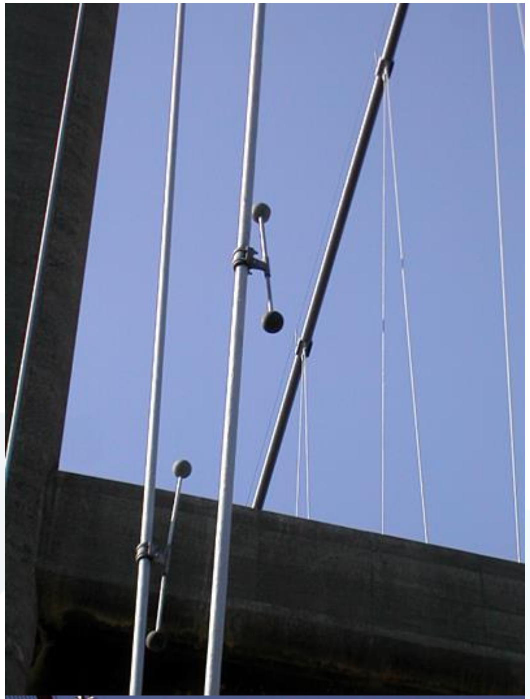
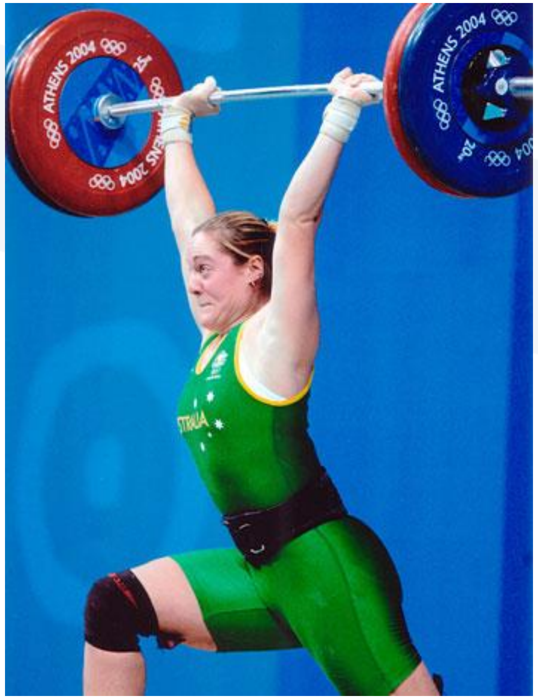
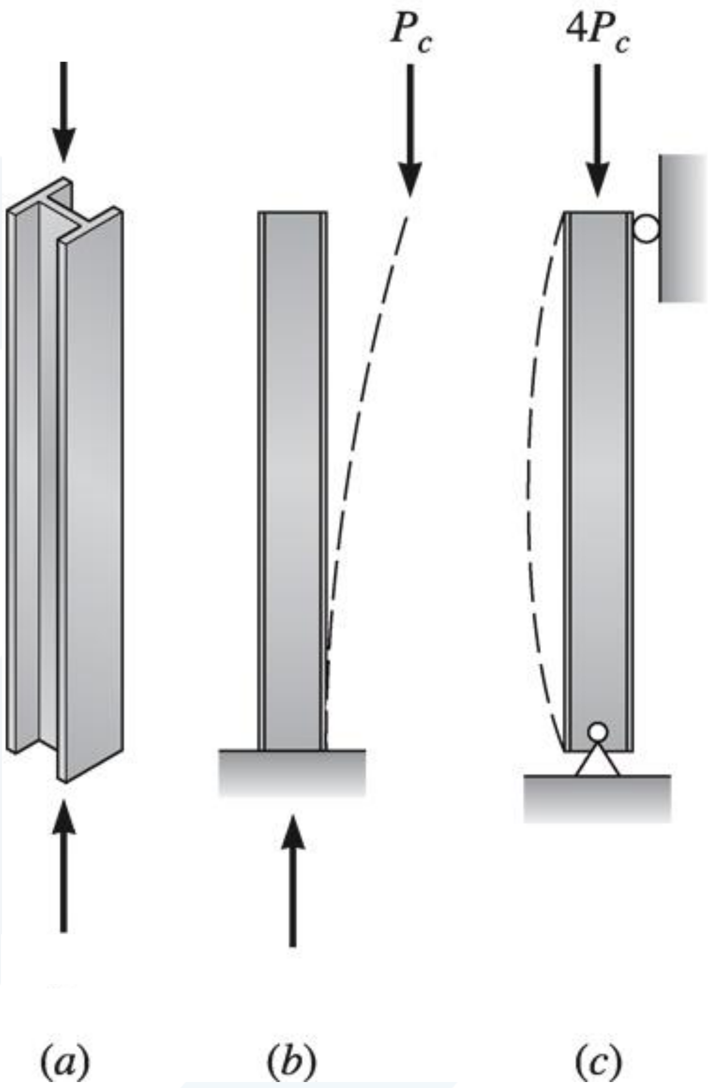
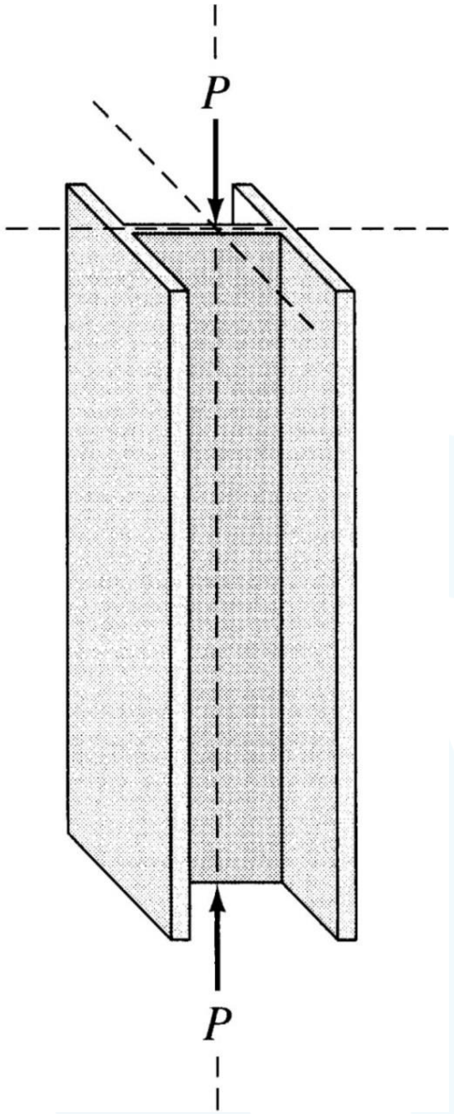


Classification Of Structures

2-Compression Structures



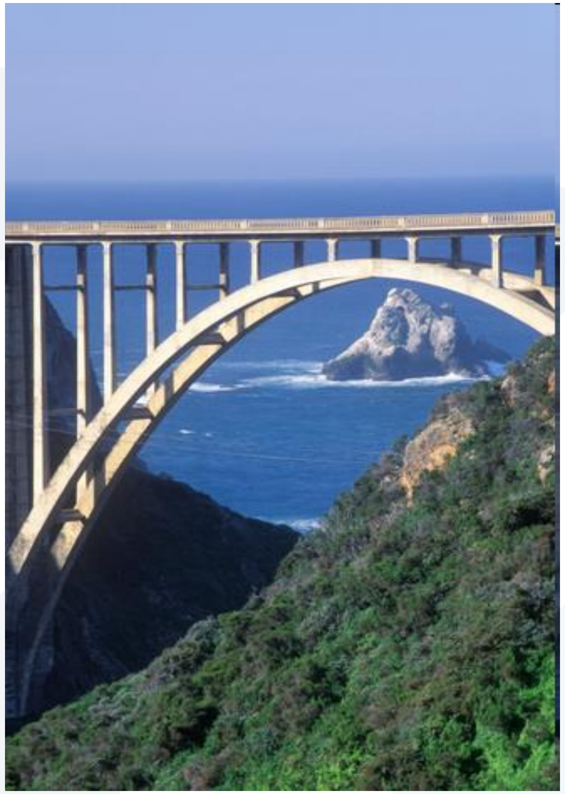




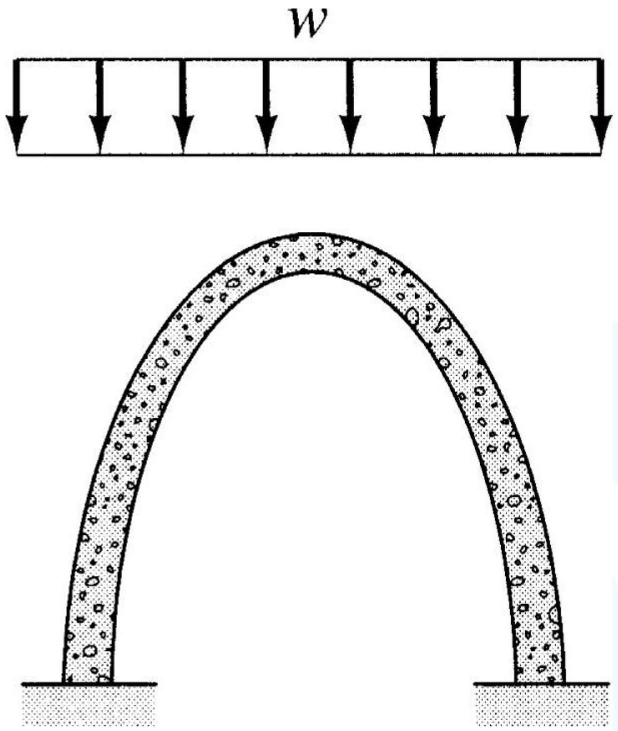
Classification Of Structures

2-Compression Structures

Wanxian Bridge, China.
Span ≈ 400m



Bixby Bridge California
Span ≈ 200m



A proper shape eliminates tension

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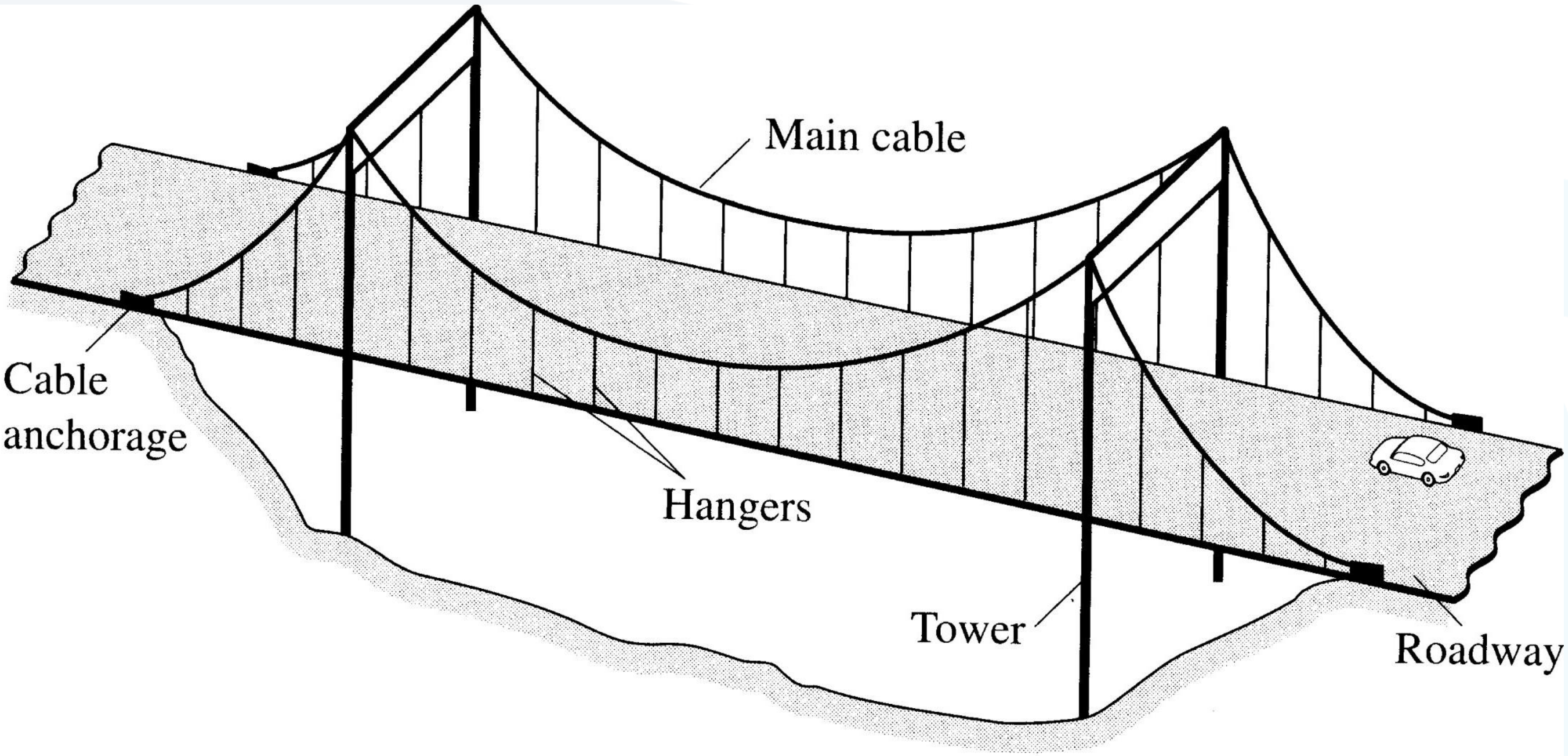
Classification Of Structures

Combination of tension members with Compression members in the same Structure

Suspended Bridges



Classification Of Structures

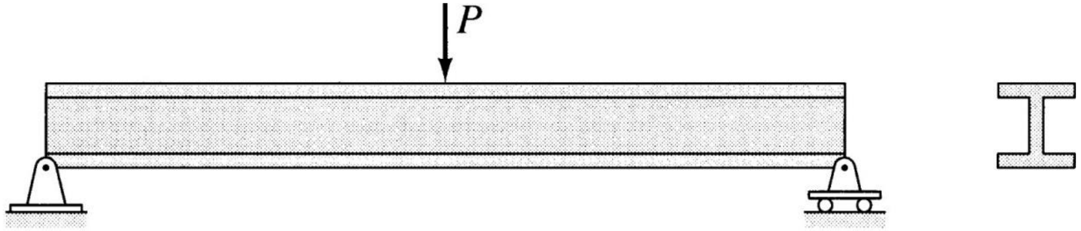
Combination of tension members with Compression members in the same Structure

Trusses

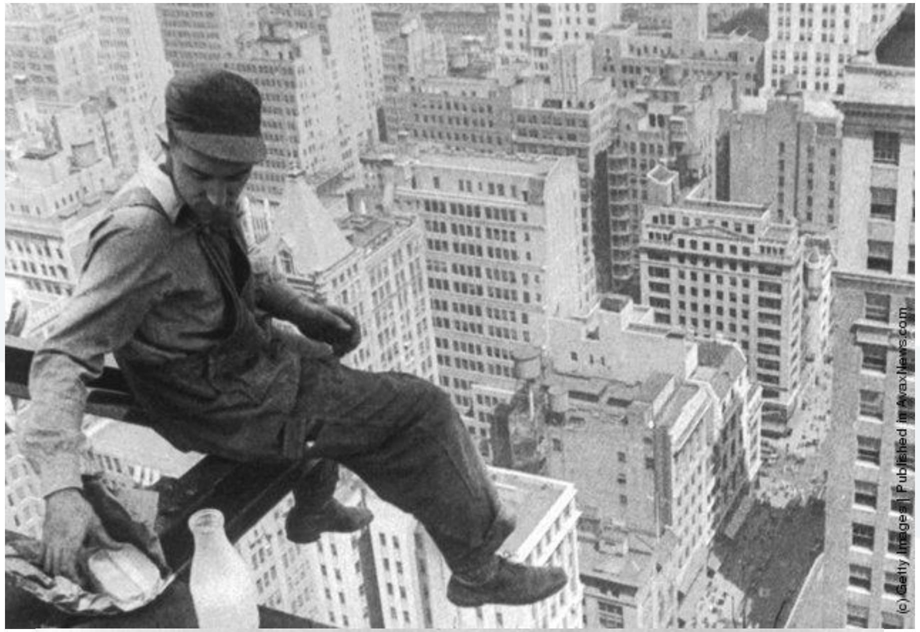
Trusses are very efficient structures

The ratio of the self weight to the load bearing capacity, is very small

Classification Of Structures



1. Bending Structures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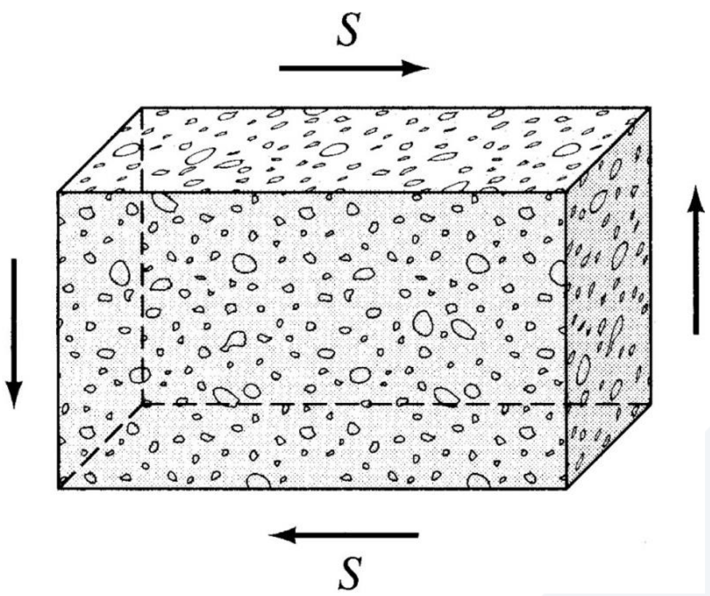
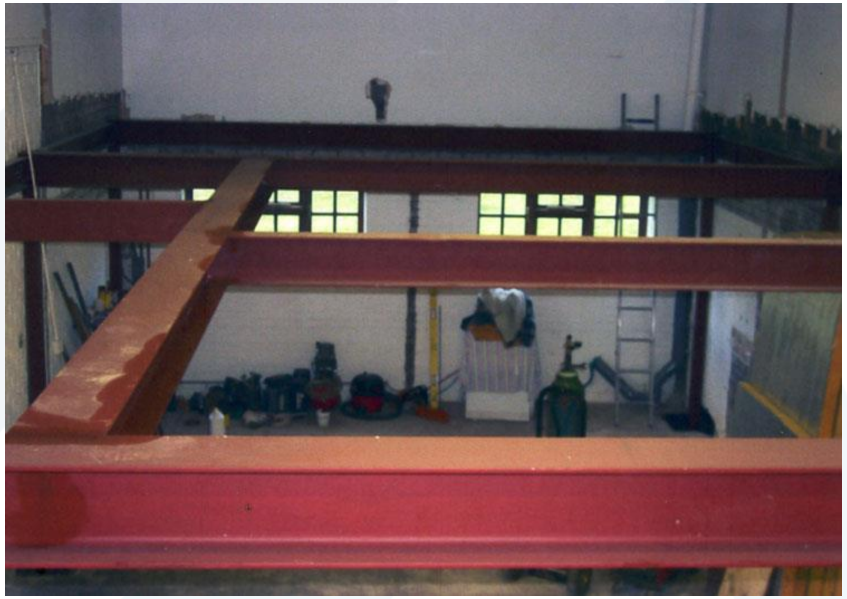
4- Shear Structures



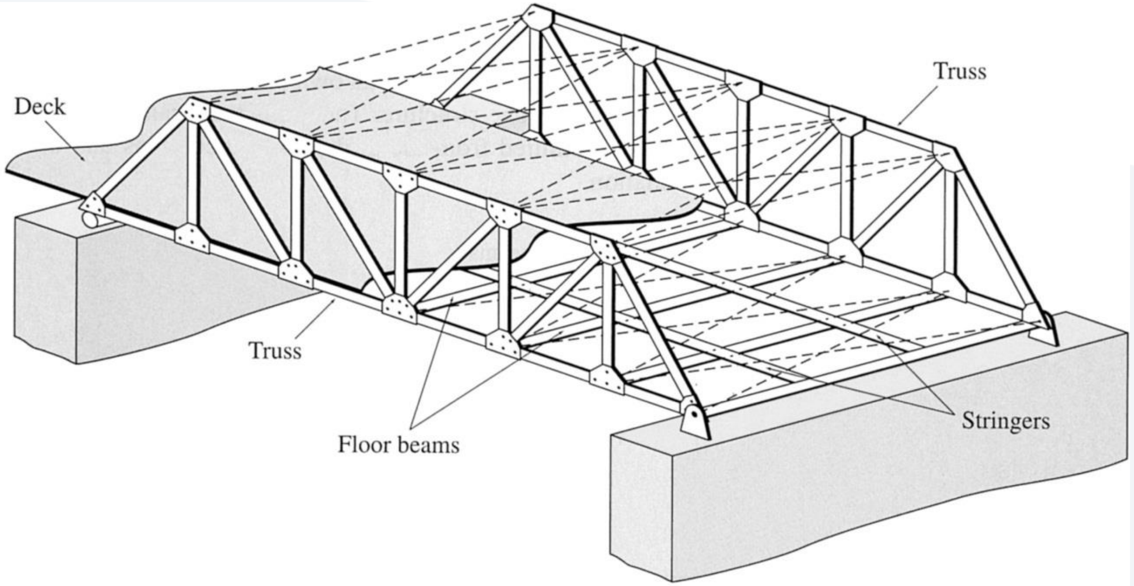
Loads on Structures

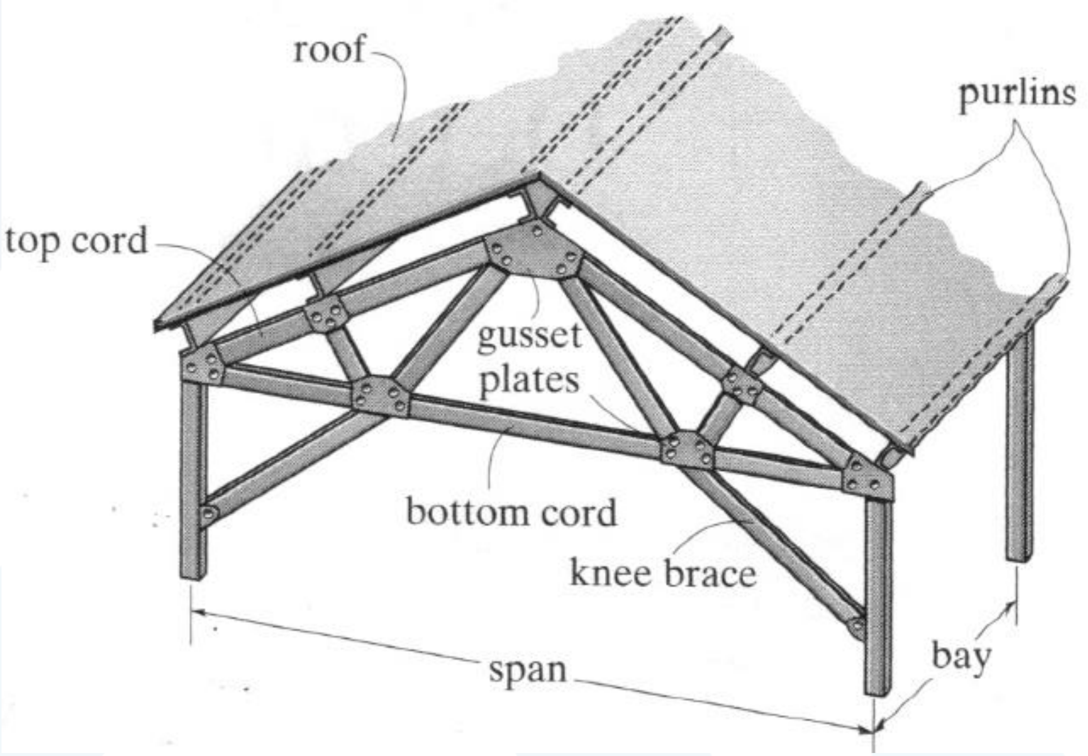
The main beam (or the girder) resting on a column or on basement walls & supporting all the other secondary beams (or the joists), which at their turn are support the slab.



The top surfaces of the main beams and of the secondary ones are at the same level. So, they are all supporting the slab directly

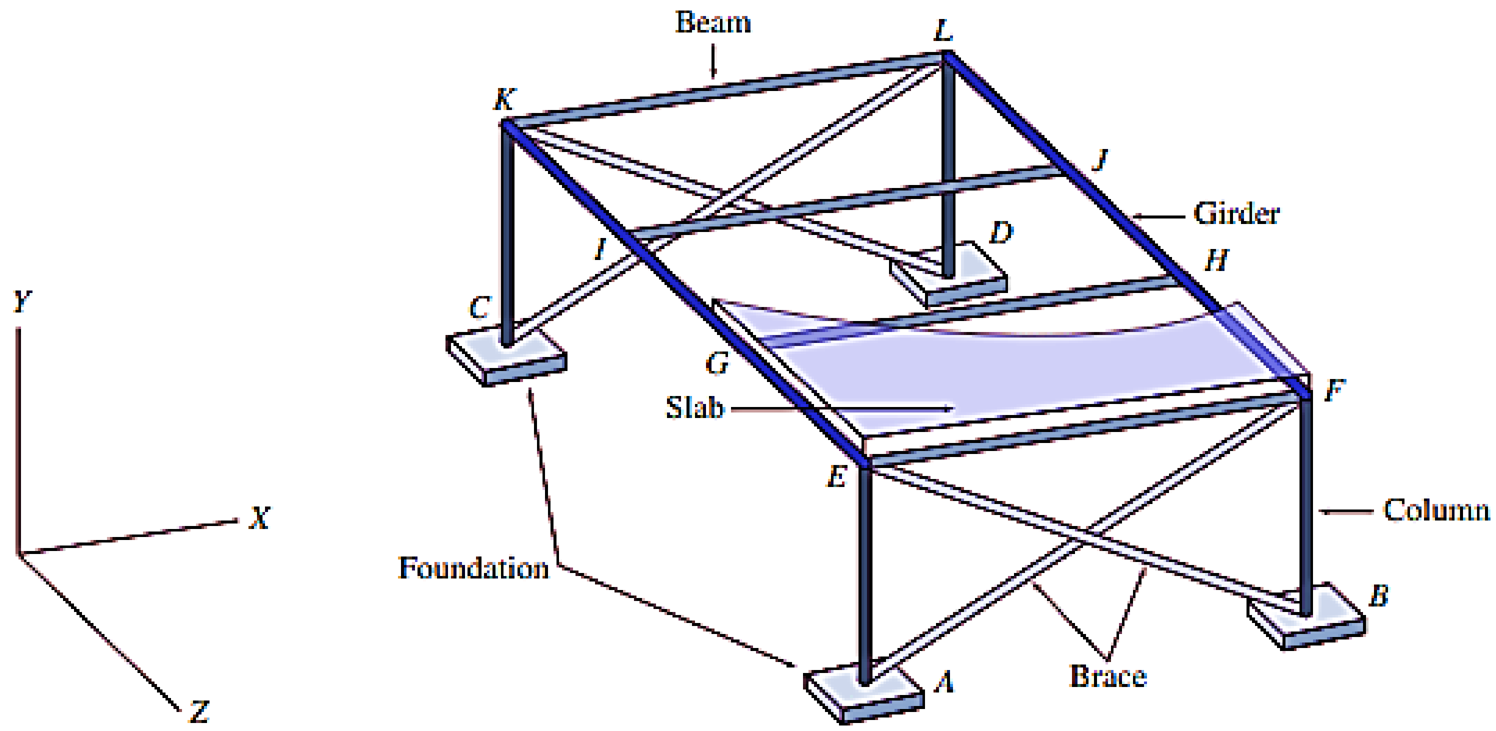
Loads on Structures





Loads on Structures

Structural Systems for Transmitting Loads



(a) Structural System for a Single-Story Building

Loads on Structures

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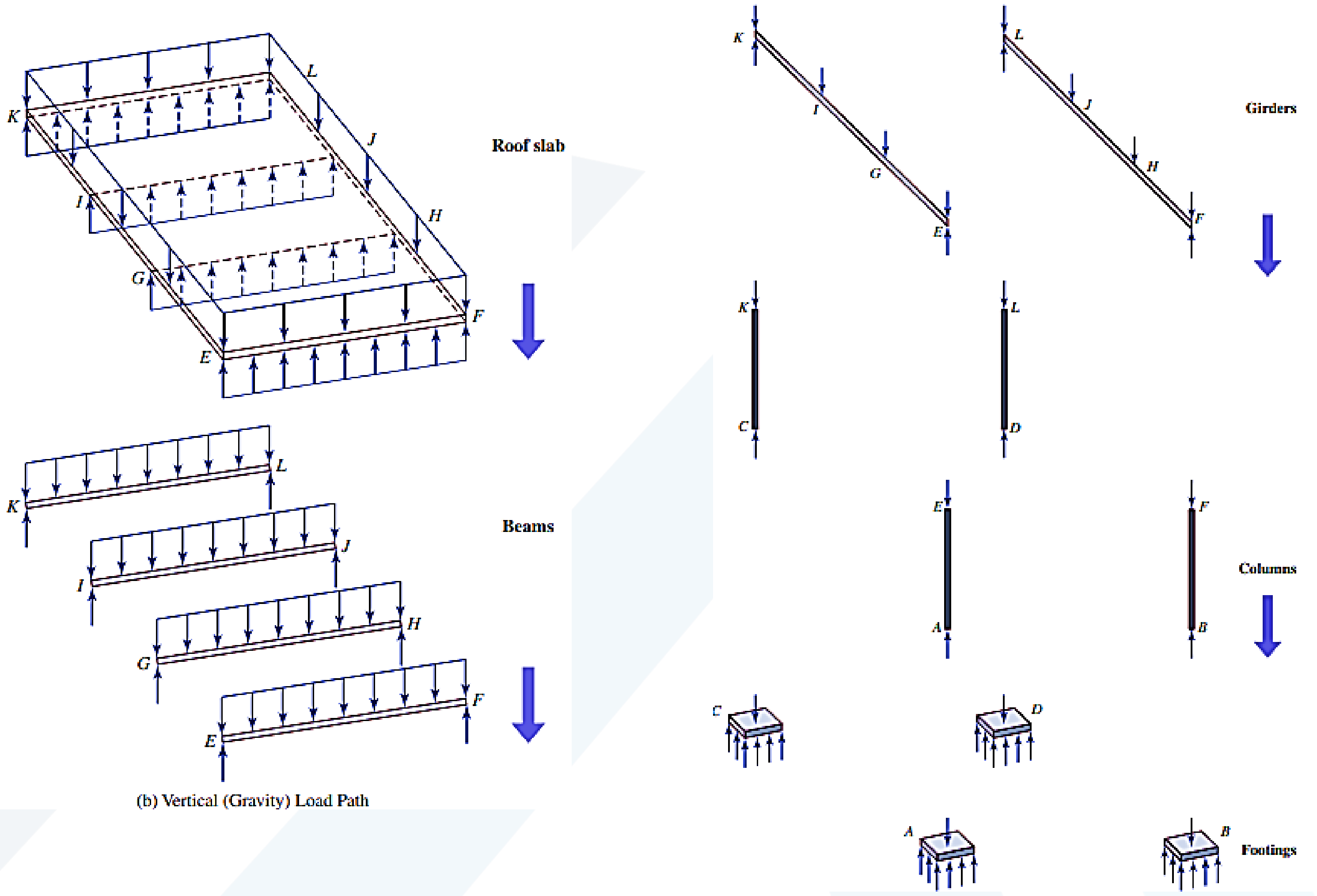
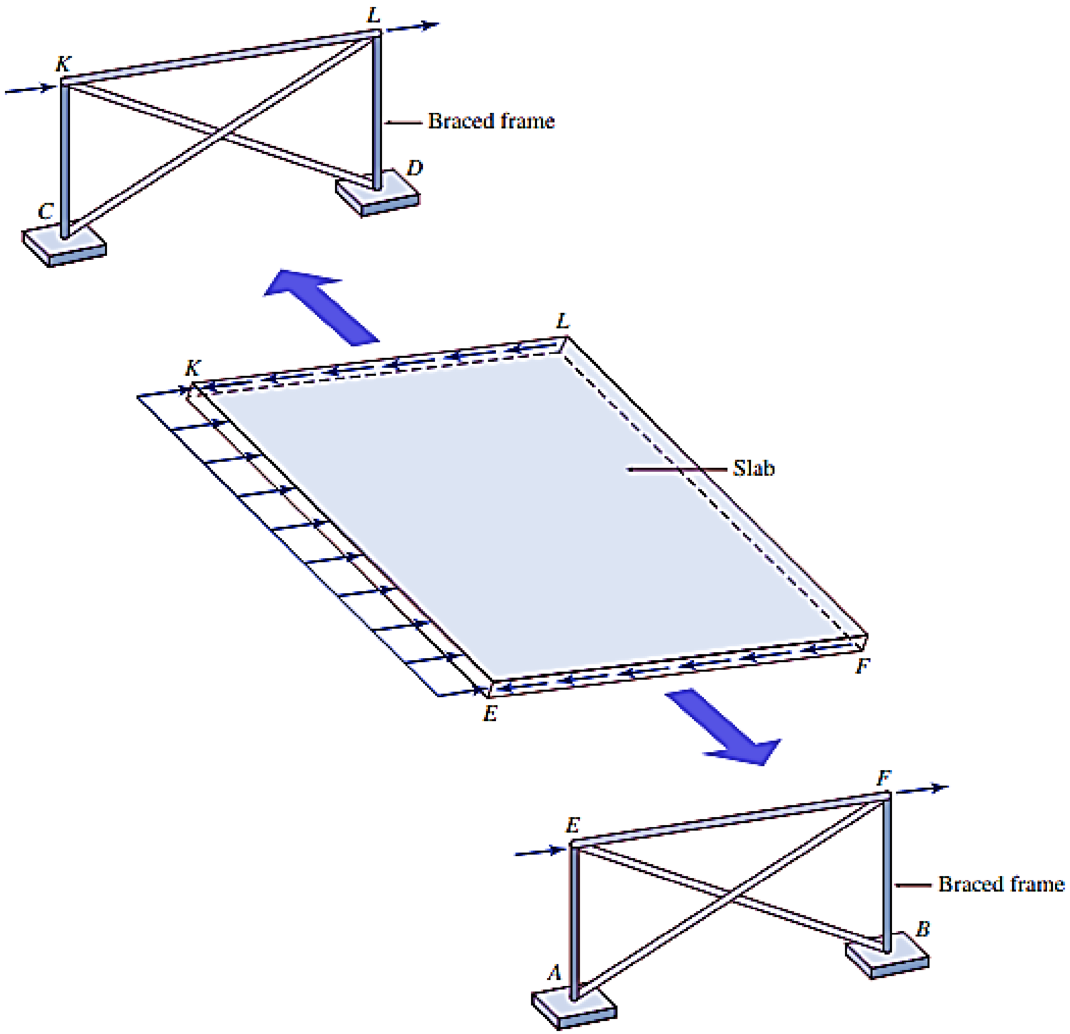
Load Path: A term used to describe how a load acting on the building (or bridge) is transmitted through the various members of the structural system to the ground.



(b) Vertical (Gravity) Load Path

Loads on Structures



(c) Horizontal (Lateral) Load Path

Loads on Structures

Multistory Building with Braced Frames to Transmit Lateral Loads Due to Wind and Earthquakes

This Steel Frame Building Uses Masonry Shafts for Elevators and Stairs to Resist Lateral Loads Due to Wind and Earthquakes

Loads on Structures

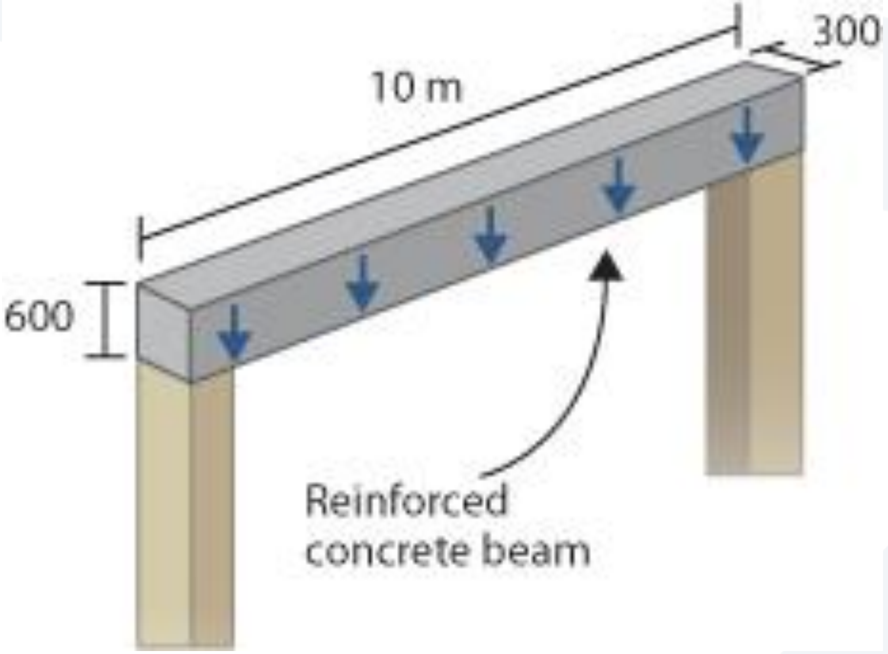
Dead Loads

Dead Loads are gravity loads of constant magnitudes and fixed positions that act permanently on the structure. Such loads consist of the weights of the structural system itself and of all other material and equipment permanently attached to the structural system.

Unit Weights of Construction Materials	
Materials	**Unit Weight [kN/m^3]**
Aluminum	**26**
Brick	**19**
Concrete, reinforced	**24**
Structural steel	**77**
Wood	**≈ 6**

Loads on Structures

Dead Loads



Volume of the beam: 10.0 x 0.6 x 0.3 = 1.8 m^3

Unit weight of reinforced concrete = 24 kN/m^3

Therefore, dead load on the beam = volume x unit weight

= 1.8 m^3 x 24 kN/m^3

= 43.2 kN

It is distributed uniformly with intensity: 43.2/10=4.32 kN/m

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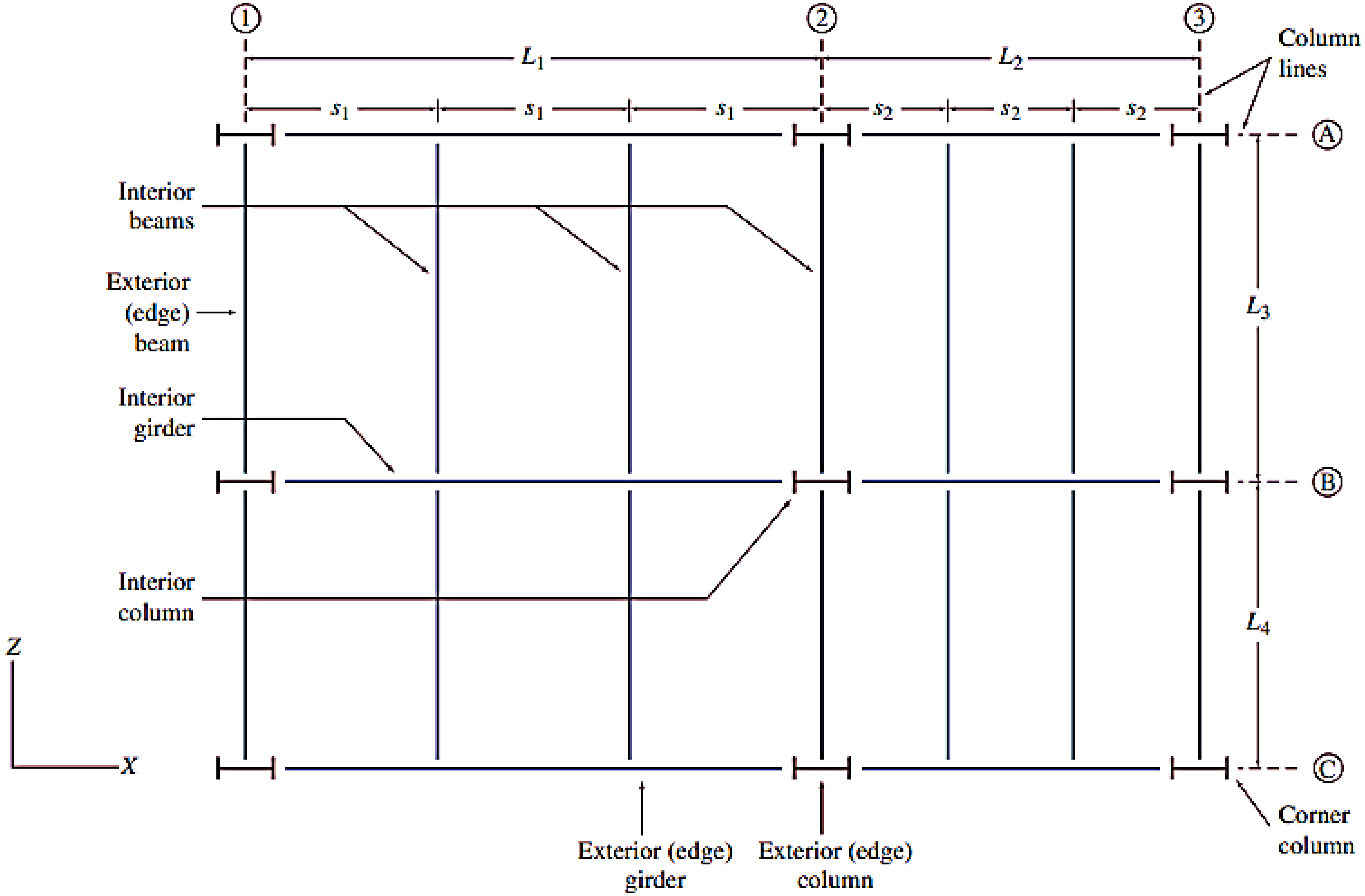
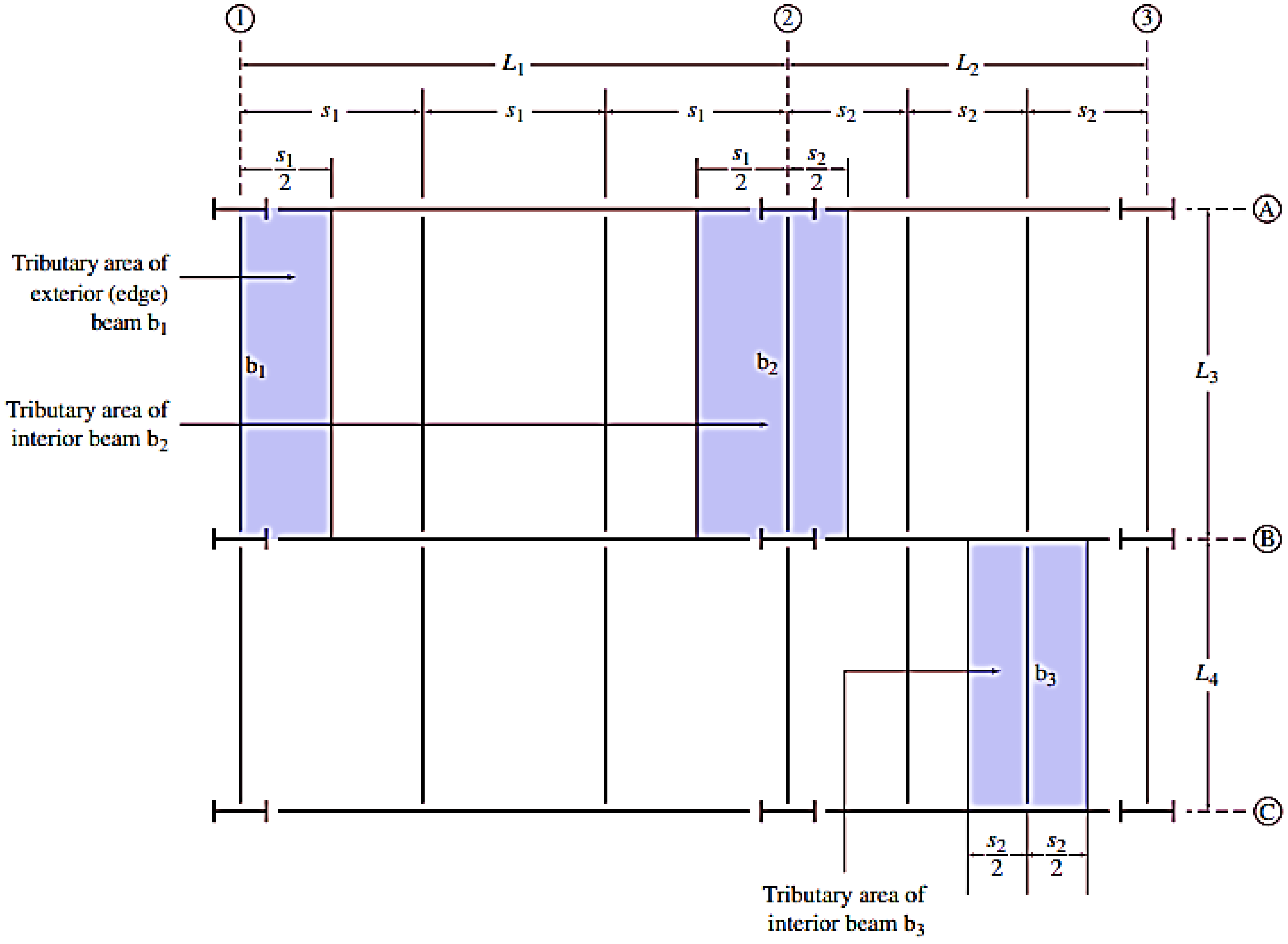
Loads on Structures



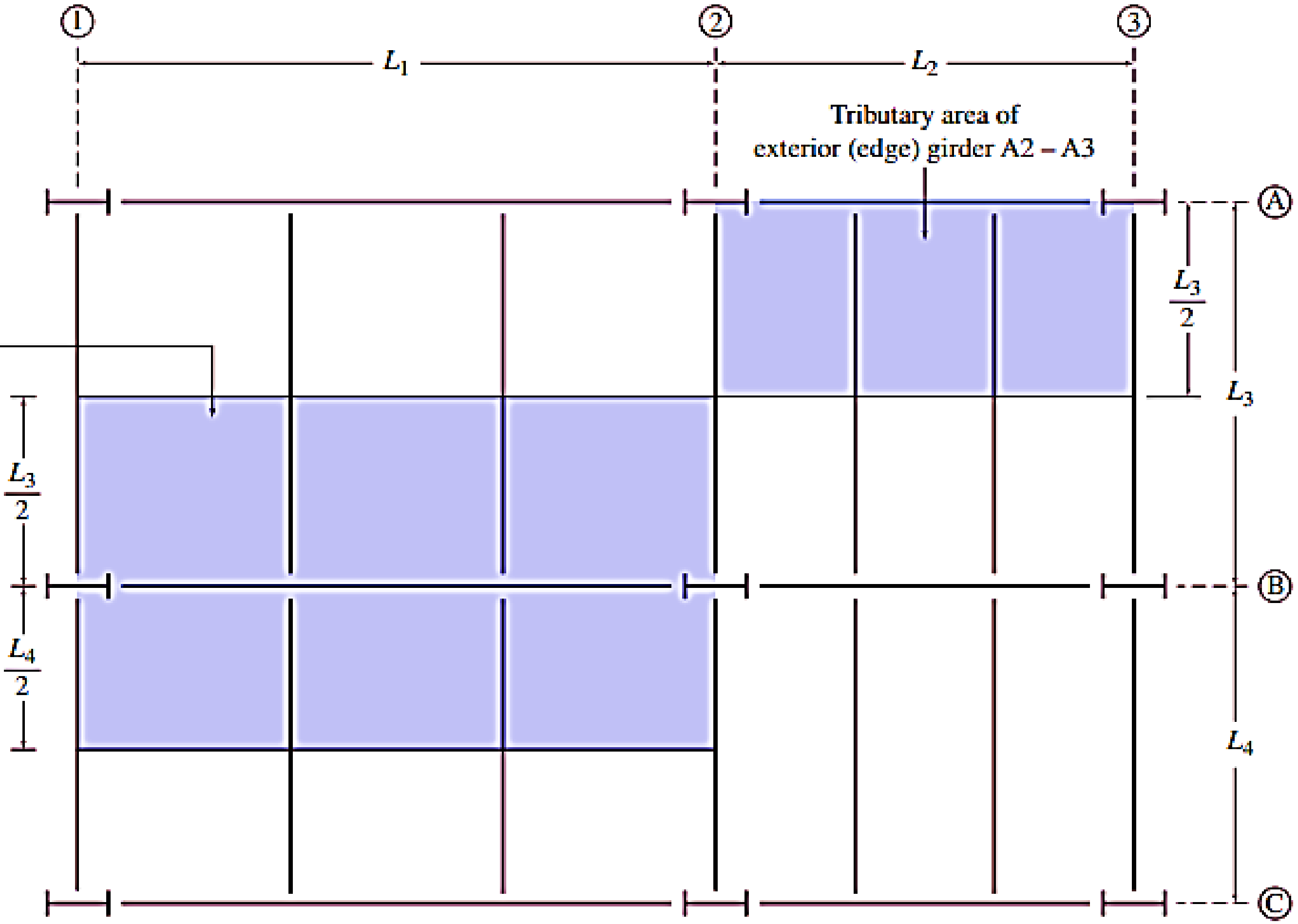
(a) A Typical Floor Framing Plan

Loads on Structures



(b) Tributary Areas of Beams

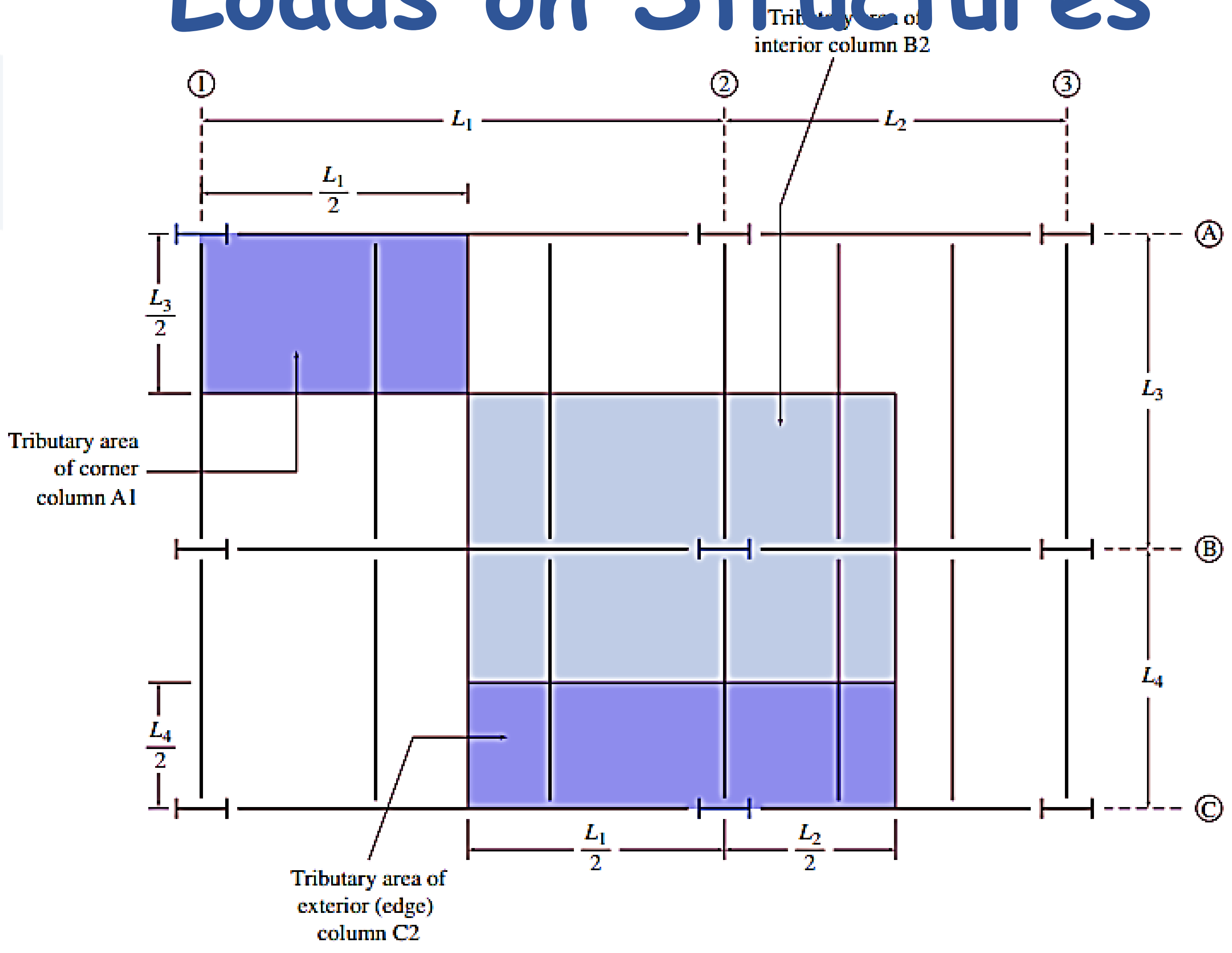
Loads on Structures



i)

(c) Tributary Areas of Girders

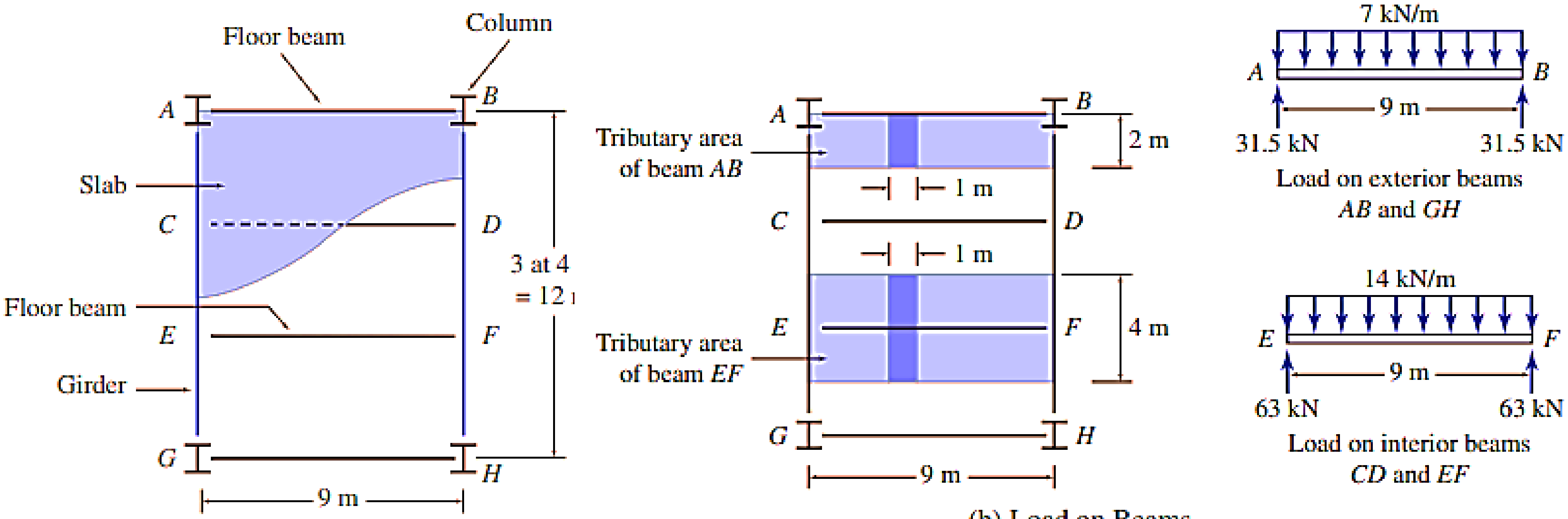
Loads on Structures



(d) Tributary Areas of Columns

Loads on Structures

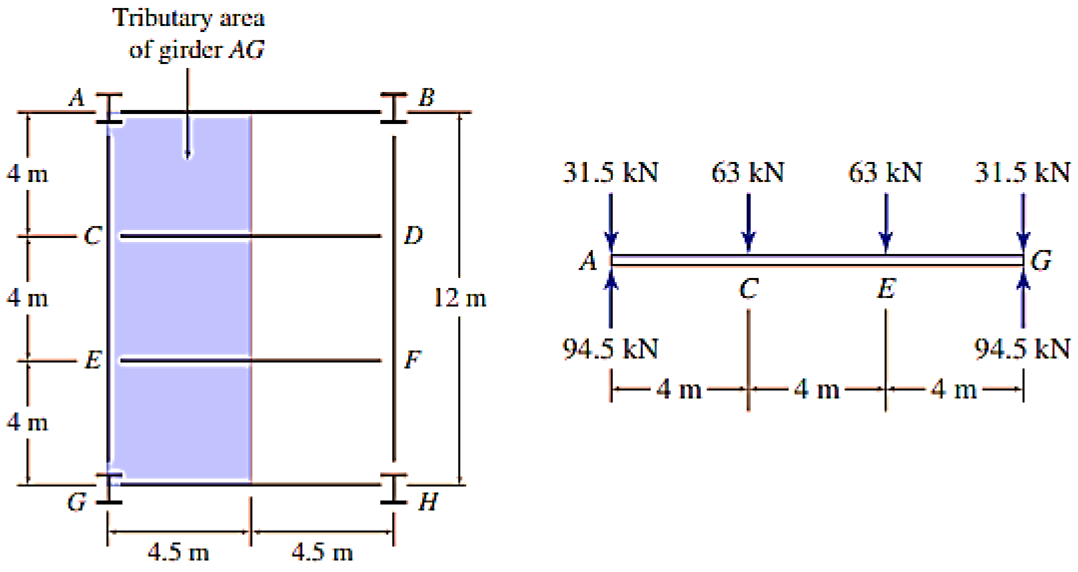
Tributary Area: The floor of a building, shown in following figure, is subjected to a uniformly distributed load of 3.5 kPa over its surface area. Determine the loads acting on all the members of the floor system.



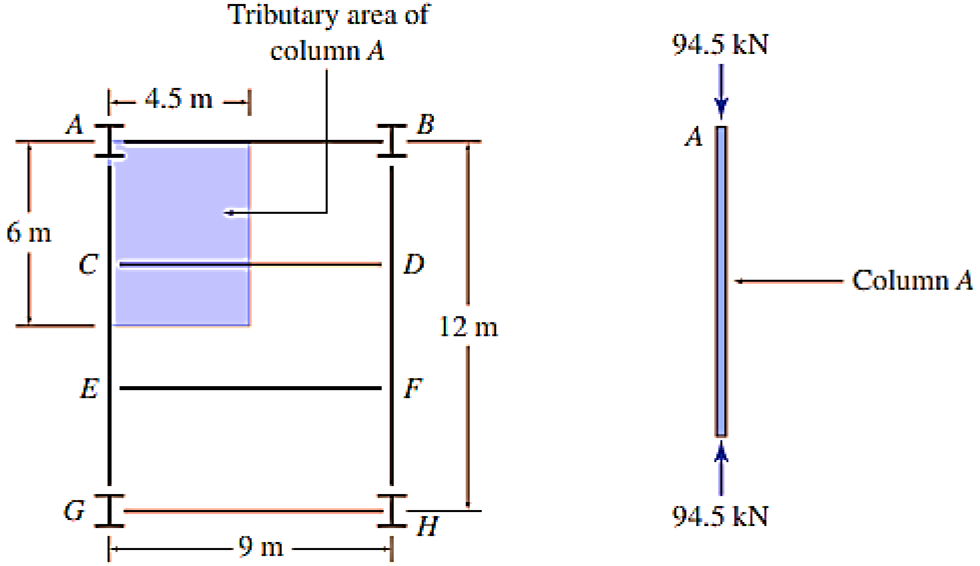
(a) Framing Plan

(b) Load on Beams

Loads on Structures



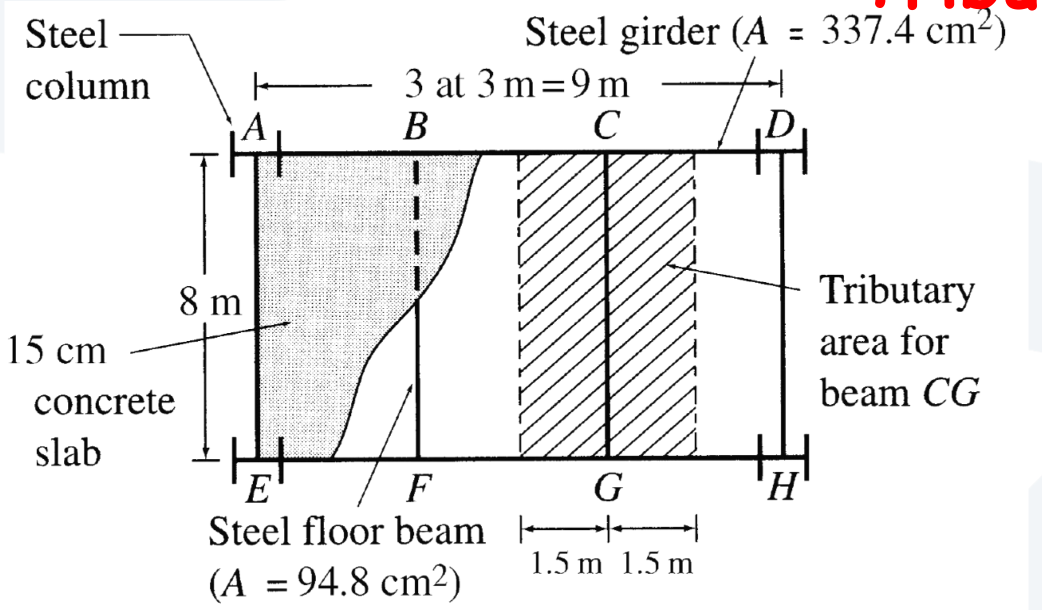
(c) Load on Girders *AG* and *BH*



(d) Compressive Axial Load on Columns *A*, *B*, *G*, and *H*

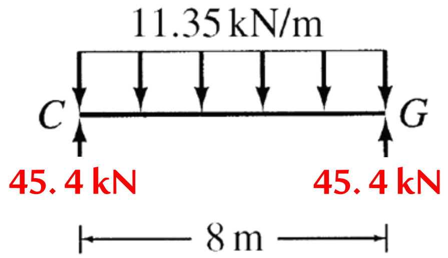
Loads on Structures

Tributary Area

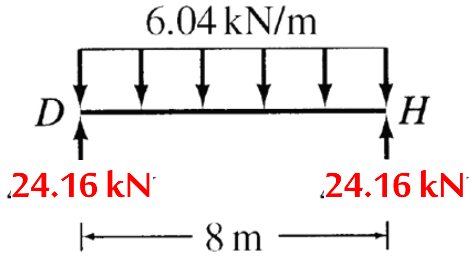


(a) Framing Plan

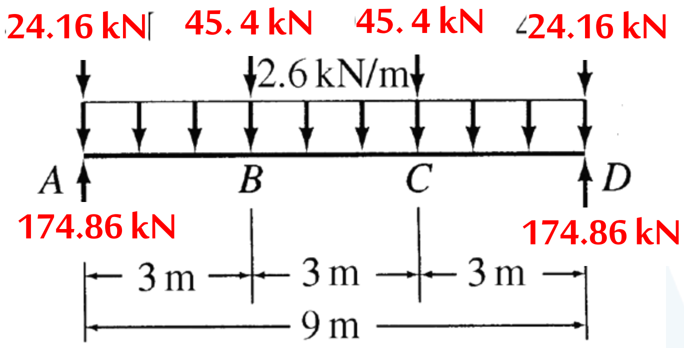
Tributary Area: The floor system of a building consists of a 15 cm thick RC slab resting on 4 steel floor beams, which in turn are supported by 2 steel girders. The cross-sectional areas of the floor beams and the girders are 94.8 cm^2 & 337.4 cm^2, respectively. Determine the dead loads acting on the beams CG and DH and the girder AD.



(b) Load on Beam CG



(c) Load on Beam DH



(d) Load on Girder AD