1.1 Introduction

Structural systems are those elements of construction that are designed to form part of a building's structure either to support the entire building (or other built asset, such as a bridge or tunnel) or just a part of it. So, a steel frame is a **structural system** that supports the building and everything on it and in it. A space frame is a **structural system** that typically supports the roof.

Types of structural system

Load-bearing Structure

A load-bearing wall or bearing wall is a wall that is an active structural element of a building, which holds the weight of the elements above it, by conducting its weight to a foundation structure Continuous structures

These comprise continuous supporting walls through which the combined loads and forces in a building are transferred, mainly by direct compression, into the subsoil through the foundations. The timber floors of a traditional brick-built house, for example, provide lateral bracing and prevent potential deflection of the walls. Laying the bricks in a bond pattern (i.e. with staggered vertical joints) allows compression forces to be evenly distributed throughout the wall volume.

Framed structures

Timber, reinforced concrete and steel can all be used to create regular frameworks comprising beams and columns.

The beams transfer loads from roof, floors and walls to the columns. The columns transfer the beam loads to the sub-soil through the foundations. The dead and imposed loads from roofs or floor slabs will be transferred to the floor beams and then to the structural frame. Compared to a continuous support-type structure of similar weight, a framed structure typically transfers more concentrated loads into the subsoil.

External walls in framed buildings act as infill panels between columns and beams. Because they are non-load bearing (although they carry their own weight and must resist wind forces), they can be of any durable material that fulfils thermal, acoustic, fire and environmental criteria. When positioned on the outside of the frame they form a part of the building envelope and are known as cladding. When they are positioned on a secondary steel framework attached to outside of the main structure so that a ventilation gap is created behind them, they are known as a rain screen. The position of the structural frame relative to its cladding will determine the external appearance: cladding panels can be located behind, in front of, or flush with the frame.

Load transfer mechanism

Multiple elements are used to transmit and resist external loads within a building. These elements define the mechanism of load transfer in a building known as the load path. The load path extends from the roof through each structural element to the foundation. An understanding of the critical importance of a complete load path is essential for everyone involved in building design and construction.

The load path can be identified by considering the elements in the building that contribute to resisting the load and by observing how they transmit the load to the next clement. Depending on the type of load to be transferred, there are two basic load paths:

- **gravity load path**
- **lateral load path**

Both the gravity and lateral load paths utilize a combination of horizontal and vertical structural components, as explained below.

1. Gravity Load Path

Gravity load is the vertical load acting on a building structure, including dead load and live load due to occupancy or snow. Gravity load on the floor and roof slabs is transferred to the columns or walls, down to the foundations, and then to the supporting soil beneath. **Figure 1** shows an isometric view of a concrete structure and gravity load path.

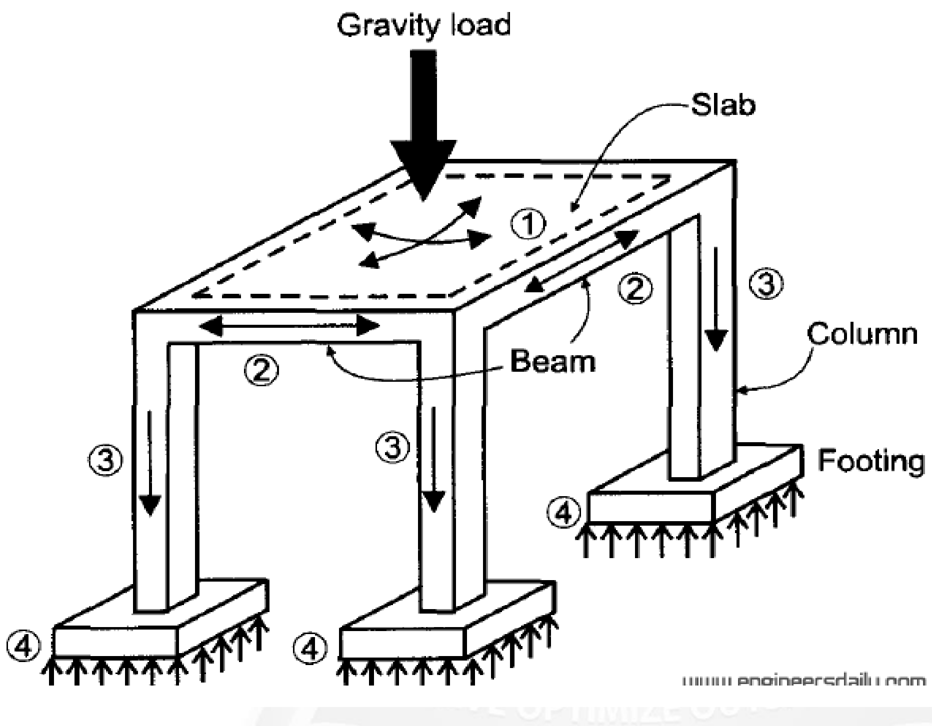

Figure :1 An isometric view of a concrete structure showing a gravity load path.

The vertical gravity load acts on a slab (1), which transfers the load to the beams (2), which in turn transfer the load to the columns (3) and then down to the foundations (4). The gravity load path depends on the type of floor slab, that is, whether a slab is a one way or a two-way system. In the one-way system in **Figure 2a**, the effect of external loads is transferred primarily in one direction, shown with an arrow. The slab-beam and-girder floor is an example of a one-way system. The gravity load acting on this system is transferred from the slab (1) to the beams (2) and then to the girders (3). Finally, the girders transfer the load to the columns (4).

The load path in a two-way system is not as clearly defined. The slab transfers gravity load in two perpendicular directions; however, the amount carried in each direction depends on the ratio of span lengths in the two directions, the type of end supports, and other factors. For example, in the slab with beams system shown in **Figure 2b**, the load is transferred from the slab (l) to the beams aligned in the two directions (2) and then to the columns (3).

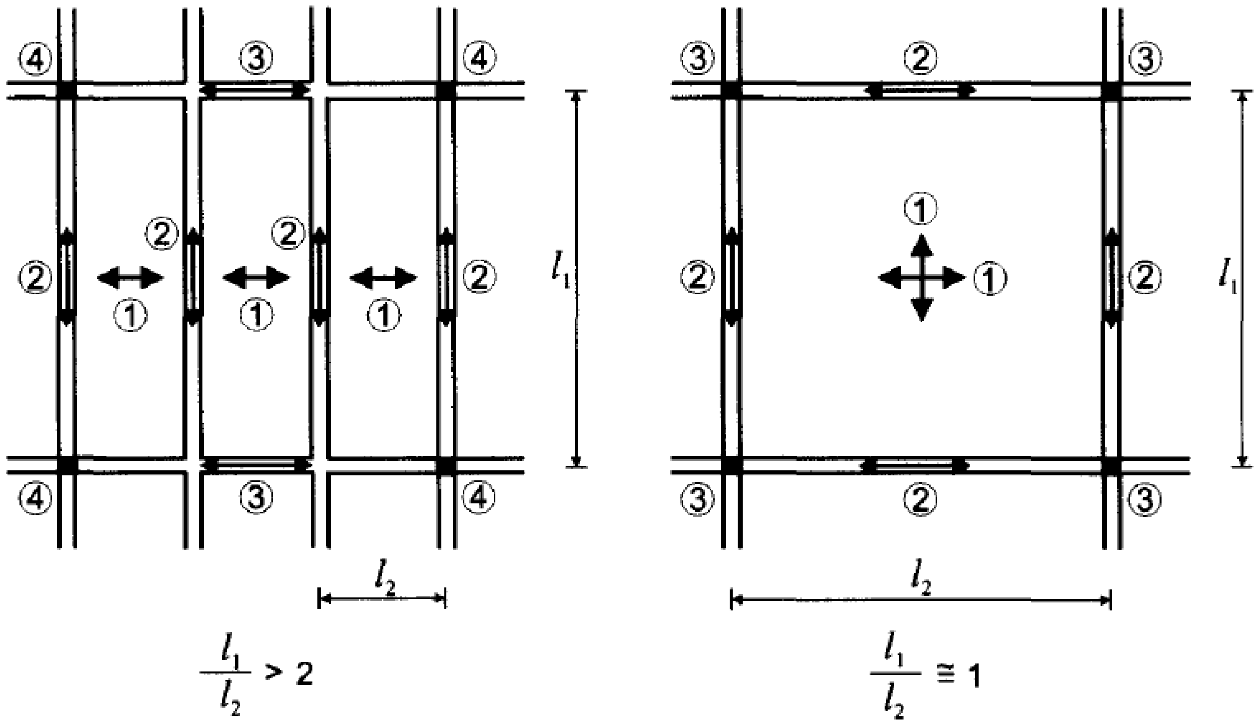

Figure: 2 Gravity load path in a floor slab: a) one-way system; b) two-way system.

2. Lateral Load Path

The lateral load path is the way lateral loads (mainly due to wind and earthquakes) are transferred through a building. The primary elements of a lateral load path are as follows:,

- **vertical components: shear walls and frames;**
- **Horizontal components: roof, floors, and foundations.**

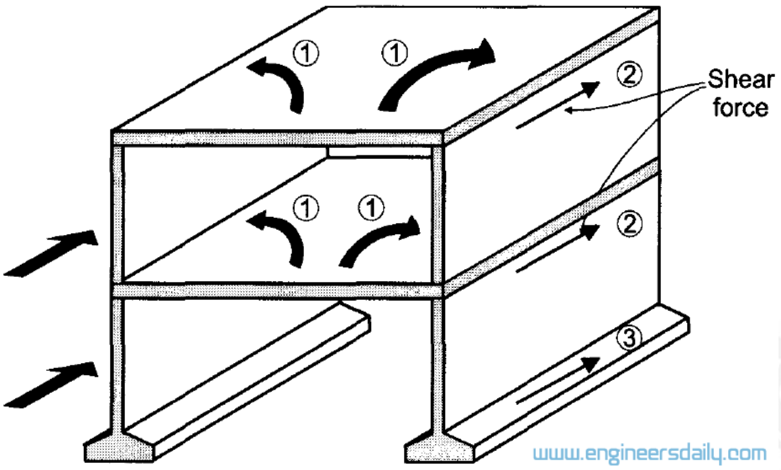

Figure :3 Lateral Load Path

Figure 3 shows a reinforced concrete structure and the elements constituting the lateral load path: roof and floor systems (I) transfer the load to the walls (2), which in turn transfer the load to the foundations (3). Roof and floor systems (also called diaphragms) take horizontal forces from the storeys at or above their level and transfer them to walls or frames in the storey immediately below. Shear walls and frames are the primary lateral-load resisting elements; however, these members also carry gravity loads. Shear walls receive lateral forces from diaphragms and transmit them to the foundations. Foundations form the final link in the load path by collecting the lateral forces from all storeys and transmitting them to the ground.

TributaryArea

The tributary area is related to the load path, and is used to determine the loads that beams, girders, columns, and walls carry. The reader is expected to be familiar with the concept of tributary area from other design courses, as it also applies to design of timber and steel structures; however, a brief overview is presented in this section. The tributary area for a beam or a girder supporting a portion of the floor is the area enclosing the member and bounded by the lines located approximately halfway between the lines of support (columns or walls), as shown in **Figure 4**. For example, a tributary area for the reinforced concrete beam AB that is a part of the one-way floor system is shown hatched in **Figure 4a**. A typical column has a tributary area bounded by the lines located halfway from the line of support in both directions (shown hatched in **Figure 4b**). In the case of uniformly loaded floors, tributary areas are approximately bounded by the lines of zero shear, that is, the lines corresponding to zero shear forces in the slabs, beams, or girders supported by the element for which the tributary area is determined. Zero-shear locations are generally determined by the analysis. For buildings with a fairly regular column spacing, the zero-shear locations may be approximated to be halfway between the lines of support.

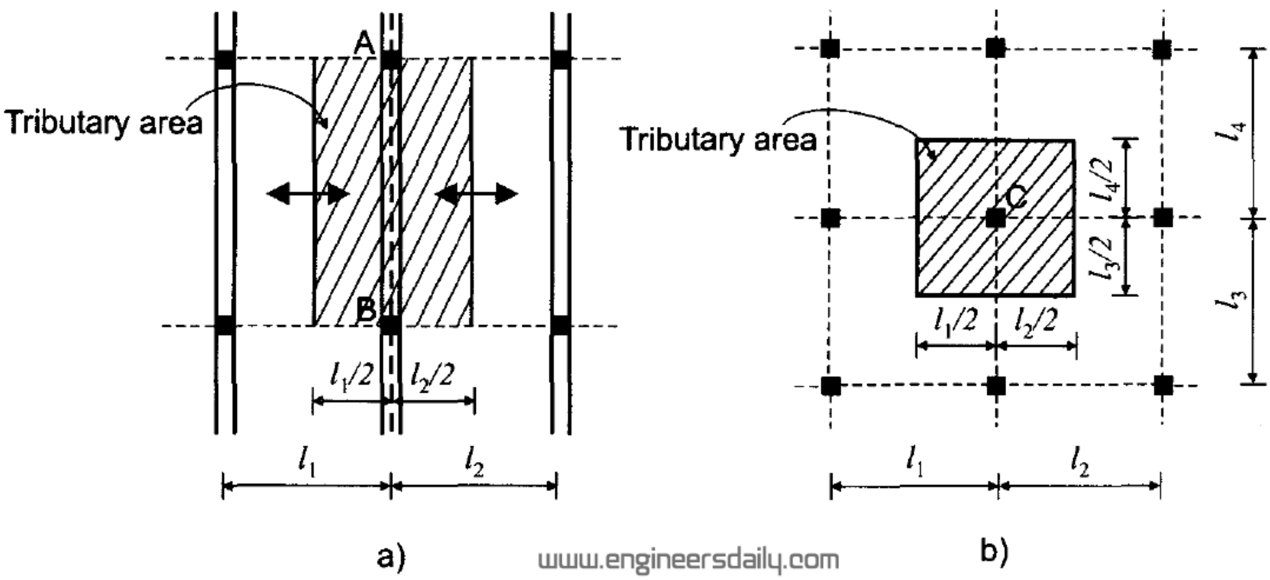

Figure: 4 Tributary area for reinforced concrete members: a) beams; b) columns.

1.1.2 Development of Construction Techniques

1.1.2.1. Architectural Technology

Primitive structures, or buildings used for people to live and stay, are mainly pit houses, made up of pits in the ground with roofing. These structures have been unearthed at various parts of the world. Thousands of years ago, with simple tools which humans learned to make and use, they constructed dwellings for shelter from rain by making use of natural materials, such as grass, wood, stone, mud and animal skin. With the development of civilized society, they came to make buildings that have symbolic meanings, such as religious, hierarchical, or memorial, beyond the original meaning of dwellings. Those buildings are temples, palaces and theaters, one of whose representatives is the pyramids. Depending on natural conditions, under which civilization it was born, and social conditions, such as thought, religion or hierarchy, a variety of buildings with various architectural forms have been built around the world. These buildings expanded their dimensions vertically and laterally as new building materials and techniques were developed. Good examples are temples and churches existent in Europe dating back to the middle ages. The emergence of modern architecture was timed with the industrial revolution in the 19th century in Europe. The industrial revolution accelerated industrialization and propelled the economy by leaps and bounds. Demands for buildings also drastically changed, requiring more functional, efficient and economical factories and other industrial facilities. Reinforced concrete and steel reinforced concrete buildings using. Ito Encyclopedia of Life Support Systems (EOLSS) such new building materials as steel, cement and glass have become a steady scene. The demand for dimensional expansion in height and space increased accordingly. Today, we see cities growing intensively populated, spatially gigantic and more and more information-oriented. Requests for buildings also become more diversified. Building technology that makes “super high rises” and “buildings with big spaces” possible has never been more important.

1.1.2.2. Seismic Technology

The conventional standard of earthquake resistance is how to construct a building rigid enough to resist seismic force (rigid structure) or flexible enough to (flexible structure). Buildings constructed with either concept will suffer less damage and will not fail in the face of a major earthquake, but equipment, furnishings and installations inside the building will receive devastating damage. The state-of-the-art building engineering concept aims at control and mitigation of seismic force itself that acts on the building in order to reduce vibration and protect the building as well as what is inside. These techniques are categorized into two types, vibration control and seismic isolation. A vibration-controlled structure is designed to set off seismic force by giving a counter force in the opposite direction and is categorized into "active" and "passive" control depending on how to set off seismic force. Active damping controls vibration energy by giving a reaction force generated with, for instance, computer-controlled hydraulic power after detecting seismic vibration with sensors. Passive damping absorbs vibration energy with inertial force generated by, for instance, pendulums. Vibration damping is an indispensable technology for today's super high rises. A seismic isolation structure has an isolation layer, in which rubber or sliding bearings are installed to absorb and reduce seismic force transmission to floors above the isolation layer for vibration mitigation. The isolation layer is generally set on the foundation, but some buildings have it among the middle-height floors depending on the building shapes. This technique is effective especially for low- to mid-rise buildings.

1.1.3.Environmental impact of materials

Green building refers to both a structure and the application of processes that are environmentally responsible and resource-efficient throughout a building's life-cycle: from planning to design, construction, operation, maintenance, renovation, and demolition.