Structural elements are the pieces that compose the "skeleton" of structures. Just like the bones of the human body, the skeleton of a building provides strength, shape, and stability. These elements come in various shapes and sizes and similar to other sciences, form follows function. This paper explains the importance and roles of the very basic structural elements such as beams, columns, and foundations. These work together along with various other elements to create a strong, stable, skeleton for buildings and structures.

Beams

A beam is a load-bearing, horizontal, straight member that has high flexural strength. Flexural strength refers to the load-bearing capability of a material or structural element. Structural elements with high flexural strengths can undergo immense bending stress without deformation or yielding. Beams are often categorized by the way they are supported. Examples of this include simply supported beams, cantilevered beams, continuous beams, and fixed supported beams.

A simply supported beam is a beam that rests on two supports with inhibited vertical movement. This is because simply supported beams have one "roller support" and one "pinned support". A roller support is a support that is free to move both horizontally and rotationally but not vertically. Contrastingly, a pinned support, also referred to as a hinge support, is a support that cannot resist movement. A pinned support allows the structural element to rotate, but resists both horizontal and vertical movement. These beams are commonly used in bridges, and are easy to install. Although easy to design and effective, simply supported beams have disadvantages. Compared to fixed beams, simply supported beams have reduced ability to resist bending loads.

Cantilevered beams are horizontal, and only have one end support. These beams are often used in buildings to support things such as eaves and roofs. Like other beams, cantilever beams resist bending and are designed and intended to bear weight. A common example of a cantilever beam is a balcony. A balcony is supported at only one end with the rest extending over open space. Cantilever beams are generally easy to install, lightweight, and can be used in a variety of structures. They also come with various disadvantages such as cantilever beams are unable to support axial loads, and the size of these beams is limited by large deflections. An axial load is a load where the force is acting on an object parallel to its axis of ration.

A continuous beam, in civil engineering, is a beam with more than two supports and is statically indeterminate. A structure is deemed statically indeterminate when the static equilibrium equations are unable to determine the forces and reactions of the structure.

The final type of beam included in this paper is the fixed beam. A fixed beam, like a simply supported beam, has a support on both ends. The difference is that both supports of a fixed beam are fixed. Due to the fixed supports, these beams do not allow for any rotation or vertical movement and are most often used in trusses.

Columns

Columns are vertical structural elements that are intended to resist axial compressive loads. Columns are designed to be load-bearing and are often reinforced to create strong, stable structural engineering. Columns connect upper floors and roofs to foundations, transferring the loads to the foundations and ground beneath. Although there are dozens or categories nad subcategories of columns, columns come in five basic shapes, geometric, L-Type, T-Type, Y-Type, and V-Type.

Geometric columns can be a variety of shapes, most commonly circular, rectangular, octagonal, hexagonal, and square. These columns are usually designed for aesthetic requirements but can have specific functions. For example, circular columns are often used in high elevation structures like bridges while rectangular columns are commonly found in commercial and residential buildings.

L-Type columns are most frequently used in bridge and metro-rail construction. They can also be used as a corner column in a structures framing and like all columns are designed to resist axial compression.

As the name implies, V-Type columns are shaped like the letter V. They are most commonly found in trapezoidal rooms and structures and while they provide support and a unique shape, they require more material than most other types of columns.

Following that theme, Y-Type columns, also referred to as Y-Shaped columns are shaped like the letter Y. While often overlooked by the general public, Y-Type columns can be found in most major cities. This is because Y-Type columns are typically the support column of choice when designing and constructing infrastructural bridges and flyovers (overpass). Similarly, L-Type columns are typically used in bridge construction and are chosen based on design and structural requirements.

These columns can be further categorized by material, column ties, frame bracing, and loading.

Types of Reinforcement

While beams and columns are what make up the majority of a building's structural engineering, the elements alone are often not enough to bear the weight of the structure and maintain structural stability against both natural and unnatural disasters. Reinforcement, increases tensile capacity providing additional strength when and where it is needed. There are several types of reinforced concrete such as steel fiber reinforced, rebar reinforced, post tensioned, and glass fiber reinforced concrete.

Glass fiber reinforced concrete (GFRC) is a cement mixture reinforced with alkali-resistant glass fibers, also referred to as AR-glass fiber, is glass fiber with zirconium oxide. Zirconium oxide is the chemical compound that makes alkali-resistant glass alkali-resistant. Alkali resistance is an important quality in the glass fibers as concrete is a very alkaline environment, an environment that will degrade standard glass. This reinforcement method is typically lighter than other options while maintaining strength and versatility. Glass fiber reinforced concrete has high flexural, tensile, and compressive strength and is used in a variety of structures and structural elements.

Steel fiber reinforced concrete is the same concept as glass fiber reinforced concrete except the composite material is instead formed using concrete and steel fibers. Although it was controversial when first introduced due to limited testing, this type of reinforced concrete has become common in tunnel linings and airport pavements in recent years. It has a high flexural strength, fatigue resistance, and abrasion resistance. Along with these benefits, steel fiber reinforced concrete also has disadvantages. Issues with uniform dispersal of fibers along with calculating the necessary quantity to achieve optimal benefits have been encountered.

Rebar is an abbreviation for reinforcement bar. Reinforcement bars are made from a variety of steel materials and are used to reinforce concrete in many structures. This reinforcement helps to strengthen a structure's structural engineering. Not only is rebar reinforcement used in beams and columns but it is also used to strengthen foundations. There are five different types of rebar reinforcement welded wire fabric, expandable metal, stainless steel rebars, sheet metal reinforcing bars, and epoxy-coated rebars. Welded wire fabric is most often made from either stainless steel rebar or galvanized steel rods which cross each other in a grid-shape. Similarly, expandable metal reinforcement is a sheet metal mesh, comparable to a thick grate.

Post-tensioned concrete uses steel strands and bars, with post-tension reinforced columns and walls typically having bars and post-tensioned reinforced beams using strands. This method is used in a variety of structures from high-rises to parking garages. Post-tensioning concrete combines the strong compression resistance of concrete with the strong tension resistance of steel (American Concrete Institute 266).

Loads

A load is simply the weight of force borne by a structure or object. In civil engineering, the three most common types of loads are live loads, dead loads, and environmental loads.

A live load is a load that is temporary or changing. They vary in magnitude and position bases in the use of the structure. For example the weight of the second floor of a building can vary based on how many people are on the floor, what furniture is in place, and many other factors. Another example of this is the number of cars on a bridge. The load borne by the supporting structural elements of the bridge varies based on how many vehicles are on the bridge.

Contrastingly, a dead load is a downward force borne by a structural element that does not vary or change over time. A dead load is calculated by multiplying the sum of the mass of all the components by the gravitational field strength. Dead weight results from the self-weight of the building self-weight being the combined weights of all the structural elements including but not limited to the columns, beams, walls, and floors.

Environmental loads come in a variety of forms such as wind, earthquake, thermal, settlement, and snow loads. Environmental loads are caused by natural forces and factor heavily into a strucutre’s design and engineering. Buildings are subject to different environmental forces based on location. A structure located far from the ocean, such as in the United States Midwest does not need to be built to withstand hurricane damage, but it does have to be able to resist high wind levels due to tornados. Comparatively, a building located in the upper region of the northern hemisphere must be built to withstand the additional vertical load imposed by snow during snowfall and storms. There are three types of wind loads that can cause structural failure, uplift, shear, and lateral. Uplift loads cause a strong uplifting force that could result in the structure moving upward. Shear loads apply a force that could cause the building to tilt and walls to crack. Lastly, lateral loads are a horizontal force that can make a building shift off of its foundation. All of these are dangerous and must be considered when designing a building's structural engineering. Earthquake loads, as one might assume, are additional loads resulting from earthquakes or other seismic activity. Because of this they are also referred to as seismic loads. The ground movement during earthquakes and seismic activity can cause a building to sway which may result in building failure. Structures located in places designated as high seismic activity zones require careful analysis and specialized structural engineering. Snow loads are typically additional vertical weight caused by snow deposits on the top (roof) of structures. Not only must the structural engineers account for the potential weight of these snow deposits, but they must also factor in shifting of these deposits caused by wind and other forces. This may result in unbalanced roof loads which, if not account for, can lead to structural failure.

Foundations

Foundations serve several purposes. In fact, it is so important that there is an entire branch of geotechnical engineering (a sub-discipline of civil engineering) call foundation engineering. Foundations not only provide a flat, level surface for construction but they are also responsible for transferring the “ various load combinations from the superstructure to the underlying soils or rocks (i.e., geomaterials)” (Eslami et al. 25-53). This means that the foundation must distribute the stresses (loads) from the structural elements to the ground below. Although all foundations share this common primary function, not all foundations are the same. There are two basic types of foundations, shallow and deep. Each basic type has various sub-types.

Shallow foundations transfer a building load to the surface, or near surface of the ground. This includes isolated footing, wall footing, combined footing, cantilever footing, and mat foundations. Isolated footing foundation is a common type of foundation and is used to support individual columns. It can be compared to anchoring a patio umbrella to a table, the loads borne by the umbrella are transferred to the table which acts as the umbrella’s foundation, transferring both loads to the ground below. Several isolated footing foundations are required to support an entire structure. Wall footing foundation, also referred to as strip footing foundation, distributes a structure's load by using a “footing” or strip of reinforced concrete at the walls base, running along the direction of the wall’s length. This type of foundation is used most often when transferring low magnitude loads and when the foundation must be placed in dense sand or gravel. Cantilever footing foundation, also referred to as strap footing, is a type of combined, shallow foundation using two columns to transfer loads.

Conclusion

From the foundation to the rafters, structural engineering is a complex science responsible for the strength and stability of structures.

Works Cited

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