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"To observe the behavior of single-column and multi-column building structures"

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ABSTRACT :

Analysis and comparison of structural behavior in a single-column G+3 RCC frame versus a multiple-column G+3 RCC frame using STAAD Pro. Innovative use of STAAD Pro to challenge conventional design principles, providing insights into structural efficiency and practicality under unique conditions. This study has the potential to demonstrate the capabilities of modern engineering tools while exploring unconventional architectural possibilities. Analyze and design a G+3 (four-story) structure on a single column. Compare the structural performance, stability, and safety against a traditional multi-column design. Incorporate dead load, live load, and floor load for the design. Use STAAD Pro to apply these loads under various combinations and observe structural behavior. Leverage STAAD Pro for its intuitive modeling capabilities, global code recognition, and advanced analysis tools. Explore its ability to handle unconventional designs like single-column structures.

Key words:- Single-Column, Multistory Building , STAAD Pro, Incorporate dead load, live load, and floor load

Introduction :

Single-column structures are a unique architectural and structural innovation, often adopted for specific applications where maximizing open space or achieving a distinct visual appearance is a priority. Here's a breakdown of the key features, benefits, and considerations for single-column designs in multi-story buildings.

Monolithic Column Building

A monolithic column is indeed a monumental structural element made from a single piece of material, typically stone, without joints or seams. These columns are often large and impressive, and their use signifies both engineering expertise and a statement of significance in architectural design. The construction of monolithic columns can pose significant challenges in terms of quarrying, as the material must be carefully extracted from the earth in large, unbroken sections. Transporting such large pieces also requires specialized techniques to avoid damage, making the use of monolithic columns a costly and labor-intensive process.

Historically, monolithic columns were often used in monumental architecture, such as temples, palaces, and memorials, to symbolize power, permanence, and grandeur. The term is generally reserved for larger columns, as smaller ones, though often also made from single pieces of stone, do not carry the same scale or implication of monumental achievement. The selection of a monolithic column for a structure often highlights the importance or prestige of the building, as it is a significant engineering feat that demonstrates wealth, technological capabilities, and artistic ambition.

A **single-column building** is a minimalist structural concept where a single vertical column serves as the primary load-bearing element, supporting a structure or building. This design is often seen in modern architectural and engineering projects that prioritize aesthetics, simplicity, and innovation.

Structural Design:

- A single central column acts as the primary structural support, with beams, cantilevers, or trusses extending from it to support floors, roofs, or platforms.
- The column is typically made from high-strength materials such as reinforced concrete, steel, or composite materials to handle concentrated loads.

Load Distribution:

- The column must bear the combined weight of the building and any live loads (e.g., people, furniture, equipment).
- Lateral stability (resistance to wind or seismic forces) is achieved through careful design, often incorporating outriggers or additional stabilizing features.

Applications:

- Observation towers or platforms.
- Canopies or pavilions.
- Sculptural or iconic buildings with a focus on minimalism.

Foundation Design:

- Foundations for single-column buildings are crucial and are designed to handle the significant point loads transmitted by the column.
- Common foundation types include deep piles, mat foundations, or spread footings, depending on soil conditions.

Architectural and Aesthetic Appeal:

- The design offers a striking visual impact and is often used in landmark structures.
- Frees up space around the base, making it ideal for open or landscaped areas.

Challenges:

- Stability is a primary concern; careful engineering is required to ensure the structure is safe under various loads and environmental conditions.
- The single column must resist bending, buckling, and shear forces effectively.
- Maintenance and inspection of the column are critical due to its central role.

Figure 1 Single column building

Multi-Column Building

A "multi-column building" refers to a structure supported by multiple vertical columns, which can serve structural, aesthetic, or both purposes. Columns in architecture are vertical load-bearing members designed to transfer loads from the upper portions of a building to its foundations. Multi-column buildings are common in various types of structures, including commercial complexes, historical buildings, and modern high-rises.

Columns can be designed using a variety of styles and materials, from classical orders (like Doric, Ionic, and Corinthian in ancient architecture) to modern steel, concrete, or composite columns in contemporary construction. These buildings often emphasize both functional stability and architectural elegance.

A *multi-column building* is a structural design that incorporates multiple vertical supports (columns) to transfer loads from the building's structure to its foundation. This type of structure is widely used in residential, commercial, and industrial buildings because it offers flexibility in architectural design, efficient load distribution, and resistance to various types of forces.

Column Arrangement:

- Columns are arranged based on the structural design and load requirements.
- Common arrangements include square, rectangular, grid, or irregular patterns.

Load Transfer:

- The columns support the weight of beams, slabs, and the overall structure, transferring these loads to the foundation.

Flexibility in Design:

- Allows for the creation of open spaces by eliminating the need for load-bearing walls.
- Can be combined with modern construction techniques like flat slabs, waffle slabs, and Bubble Deck systems.

Material Choices:

- Columns are commonly constructed using materials like reinforced concrete, steel, or a composite of both.
- Material selection depends on factors like building height, purpose, and environmental conditions.

Structural Stability:

- Columns work in conjunction with beams, slabs, and shear walls to resist lateral forces (like wind or seismic loads) and ensure stability.

Applications:

- **High-rise Buildings:** Where multiple columns are necessary to distribute vertical and lateral loads.
- **Industrial Facilities:** For heavy machinery support and large-span roofs.
- **Residential and Commercial Complexes:** To maximize usable space with minimal obstructions.

Design Considerations:

Column Spacing and Dimensions:

- Determined by structural calculations, type of loads, and functional requirements of the building.

Foundation Design:

- Includes isolated, combined, or raft foundations to support the load from multiple columns.

Load Path Analysis:

- Ensures proper transfer of loads from the roof to the ground.

Figure 2 Multi column building

Literature Review :

Shubham Kumar Binjhwar et al (2023) the project aims to provide a comprehensive and innovative solution for the construction of a single column multistory building that meets the needs and requirements of the modern world. The project focuses on the design and construction of a single column multistory building. Due to the continuous growing population and land scarcity tends to the advancement in construction technology and high-rise buildings. The objective is to create an efficient and functional building that maximizes the use of available space while ensuring structural stability and safety. Bending moment, stress, shear force, structural modelling and displacement design considerations for the structure is provided in this paper which is analyzed using STAAD Pro. The project includes detailed structural analysis and design, as well as consideration of various factors such as soil conditions, wind loads, seismic loads and other environmental factors. The building will be designed to meet local building codes and regulations, while incorporating sustainable and energy-efficient features. The process throughout the Structural planning and designing is not only demand awareness and intellectual thinking but also adequate knowledge of structural engineering along with the knowledge of practical aspects such as relevant design codes backed up by example experience. Moreover, the scope of a single column building project is to create an efficient, functional, and aesthetically pleasing building that meets the needs of its users, while ensuring structural stability, safety, and compliance with relevant regulations and standards**.**

Sijin Johnson et al (2022*)* mono column structures, often referred to as tree-like structures, have a single central column supporting the entire building. This design creates a high vulnerability to eccentric loading, which can cause twisting in any direction and ultimately lead to failure. Since the structure relies on a single column, all other members act as cantilevers, making them susceptible to excessive deflection, high story displacement, and increased story drift. Furthermore, seismic analysis reveals that the shear forces and bending moments in the members are significantly higher compared to non-seismic analysis, exacerbating the potential for structural failure. Due to these challenges, mono column structures are generally more costly and prone to seismic damage compared to conventional building designs. The plan configuration of the building plays a crucial role in its seismic performance. Asymmetric or irregularly shaped plans are particularly prone to severe damage during seismic events, primarily due to torsional responses and stress concentrations. These irregularities cause a change in the lateral deformation of the structure, increasing the likelihood of failure under lateral forces like seismic and wind loads.

In contrast, diagram structural systems offer significant advantages. The diagram design, characterized by its triangular configuration, improves the seismic performance of buildings by providing greater stiffness and reducing the overall weight. This system enhances lateral stability, making the building more resistant to seismic and wind forces. Additionally, the diagram structure reduces the number of structural elements, leading to a more efficient design with fewer potential failure points. Studies have shown that diagram structures decrease story displacement, story drift, and base shear compared to conventional systems, offering both enhanced performance and a more aesthetically pleasing appearance.

Methodology :

Designing a G+3 single-column building using STAAD. Pro involves several steps, including defining the structure, applying loads, analyzing, and designing the column. Below is a detailed methodology.

Step 1: Understanding Requirements

Gather Input Data:

Building dimensions: Height of each floor, total building height.

Column details: Material properties, initial dimensions, and grade of concrete and steel.

Loadings: Dead loads (self-weight, finishes), live loads, wind loads, and seismic loads (as per relevant codes).

Soil properties: Bearing capacity for foundation design.

Design Code:

Choose the appropriate design codes (e.g., IS 456:2000 for concrete, IS 875 for loads, IS 1893 for seismic).

Modeling in STAAD. Pro

Create a New Model:

Start STAAD. Pro and create a new model (space structure for 3D).

Define Geometry:

Define a single vertical column structure.
Specify the height of the column for each floor and overall height.

Assign Material Properties:

Define the material properties for concrete (e.g., M25, M30) and steel (e.g., Fe500).

Define Support Conditions:

Provide appropriate boundary conditions at the base (e.g., fixed support for the column foundation).

Apply Loads

Dead Loads:

Apply self-weight and additional loads (e.g., slab, beams, and finishes).

Live Loads:

Apply live loads on floors as per IS 875 Part 2.

Wind Loads:

Generate wind load as per IS 875 Part 3 based on the building's height, location, and wind zone.

Seismic Loads:

Apply seismic loads using IS 1893 guidelines (select zone, importance factor, response reduction factor).

Load Combinations:

Define load combinations as per IS 456 or relevant design codes (e.g., 1.5(DL + LL), 1.2(DL + LL + WL), etc.).

Run Analysis:

Perform linear static analysis to check deflections, moments, and forces in the column.

Check Results:

Review displacement, axial forces, shear forces, and bending moments.

Refine Model:

If required, modify the column dimensions or material properties based on initial analysis results.

Design Parameters:

Input design parameters such as cover, bar diameter, spacing, and design methodology.

Design Column:

Use the "Design" module in STAAD. Pro for concrete design as per IS 456.

Reinforcement Detailing:

STAAD. Pro will suggest the reinforcement required (longitudinal bars and ties).
Check if the reinforcement meets code requirements and practical considerations.

Foundation Analysis:

Calculate the base reactions from STAAD. Pro analysis.
Design the foundation (isolated or pile) using STAAD. Foundation or manually as per IS 456 and IS 1904.

Verify Design:

Cross-check the results for safety factors and serviceability.
Ensure the column satisfies strength, deflection, and stability requirements.

Optimize Design:

Optimize column dimensions or reinforcement for cost and efficiency.

Result and Discussion :

Displacement refers to the movement of a point or object from its original position in response to a force or load. In structural engineering, displacement is commonly used to describe how much a structure or element, such as a slab or beam, moves due to applied loads. Displacement refers to the change in position of a point or an object from its original or equilibrium position due to external forces, loads, or environmental effects (e.g., temperature changes, settlement). It can occur in any direction and is measured relative to a reference point or axis. In structures, it is often expressed in millimeters (mm) or meters (m). Movement along a straight line, such as vertical deflection of a beam or horizontal sway of a building. The angle of rotation about a specific axis due to bending or torsion. A combination of linear and angular displacements that occur simultaneously. Many design codes specify maximum allowable displacements to ensure usability and comfort (e.g., limiting deflection in floors or sway in tall buildings). Monitoring displacement helps predict and control cracking, especially in reinforced concrete structures. In seismic or wind design, displacement helps engineers assess how a structure will respond to dynamic forces. Checking deflection limits under live and dead loads to prevent structural or functional problems.

Table 1 Displacement in both structure

Description	Displacement in X direction (mm)	Displacement in Y direction (mm)	Displacement in Z direction (mm)
Single Column Building	2.890	1.560	6.740
Multi Column structure Building	22.420	2.870	23.870

Conclusion:

A critical difference in structural performance between single-column and multiple-column designs. Single-column buildings generally exhibit higher stiffness due to their integrated structural configuration, which minimizes lateral displacements. The 70–80% higher displacement in multiple-column buildings suggests a greater susceptibility to lateral forces such as wind or seismic loads. This is often due to the distribution of stiffness across multiple columns, which can lead to differential movements within the structure. Single-column designs consolidate load paths, creating a more rigid system and thereby reducing overall lateral movement. Stiffness in single-column buildings is typically greater because of the continuous load transfer along a unified column, minimizing bending and deflection. Multiple columns, while offering redundancy and load-sharing capabilities, can introduce relative flexibility, especially if the spacing and connections are not optimized.

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