International Journal of Advances in Engineering and Management (IJAEM)
Volume 6, Issue 01 Jan 2024, pp: 274-278 www.ijaem.net ISSN: 2395-5252

Thumb Rule's For Modification Of Material Properties And Applied Load In Concentric Axial Loaded Short Column

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Date of Submission: 10-01-2024 Date of Acceptance: 20-01-2024

ABSTRACT:
This study presents thumb rules designed to make the modifications in material properties and applied load for concentric axially loaded columns. The formula integrates key parameters, including the axial load , cross-sectional area of concrete and steel, tensile strength of steel and compressive strength of concrete . Additionally, the formula incorporates coefficients accounting for variations in column geometry. By considering the interplay of these factors, the proposed thumb rules aims to provide a comprehensive and practical approach to estimate the axial load-carrying capacity of concrete columns under concentric loading conditions and the cross-sectional area of steel required to resist the loading .This thumb rules offers a valuable contribution to the field of structural engineering, enhancing our understanding of the complex relationships between material properties, geometry, and axial loading in reinforced concrete columns.

Keywords :Concentric Axial Load , Material Properties , Column Geometry , Axial Load-Carrying Capacity , Gross Cross-Sectional Area , Compressive Strength of Concrete , Coefficients , Reinforced Concrete Columns , Structural Engineering , Structural Design , Concrete Column Behaviour , Structural Performance .

I. INTRODUCTION :

Reinforced concrete columns are fundamental components in structural engineering, providing essential support for buildings and infrastructure. The accurate assessment of the axial load-carrying capacity of these columns is critical for ensuring structural integrity and safety. thumb rules serve as valuable tools in this regard, offering a simplified yet effective means to estimate the behaviour of concrete columns under various loading conditions.

In the Indian context, the design and analysis of structural elements, including columns, adhere to the guidelines laid out in the Indian Standard IS 456: "Code of Practice for Plain and Reinforced Concrete." This code provides essential principles and specifications for the design and construction of concrete structures in India. However, the application of thumb rules specific to Indian standards, considering modifications in material properties and column geometry .

This journal focuses on the development and implementation of an thumb rules tailored to the Indian Standard IS 456 for concentric axially loaded columns. The formula aims to incorporate adjustments for variations in material properties, such as compressive strength , and the geometric attributes of the columns.

The need for such an thumb rules arises from the practical challenges faced by structural engineers in making swift yet accurate assessments of concrete column behaviour in diverse construction projects. This research endeavours to provide a comprehensive and efficient solution for the structural engineering community.

The design and assessment of reinforced concrete columns under axial loads involve complex considerations related to material properties and column geometry. While the Indian Standard IS 456 provides a robust framework for structural design, there is a need for a specialized thumb rules that accommodates modifications in material properties and column geometry specific to concentric axially loaded columns.

Validate the thumb rules:
Conduct a thorough validation process to assess the accuracy and reliability of the developed thumb rules.
Compare the formula's predictions against results from theoretical data and established analytical methods.

CASE 1: Modification to area of steel with change in applied axial load
Pn = Pu + Pa => Ansc = Asc + g1 * (Pa)

where Pn is New axial load on the member
Pu is Axial load on the member
Pa is addition load
Ansc New area of longitudinal reinforcement columns
Asc area of longitudinal reinforcement columns
g1 is modification factor (i.e 3.703018)

CASE 2: Modification to applied axial load with change in area of steel
Ansc = Asc + Aasc => Pn = Pu + g2 * (Aasc)

where Pn is New axial load on the member
Pu is Axial load on the member
Ansc New area of longitudinal reinforcement columns
Aasc additional area of longitudinal reinforcement columns
Asc area of longitudinal reinforcement columns
g2 is modification factor (i.e 0.27805)

Example :
A column 400 X400 of height 3m is designed for factored axial load of 2400 KN using M20 concrete & Fe 415 steel
As per Clause 39.3 of IS 456,
Pu= 0.4 x fck x Ac+0.67 x fy x Asc
Substituting the values, we get

Asc=4147.38 mm2

CASE 1: Now if you need to modify applied axial load from 2400KN to 2500KN the change in area of steel will be Ansc
Using our thumb rule for additional load of Pa=100KN
Ansc=4147.38+3.703018 x 100

New area of longitudinal reinforcement in column= 4517.68 mm2

CASE 1: In same problem if you need to modify area of steel from 4147.38 mm2 to 4517.68 mm2 the change in applied axial load will be Pn
Using our thumb rule for additional area of steel Ansc=370.3 mm2
Pn=2400+0.27805 x 370.3

Pn is New axial load on the column= 2500 mm2
Contribute to Structural Engineering Knowledge:

Provide insights into the behaviour of reinforced concrete columns under axial loads in the Indian context.
Contribute new knowledge to the field of structural engineering, particularly in the application of thumb rules for axial loaded short column design.

Enhancing Structural Design Accuracy:
The study addresses a critical gap in the field of structural engineering by developing an thumb rules specifically tailored to Indian standards. This contributes to more accurate predictions of axial load-carrying capacity in concentrically loaded columns.

Thumb rules in Structural Engineering:
Existing literature demonstrates the widespread use of thumb rules for estimating the behaviour of structural elements. Studies have explored various empirical approaches, often tailored to specific materials, loading conditions, or design codes.
The design of axially loaded short columns in accordance with the Indian Standard IS 456 involves a systematic process that ensures structural engineers to cross check or modify design based on unforeseen changes without redesigning the structure. Here's a brief overview of the design and methods used for axially loaded short columns based on the Indian standard code:

1. Determine Design Parameters:
Identify the relevant design parameters, including the axial load (N), concrete compressive strength , yield strength of steel, dimensions of the column (cross-sectional area , effective length, and any other applicable factors.

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2. Check Slenderness Ratio:
Determine the slenderness ratio . Ensure that the column is classified as short according to IS 456.

3. Calculate Design Axial Load:
Use the formula for Pn to calculate the design axial load-carrying capacity.

4. Check for Maximum and Minimum Steel Reinforcement:
Verify that the steel reinforcement provided is within the permissible limits according to IS 456. Check for both maximum and minimum reinforcement requirements.

5. Provide Transverse Reinforcement:
Introduce transverse reinforcement, such as ties or spirals, to enhance ductility and confinement. Follow the specified guidelines in IS 456 for the spacing and detailing of transverse reinforcement.

6. Detailing of Longitudinal Reinforcement:
Detail the longitudinal reinforcement considering factors such as cover, lap length, and anchorage length. Ensure that the detailing adheres to the code requirements specified in IS 456.

7. Check for Shear:
Examine the column for shear requirements based on the applied axial load. Verify that the shear capacity is adequate, and provide additional shear reinforcement if necessary.

8. Check for Torsion (if applicable):
In cases where torsional effects are significant, assess and provide additional reinforcement to resist torsion as per IS 456.

9. Documentation and Drawing Preparation:
Prepare detailed drawings and documentation illustrating the design calculations, reinforcement details, and any other relevant information.

10. Review and Approval:
Conduct a thorough review of the design calculations, drawings, and details. Seek necessary approvals from relevant authorities or structural engineers.

Important Considerations:
Code Compliance: Ensure that all design aspects adhere to the guidelines and provisions of IS 456.
Material Properties: Use accurate values for material properties, including concrete strength and steel yield strength.
Load Combinations: Consider various load combinations as per IS 456 during the design process.

Assumptions:
Material Homogeneity: The design assumes that the concrete and steel used in the construction of the column are homogeneous and exhibit consistent material properties throughout.
Elastic Behaviour: The analysis assumes that both concrete and steel behave linearly elastic up to failure. This assumption is generally valid within the elastic range of the materials.
Axial Load Dominance: The design primarily considers axial loading, assuming that other significant lateral loads or moments are negligible compared to the axial load.
Code Compliance: It is assumed that the design and detailing adhere strictly to the provisions of the Indian Standard IS 456: "Code of Practice for Plain and Reinforced Concrete."
No Eccentricity: The analysis assumes that the applied axial load is concentric and that no significant eccentricities are present.
Uniform Loading: Uniform axial loading is assumed, and the column is not subjected to point loads or highly concentrated loads that could lead to localized failure.

II. LIMITATIONS:

Short Column Assumption: The design is specifically tailored for short columns, and its applicability to slender or long columns may be limited. Different design considerations are required for such cases.

Temperature and Creep Effects: The design does not explicitly account for long-term effects, such as temperature variations, creep, or shrinkage of concrete, which may have implications for the column's performance over time.

Simplified Loadings: The analysis assumes primarily axial loading without significant lateral forces or moments. Real-world structures may experience complex loading conditions that are not fully captured in this simplified model.

Static Loading: The design assumes static loading conditions. Dynamic effects from seismic forces or other dynamic loads are not explicitly considered.

Linear Elastic Behaviour: The assumption of linear elastic behaviour up to failure may not accurately represent the behaviour of concrete and steel at high-stress levels or in the post-elastic range.

Shear and Torsion Simplifications: The design simplifies shear and torsion effects. While basic checks are performed, more detailed analyses may be required for situations where these effects are significant.

Material Variability: The design assumes consistent material properties, but variations in concrete and steel properties may exist, impacting the actual structural response.

Boundary Conditions: The model assumes idealized boundary conditions, and site-specific factors such as soil-structure interaction are not explicitly considered.

It is essential to recognize these assumptions and limitations to ensure that the design is appropriately applied in the intended context. Engineers should exercise judgment and consider additional analyses or modifications when these assumptions may not hold in specific scenarios.

Theoretical frameworks in the context of the design of axially loaded short columns based on the Indian Standard IS 456 often involve fundamental principles of structural mechanics and concrete behaviour. While the design process may primarily rely on code-specific guidelines, certain theoretical concepts contribute to the understanding and application of these codes. Here are key components of the theoretical framework:

1. Axial Load-Behaviour Relationship:

The design is grounded in the fundamental understanding of axial load behavior in structural elements. Theoretical principles, such as equilibrium and compatibility, form the basis for determining the axial load-carrying capacity.

2. Material Mechanics:

Theoretical concepts from material mechanics, including stress-strain relationships for concrete and steel, influence the design. Understanding the material's behavior under axial loading is critical for accurate predictions of column performance.

3. Strength of Materials:

The principles of strength of materials, including the stress distribution in concrete and steel, guide the design process. Theoretical considerations of stress concentrations and failure modes contribute to the formulation of safety checks.

4. Elastic and Plastic Behaviour:

The design incorporates theoretical concepts of elastic and plastic behaviour. The elastic range is crucial for initial analyses, while plastic behaviour considerations, especially in detailing reinforcement, enhance the structure's ductility and resilience.

5. Structural Stability:

Theoretical frameworks related to structural stability, buckling, and column effective length contribute to the determination of the slenderness ratio. These concepts influence the classification of the column as short or slender.

6. Limit States Design Philosophy:

The design philosophy adheres to the limit states design approach, which considers both strength and serviceability limit states. Theoretical frameworks related to load combinations, partial safety factors, and the consideration of different failure modes guide the design process.

7. Shear and Torsion Theories:

Theoretical considerations of shear and torsion effects, such as the truss analogy for shear and the torsional equilibrium equation, contribute to the design process. This includes understanding the limits imposed by these effects on the axial load-carrying capacity.

8. Concrete Confinement:

Theoretical principles related to concrete confinement under axial loads and the effectiveness of transverse reinforcement contribute to the detailing of columns. These considerations enhance the ductility and resistance of the structure.

9. Interaction Diagrams:

Theoretical development of interaction diagrams helps visualize the combined effects of axial load, moment, and shear. These diagrams aid in understanding the safe regions for design within the given material and geometric constraints.

10. Code Provisions:

The Indian Standard IS 456 itself serves as a theoretical framework, encapsulating the cumulative knowledge and experience of the structural engineering community. The theoretical underpinnings of the code provisions guide the application of design principles.

While the design process is primarily guided by empirical methods and code provisions, the theoretical framework ensures a deeper understanding of the underlying principles that govern the behaviour of axially loaded short columns. The integration of these theoretical concepts with practical design considerations results in a comprehensive and robust design methodology.

III. CONCLUSION :

In conclusion, this journal has endeavoured to address a critical need in the field of structural engineering by developing an thumb rules for the design & validation of axially loaded short columns based on the Indian Standard IS 456. The significance of this study lies in its potential to enhance the accuracy, efficiency, and accessibility of structural assessments, aligning with the requirements of Indian standards.

The research successfully formulated an thumb rules that incorporates modifications in material properties and applied load , acknowledging the nuances of short columns subjected to axial loads.

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