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FORMULATION OF DESIGN TABLES AND CHARTS FOR REINFORCED CONCRETE COLUMNS AND SLABS

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ABSTRACT
The design of reinforced concrete (RC) columns and slabs is a fundamental aspect of structural engineering, requiring adherence to safety, serviceability, and economic considerations. Traditional manual design methods, though effective, are often time-consuming and susceptible to computational errors, especially when dealing with complex geometries and multiple iterations. This study presents the formulation of simplified design tables and charts for reinforced concrete columns and slabs based on established design codes such as BS 8110 and Eurocode 2. Mathematical models were developed to derive expressions for reinforcement requirements at ultimate limit states (ULS). Additionally, a Python-based computational tool was developed to enhance accuracy and efficiency in structural design. Results obtained from the developed charts and program were validated against standard code provisions, demonstrating high accuracy and improved efficiency. The study contributes to simplifying structural design processes while maintaining reliability and safety in engineering practice [1], [2].

Keywords:
Reinforced Concrete, Design Charts, Columns, Slabs, Ultimate Limit State, Eurocode 2, BS 8110, Structural Design, Python Programming

INTRODUCTION

Reinforced concrete is a composite material combining concrete and steel to exploit their complementary properties—concrete's compressive strength and steel's tensile strength [1]. RC columns and slabs are critical structural elements widely used in buildings and infrastructure systems. Their design must satisfy both ultimate and serviceability limit states while ensuring durability and cost-effectiveness.

Traditional design methods rely heavily on manual calculations guided by design codes such as BS 8110 and Eurocode 2. However, these methods become cumbersome when handling multiple design scenarios or complex geometries. The use of design charts and computational tools has therefore become essential in simplifying and accelerating the design process [2].
The design of RC columns and slabs involves determining internal forces, selecting appropriate reinforcement, and ensuring compliance with design standards. Manual approaches are:

- Time-consuming
- Error-prone
- Inefficient for iterative designs

Existing design charts are often outdated and do not incorporate modern safety factors or harmonized code provisions. Hence, there is a need for updated, simplified, and reliable design aids [1].
The aim of this study is to develop simplified design tables and charts for RC columns and slabs.
Objectives include:

- Reviewing relevant design codes (BS 8110, Eurocode 2)
- Formulating design procedures
- Developing design tables and charts
- Creating a Python-based design tool
- Validating results against standard methods

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Review of past works on formulation of design charts and tables

[8] conducted a study on development of design charts for rectangular section. Simplified design chart has been developed based on BS: 8110 – 97 design rules and several design examples were solved using the developed charts and tables. [9] carried out a study on development of design charts for concrete industrial slabs. The charts are based on finite element analyses in which the slab is modeled as an elastic plate and the soil is idealized as an equivalent homogeneous isotropic elastic layer of limited depth. The primary design objective is to limit the flexural tensile stresses in the slab to specified allowable values. In developing the design chars, a standard set of parameters has been selected for the main analyses, and then correction factors have been derived to account for the effects of variations from the standard values of soil Young's modulus, soil layer depth, and the loading details. The charts then relate the slab thickness to the maximum flexural tensile stress in the slab. [10] developed the design charts for steel fiber reinforced concrete elevated slabs. Determination of the bearing capacity of the slabs was made by using the Yield line theory. Different materials as well as different geometry were considered, making in total four hundred and five (405) combinations. All these combinations were a subject of design by the Yield line theory at the ultimate limit state and design charts with respect of some of the variables was developed. [11], developed the design charts of a parallelogram shaped slab by using the yield line method. Load-deflection behavior of simply supported reinforced concrete parallelogram shaped slabs was analyzed using experimental and analytical methods. Finite element modeling of eighteen numbers of simply supported reinforced concrete parallelogram shaped slabs were made and non-linear analysis carried out on all parallelogram shaped slabs to obtain the load-deflection relationship under the action of uniformly distributed load. To carry out this analysis, a free MS Office (MS Excel sheet) was used. Also, this can be compared with an experimental load deflection curve and using theoretical method, with this result. The current study however focused on development of simplified design tables and charts for the analysis and design of reinforced concrete slabs with varying cross sections.

Object-oriented Approach to Finite Element Programming

Computer programming packages are available for analyses of thermal effects on bridges. Most of the software like STAADPRO, SAFE are sold as commercial packages and will require adequate training to use. Computer programs9 can also be written to validate the results of manual analyses and to reduce the time spent as well as the error made during manual calculations. Several object-oriented programming languages have been developed in recent years. These include C++, C#, and Java. Java is one of the more popular object-oriented programming languages because it has several unique features. During the last fifteen years, finite element development has gradually shifted from procedural approach (Fortan, C) towards an object-oriented approach. Mostly, object-oriented finite element algorithms have been implemented in C++ programming language. It was shown that an object-oriented approach with the C++ programming language could be used without sacrificing computational efficiency (1993) compared to Fortran.

MATERIALS AND METHODS

2.1 Materials and Tools

- Design codes: BS 8110, Eurocode 2
- Textbooks on reinforced concrete design [1], [2]
- Software: Python (NumPy, Pandas), Microsoft Excel

2.2 Theoretical Framework

The study is based on limit state design principles, ensuring structures satisfy both:

- Ultimate Limit State (ULS)
- Serviceability Limit State (SLS)

2.3 Assumptions

- Concrete resists compression only
- Steel resists tension only
- Linear strain distribution across section depth
- Rectangular stress block approximation

2.4 Mathematical Formulation

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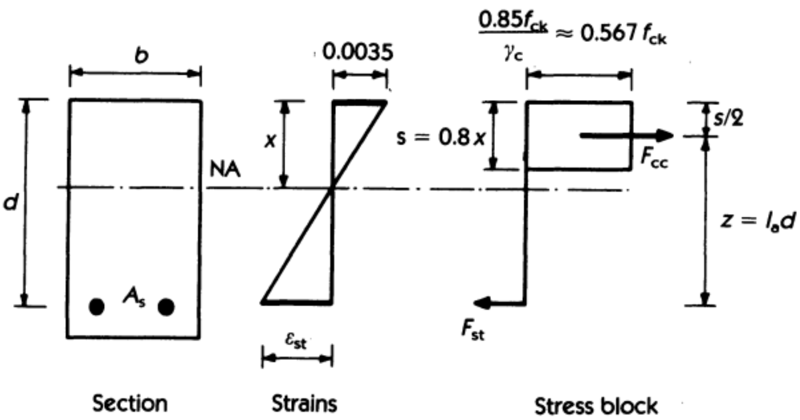

Figure 1: Singly reinforced section with rectangular stress blocks

For a singly reinforced rectangular section:

Force equilibrium:

$$C = T$$

Moment of resistance:

$$M = F_s \cdot z$$

Where:

$$F_s = 0.87 f_y A_s$$
$$z = d - \frac{x}{2}$$

These equations were used to derive expressions for reinforcement ratios and generate design charts.

2.5 Development of Design Charts

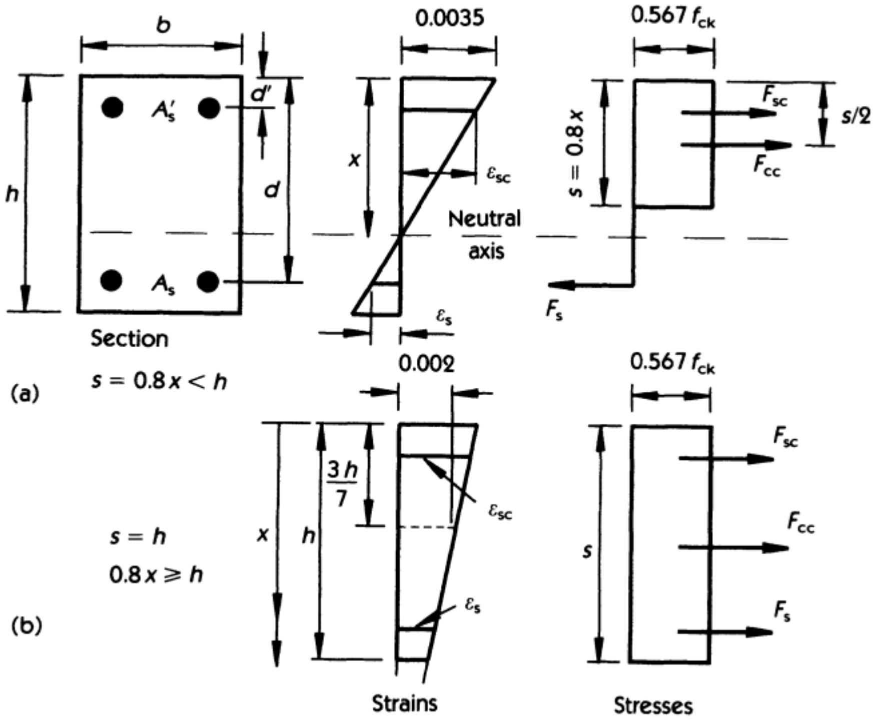

Figure 2 Bending plus axial load with varying position of the neutral axis

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Design charts were generated by:

- Varying parameters such as slab thickness, span, and material strength
- Plotting reinforcement ratios against bending moments
- Validating results using code-based calculations

2.6 Computational Implementation

A Python-based program was developed to:

- Automate calculations
- Generate design outputs
- Validate chart results

RESULTS AND DISCUSSION

Design Chart Performance

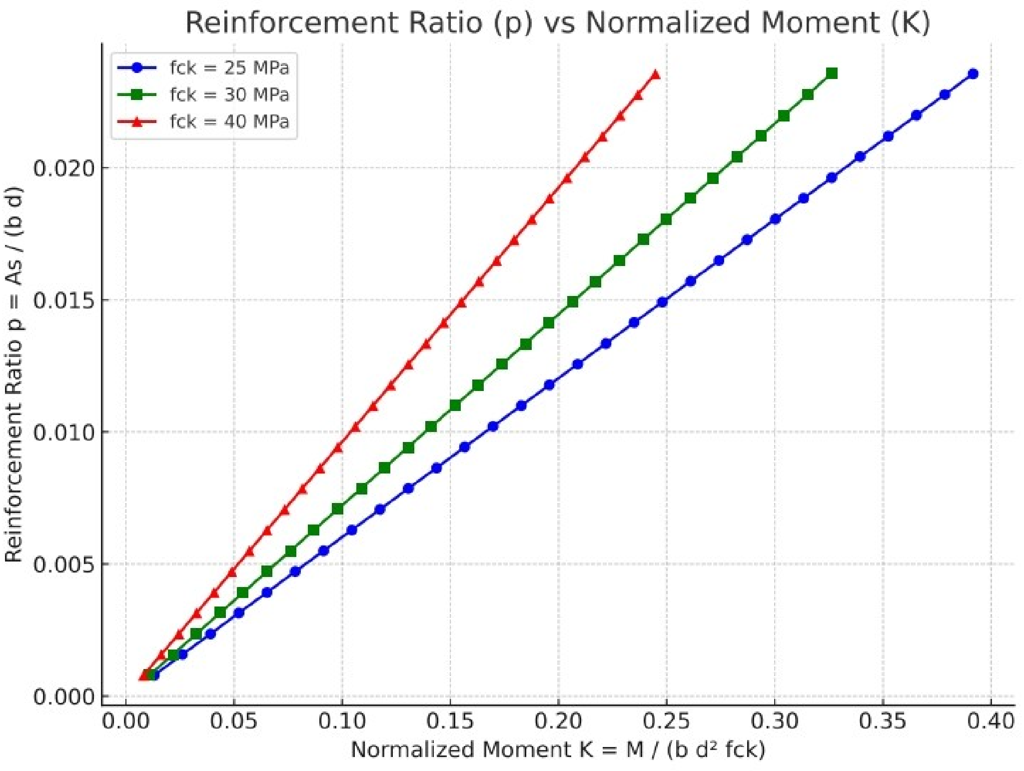

Figure 1: Generated graph to determine reinforcement ratios

The developed charts:

- Simplified reinforcement estimation
- Reduced computational time
- Provided reliable results across varying slab geometries

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Table 3 Generated Column Design Table using Python Programming

Final Design Table

Row	h (mm)	s (mm)	Axial Load N (N)	M (kNm)	Normalised N	Normalised M
1	225	88.85	247,574	3.4	0.159	0.017
2	300	126	392,799	25.58	0.19	0.0412
3	400	175	584,443	68.95	0.212	0.0624
4	450	198	674,398	91.76	0.217	0.0657
5	500	222	768,264	120.08	0.223	0.0696
6	550	247	866,042	150.74	0.228	0.0722
7	600	271	959,908	183.51	0.232	0.0738

Results from the charts were compared with:

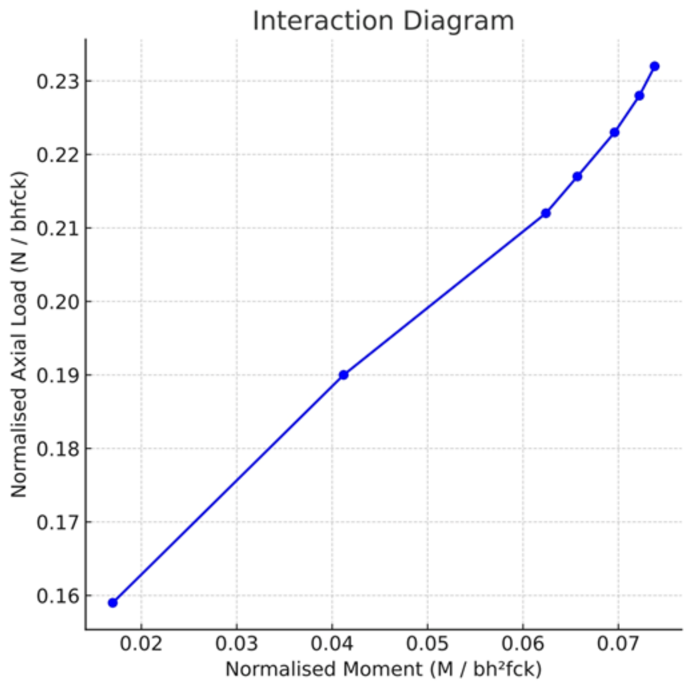

Figure 4.2: Interaction Diagram for a rectangular Column Section Capacity

- BS 8110 design outputs
- Python-generated results

The comparison showed:

- High level of accuracy
- Minimal deviation from standard code results

3.3 Observations

- Increased span leads to higher reinforcement requirements
- Thicker slabs reduce reinforcement demand

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- Charts are effective for standard slab configurations

3.4 Limitations

- Not directly applicable to complex geometries (e.g., ribbed slabs)
- Focused mainly on vertical loading
- Requires adjustment for varying material properties

CONCLUSIONS

This study successfully developed simplified design tables and charts for reinforced concrete columns and slabs. The integration of mathematical modelling, code provisions, and computational tools resulted in a reliable and efficient design approach. The developed charts significantly reduce design time while maintaining accuracy and compliance with standard codes.

The Python-based tool further enhances usability by automating calculations and reducing human errors. Overall, the study provides a practical solution for structural engineers, improving efficiency and promoting safer design practices.

REFERENCES

[1] Oyenuga, V.O. (2011). *Simplified Reinforced Concrete Design*.
[2] Mosley, W.H., Bungey, J.H., & Hulse, R. (2007). *Reinforced Concrete Design*.
[3] BSI (1997). *BS 8110: Structural Use of Concrete*.
[4] Eurocode 2 (EN 1992-1-1). *Design of Concrete Structures*.
[5] Reynolds, C.E., & Steedman, J.C. (2008). *Reinforced Concrete Designer's Handbook*.
[6] Sabah, S. (2017). *Structural Design of Slabs*.
[7] Reed, M., et al. (2008). *History of Concrete Technology*.
[8] Bayagoob, K., Yardim, Y., & Ramoda, R. (2013). Development of RC Design Charts.
[9] Poulos, H.G., & Small, J.C. (2017). Design Charts for Industrial Slabs.
[10] Nakov, D. (2012). Design Charts for Fiber Reinforced Concrete Slabs.
[11] Gupta, A., & Shanmukesh, K. (2020). Yield Line Analysis of Slabs