International Journal of Civil, Structural, Environmental and Infrastructure Engineering Research and Development (IJCSEIERD)
ISSN (P): 2249–6866; ISSN (E): 2249–7978
Vol. 13, Issue 1, Jun 2023, 9–16

TRANS STELLAR • Journal Publications • Research Consultancy

STUDY OF REINFORCED CEMENT CONCRETE UNDER AXIAL AND FLEXURAL LOADS

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ABSTRACT

Knowing the material and geometrical qualities of members is crucial in structural analysis, particularly for indeterminate systems. The recommended elastic characteristics of concrete and steel are quite precise and are codified in the rules. Modulus of elasticity of concrete is represented as a function of the grade of concrete in the current IS: 456-2000 codal requirements. The concrete modulus of elasticity may be calculated using a variety of methods. Concrete cylinder or cube specimens may be used to plot a stress-strain curve. This curve's incline represents the modulus of elasticity of regular concrete. The modulus of elasticity of concrete may also be calculated using the flexural test of a beam specimen. Secant modulus is often used as the modulus of elasticity for concrete. A tension test on a steel bar may be used to measure the material's modulus of elasticity. Any programme that does analysis on a high-rise structure will only analyse the cross-section of plain concrete, ignoring the influence of reinforcing bars and the confinement of the concrete inside stirrups.

The purpose of the current investigation is to establish the elastic characteristics of reinforced cement concrete beams and columns. When analysing a tall RCC structure modelled as a flat frame, AE and EI are two crucial stiffness parameters to keep in mind. Beams with reinforcement percentages between 0.54 and 1.63% are being tested as part of the experimental programme, with reinforcement percentages between 0.894 and 3.57% being tested on flexural members and columns, respectively, to ensure consistency with the current Codal provisions of IS: 456-2000. The impact of confinement is taken into account here. 3D finite element methods are used to verify the experimental findings.

KEYWORDS: RCC beam, RCC column, high-rise building, Axial Load, Flexural Load, Finite Element

Received: Jan 10, 2023; **Accepted**: Jan 30, 2023; **Published**: Feb 06, 2023; **Paper Id**: IJCSEIERDJUN20232

Original Article

INTRODUCTION

To construct an RC structural element, one must be familiar with the behaviour of reinforced concrete structures and with the fundamental material characteristics. Knowing the basics of performance requirements in reinforced concrete design is essential. Structural design's ultimate objective is to produce a building that is both safe and cost-efficient to maintain and operate. The elements of security include strength, stability, and structural integrity. Effective serviceability is influenced by properties such as stiffness, durability, and creep. There are two stages to a section's behaviour under varying stress conditions: before it cracks and after it collapses.

Based on current RCC design standards, an extra cycle of analysis and design work is required. When it comes to composite reinforced concrete, the IS Code only provides details for the E value of plain concrete. In the second round of examination, the accessible design from the previous round may be implemented. Beam and column steel areas are known in this cycle; thus, they must be included in the effective area of cross section and effective moment of inertia. Pre-cracking and post-cracking RC member analyses are presented. To do this, we need to be well-versed in E, A, and I, along with other material and geometrical aspects.

In order for a beam segment to be considered safe according to the IS Code, the ultimate moment of resistance, Mur, must be greater than or equal to the factored moment, Mu. Another requirement of the rule is that ductile or tension failure must occur at the point of ultimate failure in flexure. Minimum reinforcement cover is an issue that must be taken into account simultaneously. Early-loading cracking occurs when reinforcement in beams or columns is over-covered. Over-reinforced sections may pass the strength criteria but fail the ductility requirement. In mild steel, the ductility criterion may be partly satisfied even if x_u is somewhat higher than x_{umax}.

Particularly in the case of indeterminate structures, it is essential to understand the geometrical and material properties of members before proceeding with the structural analysis. The IS codal norms prescribe the elastic characteristics of concrete and steel, and they are generally accurate. Elastic properties of concrete and steel are well-known. However, reinforced concrete is a hybrid material that combines steel and concrete. Whenever software is used to assess a tall building, the cross section of plain concrete is taken into account, but the effects of reinforcing bars and concrete held in place by stirrups are disregarded. Finding out how elastic reinforced cement concrete is the focus of this research. The stiffness parameters AE and EI play a significant role in the study of a tall RCC structure treated as a planar frame. It is believed that improved analysis and cost-effective design would result from a deeper knowledge of material and geometrical properties. Knowing the material and geometrical qualities of members is crucial in structural analysis, particularly for indeterminate systems. Recommended elastic qualities of concrete and steel may be found in the IS codal regulations, and they are quite accurate.

Independent research has shown these elastic characteristics for both concrete and steel. However, reinforced concrete is not only concrete but a composite material that also includes steel. Any programme that does analysis on a high-rise structure will only analyse the cross section of plain concrete, ignoring the impacts of reinforcing bars and concrete restricted by stirrups. The purpose of this research is to establish the elastic characteristics of reinforced cement concrete. When analysing a tall RCC structure modelled as a flat frame, AE and EI are two crucial stiffness parameters to keep in mind. Because of this, it is envisaged that precise material and geometrical qualities would lead to more precise analysis and cost-effective design.

METHODOLOGY

1. Experimental Setup for Beam Specimen

In this study, we give the experimental protocol, which includes the characteristics of reinforced concrete beam and column specimens. The average compressive strength of the concrete used in reinforced concrete beam specimens is calculated using the findings of plain concrete cubes. A Universal Testing Machine is used to measure the modulus of elasticity of RCC beam and column specimens. A mix of M20, M25, and M30 concrete was used. Beam specimens undergo flexure testing, whereas column specimens undergo uniaxial compression testing. The modulus of elasticity of RCC beams and columns, and how factors like the grade of concrete, percentage of reinforcement, and confinement affect it, have been examined.

The current research was an experimental examination of the RCC models subjected to flexural loadings. Tables 1 show the various reinforcing combinations that may be used in a flexure test for M20, M25, and M30 grades of concrete, respectively. Clause 7.3 of the International Standard (IS) 516:1959 (Reaffirmed 2004) specifies a model size of 150 mm x

150 mm x 700 mm for testing the strength of concrete. After taking beam samples, we soaked them in water for 28 days to cure them.

Three models per combination were tried, and the averages are shown below.

The International Standard (IS) 456-2000 recommends using at least (0.85% of net area)/fy and no more than 0.4% of gross area for tension steel. Two bars of 8mm diameter of steel were always available in the compression zone. Area of tension steel, concrete strength, and steel content are tabulated below based on the provided data. The stirrup spacing in the pure flexure zone of each modelled reinforced concrete beam ranged from 50 mm to 200 mm.

Table 1: Reinforcement Details for Flexural Strength Test in M20, M25 and M30

Mix No	Diameter	Number of Bars	A_{st}(mm^2)	P_t (%)
M20-1	-	-	-	0.00
M20-2	08	02	100.55	0.55
M20-3	08+06	02+01	128.83	0.70
M20-4	08	03	150.76	0.80
M20-5	10	02	157.10	0.85
M25-1	-	-	-	0.00
M25-2	08	02	100.55	0.55
M25-3	08+06	02+01	128.85	0.70
M25-4	08	03	150.78	0.80
M25-5	10	02	157.09	0.85
M25-6	12	02	226.18	1.20
M30-1	-	-	-	0.00
M30-2	08	02	100.55	0.55
M30-3	08+06	02+01	128.85	0.70
M30-4	08	03	150.75	0.80
M30-5	10	02	157.09	0.85
M30-6	12	02	226.20	1.20
M30-7	12+10	02+01	304.75	1.65

2. Experimental Setup for Column Specimen

Under axial stress, the performance of reinforced concrete columns was tested experimentally. In this study, determining the compression elastic modulus of RCC specimens was the major focus. This is why the steel reinforcement percentages in the reinforced concrete column examples were cast to vary.

Three models per combination were tried, and the averages are shown below.

The International Standard (IS) 456-2000 suggests a minimum steel area of 0.8% of the gross area of the column, with a maximum steel area of 6% of the gross area of the column. However, reinforcement that accounts for just 6% of the gross area of the column would be very crowded. For this reason, the total steel area may be no more than 4% of the building's total floor space. The recommended steel area for M20, M25, and M30 concrete is reported in Table 2 below. Both 50mm and 62.5mm stirrup spacings were used in the concrete models.

Table 2: Reinforcement Details of Axial Compression Test

Sl. No	Model No.	Reinforcement	Percentage of Steel
1	1	Plain	0.00
2	2	4-8mm φ bars	0.895
3	3	4- 10mm φ bars	1.390
4	4	4-10mm φ bars+2-8mm φ bars	1.840
5	5	4-12mm φ bars	2.010
6	6	4-12mm φ bars+2-10mm φ bars	2.710
7	7	4-16mm φ bars	3.570

All column samples were standardised to 150 mm 150 mm 300 mm in accordance with paragraph no.2.8/IS:516-1959 (2004). Twenty-one reinforced concrete column specimens were made for each concrete grade as part of the experimental programme. TMT type bars were the ones in question. The reinforcing bars in the column specimens were shielded from view by a 20 mm thick transparent cover. Ties were used to provide extra support to the sides. Ties made from 6mm bars were placed every 50mm and 62.5mm throughout the length of the column samples.

RESULTS AND DISCUSSIONS

1. Evaluation of Young's Modulus for Beam

The primary purpose of this study was to develop a credible equation for the modulus of elasticity of reinforced concrete. For example, reinforced concrete is a composite material that combines steel and concrete, two very non-linear elements. Recognizing how such a material ought to act is challenging. The qualities of both materials are crucial for reinforced concrete. Therefore, many characteristics must be considered to arrive at a reasonable modulus of elasticity. This chapter provides elaboration on the many experimental study criteria, including concrete quality, tension reinforcement %, and the impact of confinement. The equation used for calculating the value of modulus of elasticity (E) is shown in Equation 1. The values of obtained E have been shown in Table 3.

$$\delta = \left(\frac{5}{184}\right) \times \left(\frac{wl^4}{EI}\right) + \left(\frac{23}{648}\right) \times \left(\frac{Wl^3}{EI}\right) \quad (1)$$

where w is self-weight (N/mm) and W is half the load at the first crack (N)

Table 3: Comparison of Experimental and Analytical Results

Mix No	P_t (%)	Modulus of Elasticity (E)	
		Experimental	Analytical
M20-1	0.00	24066.80	24138.10
M20-2	0.55	28288.70	28087.00
M20-3	0.70	28453.89	27992.50
M20-4	0.80	31013.45	31071.15
M20-5	0.85	32478.30	32538.10
M25-1	0.00	25995.80	25265.70
M25-2	0.55	29160.20	29284.40
M25-3	0.70	29500.40	29476.70
M25-4	0.80	29716.25	29790.00
M25-5	0.85	31438.45	31482.10

Table 3: Contd.,

M25-6	1.20	35510.60	36395.50
M30-1	0.00	27474.65	27543.19
M30-2	0.55	28844.09	29286.29
M30-3	0.70	30176.20	29969.42
M30-4	0.80	30987.95	29780.83
M30-5	0.85	32315.05	31493.56
M30-6	1.20	32849.25	33137.29
M30-7	1.65	33593.40	33600.25

To reflect the real behaviour of RC material analytically, a significant number of permutations are required in the ANSYS beam model. Many factors govern the precise non-linear behaviour of RC beams, including the idealisation of reinforcement in concrete, the constitutive properties of concrete, the mesh density, the combination of boundary conditions for supports and symmetric planes, the incorporation of loading and support areas, the influence of shear reinforcement on flexural behaviour, the effect of convergence criterion, the effect of percentage of reinforcement, and many more. Table 3 and Figure 1 show the results of a comparison between the experimental and analytical values.

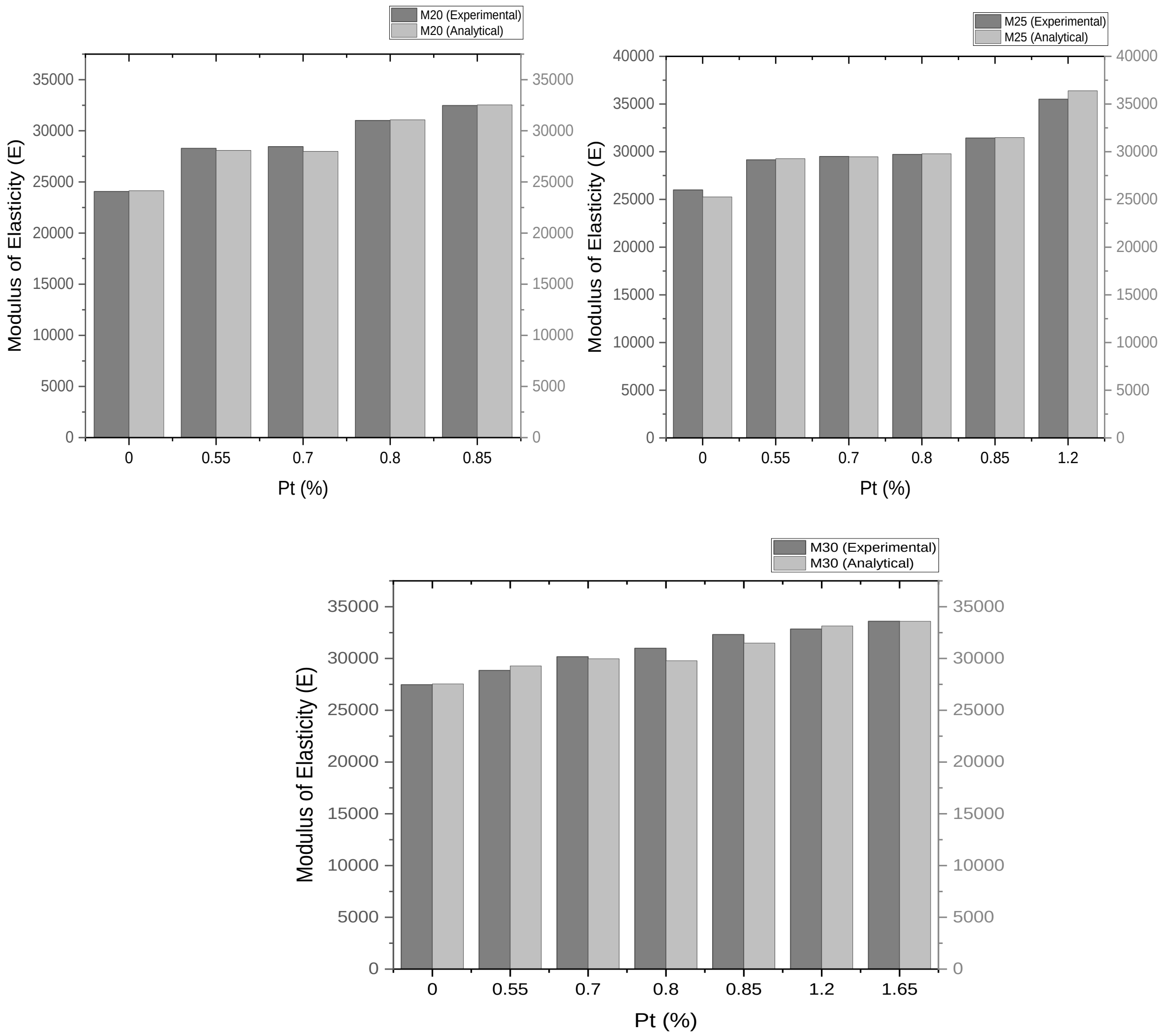

Figure 2: Experimental and Analytical Values of E

2. Evaluation of Young's Modulus for Column

Reinforced concrete columns that aren't perfectly circular benefit greatly from the use of rectangular links. When the column is subjected to axial compressive stresses, the core concrete is prevented from laterally expanding due to pressure in the lateral direction of the column section, which acts on the lateral ties. At the corners of the column section, the first fractures spread in a parallel direction with longitudinal bars as the axial stress increases. The concrete spalls off around the bending longitudinal bars. Following spalling, the restricted column displays marginally increased load-bearing capability. The longitudinal bars buckle and the hook of ties open when the axial load limit is reached. Increases in strength and ductility define the mechanical behaviour of constrained concrete. A number of confinement characteristics determine the extent of the boost. Because of the many parameters at play, including the kind of ties used for confinement, the concrete's compressive strength, and the volume ratio V, it may be difficult to clearly quantify the mechanical behaviour of confined concrete. The comparative values of experiments and ANSYS have been shown in Table 4 and Figure 2.

Table 4: Comparison of Experimental and Analytical Values

Mix No	P_t (%)	Modulus of Elasticity (E) in N/mm^2					
		Experimental			Analytical		
		M20	M25	M30	M20	M25	M30
1	0.00	22402.55	24552.80	27260.75	22065.10	24387.80	24552.80
2	0.895	23213.85	27809.89	30016.15	23582.05	28910.45	29653.15
3	1.390	24601.89	27322.10	32255.95	24019.20	27257.30	30022.15
4	1.840	26855.35	27481.95	34564.05	26947.55	27779.80	27515.90
5	2.010	27161.88	28248.40	34422.60	27727.60	28209.10	28037.55
6	2.710	28044.50	29123.05	35370.81	29280.00	29064.45	29262.80
7	3.570	29326.75	30454.70	36130.54	29062.10	30474.90	30092.20

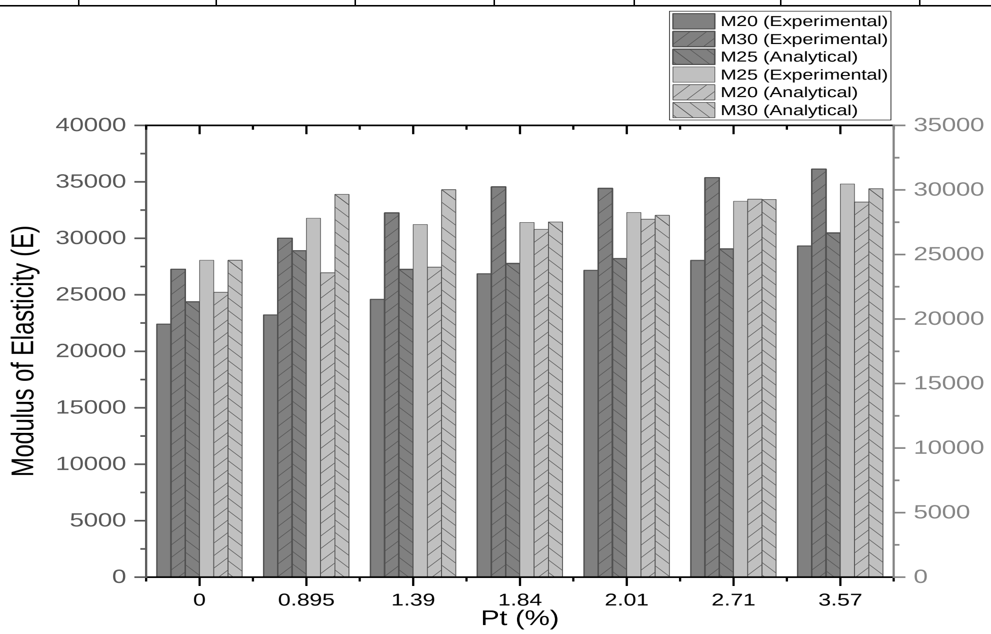

Figure 2: Experimental and Analytical Values of E

CONCLUSIONS

According to the Indian Standard requirements for RC beams, the suggested equation has a range of p_t between 0.54 and 1.63 percent of the gross area of the cross-section. The range for RC columns is 0.894–3.57 percent of the gross cross-sectional area. This precise range corresponds to the analysed models' geometric parameters.

- There is a close agreement (8% error) between the experimental and analytical values of modulus of elasticity for RC section for beams with different percentages of tension reinforcement.
- RC sections for columns with different percentages of longitudinal reinforcement have a modulus of elasticity that matches closely with analytical data (within a 1.3% error) from both experimental and analytical methods.
- At a volume ratio of 0.02, shear reinforcement in beams improves the modulus of elasticity, but changes in the volume ratio of ties in RC columns have little to no impact.
- The proposed equation of ERCC is shown to result in fewer elastic deformations in RC beams and columns than the usage of traditional E as specified by IS: 456-2000, by around 15%.
- The major action of bending moment in beams and columns of high-rise structures is found to be decreased by about 14% to 30% using the suggested ERCC. This reduction is location-specific. However, in the case of a column, axial loads are reduced by roughly 10%, but only slightly.
- Since both beams and columns in high-rise buildings experience significant flexural effects, the equation of ERCC proposed for beams can be safely applied to columns by simply adjusting the value of tension steel accordingly. This research has been found useful because it allows for steel savings compared to the traditional method.

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