A Comparative Review of Design and Analysis of G+3 Reinforced Concrete Building Using Staad.Pro Software

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***Abstract*—** The structural analysis and design of reinforced cement concrete (RCC) buildings require appropriate consideration of loading conditions, material properties, safety requirements, and design-code provisions. This study presents the analysis and design of a G+3 RCC residential building using STAAD.Pro software and compares the reinforcement requirements obtained using Indian Standard IS 456:2000 and American Standard ACI 318-2008. The building plan was prepared using AutoCAD and subsequently modelled in STAAD.Pro. Dead loads, live loads, and seismic loads were considered during structural analysis. Beams, slabs, columns, and footings were evaluated to determine the influence of the two design standards on reinforcement quantity and detailing. The results indicate that the total reinforcement quantity is 6,914.03 kg for IS 456:2000 and 8,789.56 kg for ACI 318-2008, representing an increase of approximately 27.13% under the American-code design. ACI 318-2008 requires 47.86% more reinforcement in beams, 81.73% more in columns, and 84.93% more in footings, whereas its reported slab reinforcement quantity is 19.50% lower. These variations are associated with differences in minimum reinforcement provisions, bar diameters, shear reinforcement, spacing, and detailing requirements. The study demonstrates the importance of comparative code-based design and highlights the usefulness of STAAD.Pro in evaluating reinforcement requirements and structural design economy.

Keywords: *Reinforced Concrete Building, STAAD.Pro, IS 456:2000, ACI 318-2008, Steel Reinforcement etc.*

I. INTRODUCTION

Reinforced cement concrete is one of the most widely used materials in residential construction because it combines the compressive strength of concrete with the tensile strength of steel reinforcement. The safety and serviceability of an RCC building depend on its structural configuration, material properties, applied loads, member dimensions, and reinforcement detailing. Beams, columns, slabs, and foundations must be designed to transfer loads safely while satisfying the applicable strength and serviceability requirements.

Structural analysis software has become an important tool for modern civil engineering practice. STAAD.Pro enables engineers to develop three-dimensional structural models, assign loading conditions, analyse member forces, and perform design checks. When used with appropriate engineering judgment, such software can improve the efficiency of structural analysis and facilitate comparisons between alternative designs.

Design standards differ in their approaches to load combinations, strength calculations, minimum reinforcement, shear design, and reinforcement detailing. IS 456:2000 is a principal Indian standard for plain and reinforced concrete, whereas ACI 318-2008 establishes requirements for structural concrete design under the American code framework. These standards aim to achieve structural safety, but their provisions may result in different reinforcement requirements for the same building.

The present research examines a G+3 RCC residential building using STAAD.Pro and compares reinforcement quantities obtained under IS 456:2000 and ACI 318-2008. The study considers beams, slabs, columns, and footings and investigates the contribution of different reinforcement provisions to the overall steel requirement. The comparison is intended to improve understanding of code-dependent design outcomes rather than to establish that one code is universally superior.

A. Research problem

Designing the same RCC building under different standards can produce different reinforcement quantities, even when the overall architectural arrangement remains unchanged. Without a systematic comparison, it is difficult to identify which structural elements contribute most to the difference and which design provisions govern the additional reinforcement.

B. Research gap

Previous studies reviewed in the project primarily investigated RCC building design using STAAD.Pro and Indian Standard provisions. The present study extends this approach by comparing the reinforcement requirements of a

single G+3 residential building under Indian and American concrete design standards.

C. Aim and objectives

The aim is to analyse and design a G+3 RCC building using STAAD.Pro and compare the reinforcement requirements under IS 456:2000 and ACI 318-2008.

The specific objectives are to:

1. Develop the building plan in AutoCAD and the structural model in STAAD.Pro.
2. Analyse the building under the specified dead, live, and seismic loads.
3. Design beams, slabs, columns, and footings according to the selected standards.
4. Quantify reinforcement requirements for each structural element.
5. Identify the principal reasons for differences in steel consumption.
6. Discuss the implications for structural design economy and code compliance.

II. LITERATURE REVIEW

Research on computer-aided structural design has demonstrated the usefulness of STAAD.Pro for modelling, analysing, and designing multistorey buildings. Earlier studies of G+3 residential structures have investigated member forces and reinforcement requirements under gravity and lateral loading. Such studies emphasize the importance of accurate structural modelling and appropriate load combinations.

Ranjan and Jaiswal, in the work cited in the project thesis on G+3 building analysis using STAAD.Pro and AutoCAD, examined software-based structural analysis and compared its results with manual calculations. The reported study highlights the efficiency of computer-based analysis and the importance of considering seismic effects.

Khandelwal and colleagues investigated the comparison between manual design and STAAD.Pro-based analysis for a multistorey residential building. Their work, as summarized in the project thesis, emphasizes the role of software in evaluating member forces, reinforcement, and design requirements.

Parekh's work on G+3 building design using STAAD.Pro similarly discusses structural modelling, load assignment, and automated design procedures. Related studies on RCC structures indicate that structural response and reinforcement demand depend on the building configuration, loading assumptions, member dimensions, and selected design provisions.

Despite these contributions, a project-specific comparison of reinforcement quantities under IS 456:2000 and ACI 318-2008 remains useful for understanding how differences in detailing and minimum reinforcement affect individual structural components.

Research contribution: This study presents an element-wise comparison of reported reinforcement quantities and identifies beams, columns, slabs, and footings as distinct contributors to the total difference between the two design approaches.

III. MATERIALS AND METHODOLOGY

A. Building configuration

The study considers a G+3 RCC residential building consisting of a ground floor and three upper floors. The architectural plan was prepared in AutoCAD, and the structural arrangement was modelled in STAAD.Pro.

Table 1. Summary of the study configuration

Parameter	Description
Building type	Residential RCC building
Number of floors	Ground floor + 3 upper floors
Architectural software	AutoCAD
Structural software	STAAD.Pro
Indian concrete design standard	IS 456:2000
American concrete design standard	ACI 318-2008
Location used in seismic calculations	Nagpur, Maharashtra
Seismic zone reported in thesis	Zone II
Zone factor adopted in thesis	0.10
Main comparison parameter	Reinforcement quantity (kg)
Structural elements	Beams, slabs, columns, and footings

The table summarizes the information available in the project thesis. Detailed material grades, member dimensions, support conditions, and all load combinations should be reported from the final verified model where required.

B. Structural modelling

The building geometry was developed from the architectural plan. Beams and columns were represented using structural members, and the applicable floor and foundation arrangements were defined. Material properties, member sections, and support conditions were assigned before performing the analysis.

The model was used to determine structural response under the specified loading conditions. The resulting member forces formed the basis for the subsequent design and reinforcement comparison.

C. Loading conditions

The project considered the following loading categories:

- Dead loads: Self-weight of structural members and applicable permanent loads from walls, floor finishes, and other building components.
- Live loads: Imposed loads associated with the intended residential occupancy.
- Seismic loads: Earthquake effects based on the project location and adopted seismic design assumptions.

For a technically consistent comparison, the applicable load combinations must be established separately under each code framework. The same physical building and occupancy should be represented in both models, while the relevant load standards and safety provisions must be applied correctly.

D. Design standards

IS 456:2000 was used for the Indian concrete design, while ACI 318-2008 was used for the American concrete design.

The comparison examines differences in reinforcement provisions, including minimum longitudinal steel, bar diameters, transverse reinforcement, spacing, concrete cover, and relevant strength factors.

ACI 318-2008 is a concrete design standard; it does not by itself establish every load definition required for a building analysis. Accordingly, the applicable American loading provisions and combinations must be documented to ensure a valid comparison.

E. Research methodology

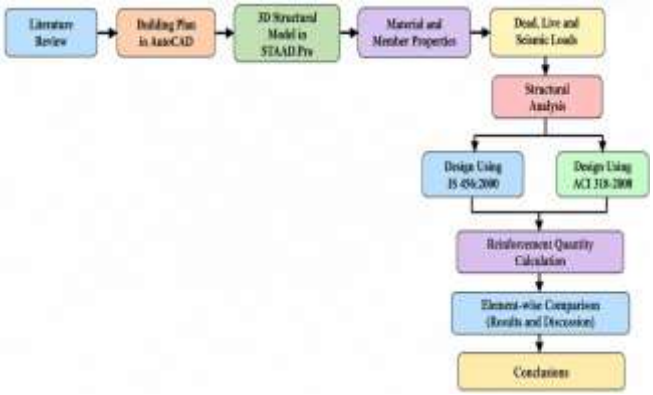


Figure 1. Research methodology for comparative analysis and design of the G+3 RCC building.

The methodology follows a common structural modelling and analysis stage, followed by two code-specific design stages. Reinforcement quantities are then compiled and compared for the same categories of structural elements.

F. Method of comparison

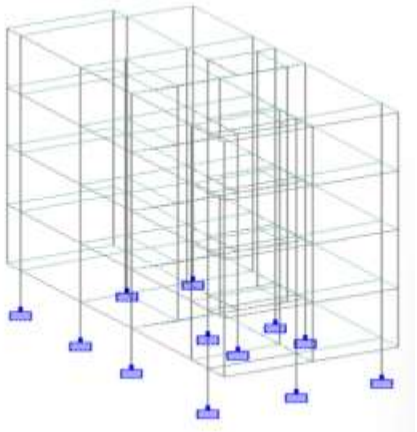
The percentage change in reinforcement was calculated using the IS design as the reference:

$$\% \text{ Change} = \frac{W_{ACI} - W_{IS}}{W_{IS}} \times 100$$

where:
- W_{ACI} is the reinforcement quantity obtained under ACI 318-2008.
- W_{IS} is the reinforcement quantity obtained under IS 456:2000.

A positive result represents an increase in the ACI design, whereas a negative result represents a decrease.

Modelling



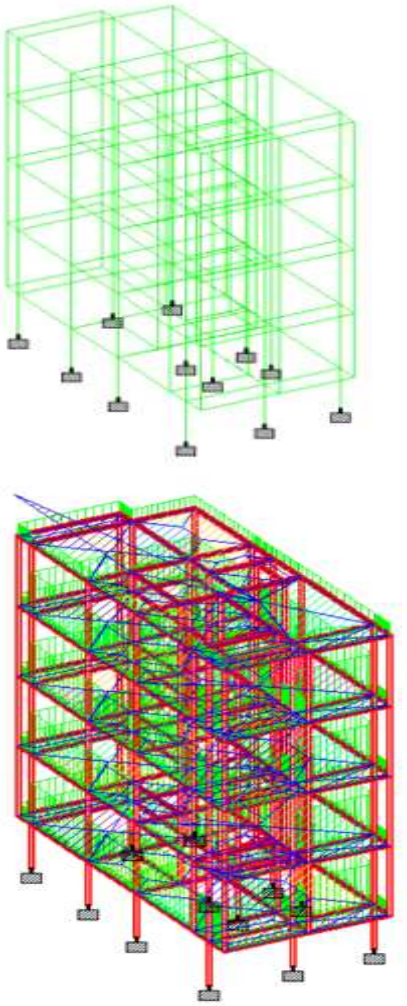


Figure 2. Modelling of Building

IV. RESULTS AND DISCUSSION

A. Comparison of total reinforcement quantity

The total reinforcement quantities reported in the thesis are presented in Table 2. The comparison indicates that the ACI-based design requires a greater total quantity of reinforcement than the IS-based design.

Table 2. Total reinforcement quantity obtained from the two design standards

Structural element	IS 456:2000 (kg)	ACI 318-2008 (kg)	Change (%)
Beams	2,049.28	3,030.13	+47.86
Slabs	3,051.00	2,456.20	−19.50
Columns	1,593.00	2,895.00	+81.73
Footings	220.75	408.23	+84.93
Total	6,914.03	8,789.56	+27.13

The overall increase is approximately 1,875.53 kg of reinforcement under ACI 318-2008. The element-wise results show that the differences are not uniform. Columns and footings have the largest percentage increases, while slabs show a reduction in the reported steel quantity. Beams also show a substantial increase.

B. Graphical comparison of reinforcement quantities

Reinforcement Quantity by Structural Element
Comparison of reported steel quantities under IS 456:2000 and ACI 318-2008. The chart excludes the total row to avoid double counting.

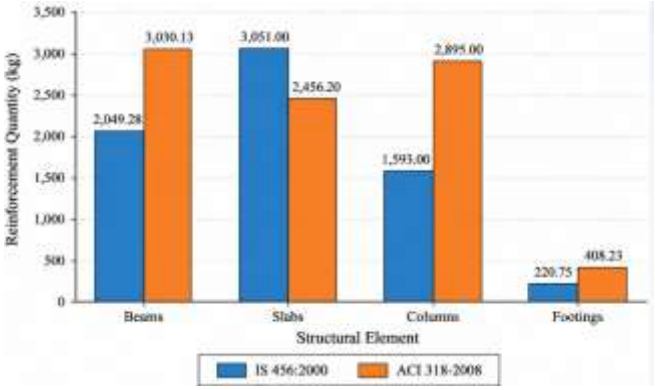


Figure 3. Bar chart comparing reinforcement quantities for beams, slabs, columns, and footings.

The graph shows that slab reinforcement is the only category in which the reported ACI quantity is lower than the IS quantity. The largest absolute quantity of reinforcement under the IS design is associated with slabs, whereas beams represent the largest quantity under the ACI design. Footings have the smallest absolute quantities in both designs, despite showing the largest percentage increase.

C. *Percentage change in reinforcement*

Percentage Change in Reinforcement Under ACI 318-2008
Percentage difference relative to IS 456:2000; negative values indicate lower ACI reinforcement.

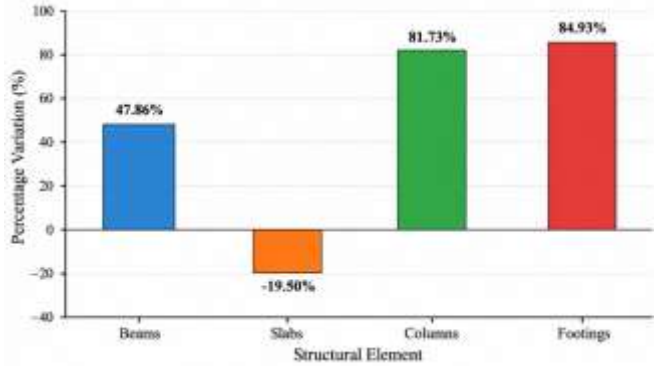


Figure 4. Percentage variation in reinforcement quantity relative to IS 456:2000.

The percentage comparison highlights the sensitivity of reinforcement requirements to design provisions. The footing increase of 84.93% is the highest, followed by columns at 81.73%. These percentages should be interpreted alongside the actual quantities because a large percentage increase in a relatively small component does not necessarily represent the largest contribution to the total steel difference.

D. *Beam reinforcement analysis*

The reinforcement quantity reported for beams increases from 2,049.28 kg under IS 456:2000 to 3,030.13 kg under ACI 318-2008. This represents an increase of 980.85 kg, or approximately 47.86%.

Table 3. Beam reinforcement comparison

Parameter	IS 456:2000	ACI 318-2008
Total beam steel	2,049.28 kg	3,030.13 kg
Reported change	—	+47.86%
Representative main-bar quantity for Beam 1	12.99 kg	10.20 kg
Representative stirrup quantity for Beam 1	6.98 kg	21.83 kg

The representative Beam 1 data show that the ACI design uses less main-bar steel but considerably more stirrup steel. This indicates that the total difference is strongly influenced by transverse reinforcement rather than by longitudinal reinforcement alone.

The thesis also reports different stirrup diameters and spacing arrangements. Such differences can affect reinforcement consumption, particularly in regions with higher shear demand. However, a final engineering interpretation should be based on verified member forces, shear design calculations, and the detailing requirements applicable to each code.

E. *Slab reinforcement analysis*

The total slab reinforcement quantity decreases from 3,051.00 kg under IS 456:2000 to 2,456.20 kg under ACI 318-2008. The difference is 594.80 kg, representing a reduction of approximately 19.50%.

Table 4. Slab reinforcement comparison

Parameter	IS 456:2000	ACI 318-2008
Total slab steel	3,051.00 kg	2,456.20 kg
Reported bar spacing	150 mm	200 mm
Reported arrangement	Cranked bars and distribution steel	Straight bars; different distribution detailing
Percentage change	—	−19.50%

The project attributes the lower ACI slab reinforcement to wider bar spacing and differences in bar arrangement. Nevertheless, the reported quantities must be checked against the reinforcement schedules for each slab panel, including the requirements for flexure, minimum steel, crack control, and serviceability.

F. *Column reinforcement analysis*

The column reinforcement increases from 1,593 kg under IS 456:2000 to 2,895 kg under ACI 318-2008, giving an increase of 1,302 kg or approximately 81.73%.

Table 5. Column reinforcement comparison

Parameter	IS 456:2000	ACI 318-2008
Total column steel	1,593 kg	2,895 kg
Minimum reinforcement ratio reported in the thesis	0.8%	1.0%
Representative longitudinal bar diameter	12 mm	20 mm
Percentage change	—	+81.73%

The reported difference is associated with minimum longitudinal reinforcement, bar selection, axial strength provisions, and transverse reinforcement detailing. The higher ACI steel quantity is therefore a result of the specific member designs and assumptions used in this project.

Column reinforcement must be verified against axial force, bending interaction, slenderness where relevant, and the applicable detailing provisions. The software-generated reinforcement should not be accepted without checking these requirements.

G. Footing reinforcement analysis

The reported footing reinforcement increases from 220.75 kg under IS 456:2000 to 408.23 kg under ACI 318-2008. The difference is 187.48 kg, corresponding to an increase of approximately 84.93%.

Table 6. Footing reinforcement comparison

Parameter	IS 456:2000	ACI 318-2008
Total footing steel	220.75 kg	408.23 kg
Reported bar arrangement	8 mm bars at 300 mm	Different bar diameters and spacing
Reported footing dimensions	2.3 × 2.3 m	1.6 × 1.6 m
Percentage change	—	+84.93%

The results indicate that a smaller footing plan area does not necessarily lead to a smaller reinforcement quantity. Bar diameter, reinforcement spacing, effective depth, bending demand, and shear requirements influence the final steel weight.

Since the reported footing dimensions differ between the two designs, the comparison should be regarded as a comparison of the project's resulting designs rather than a perfectly controlled comparison of reinforcement provisions alone. Foundation adequacy also depends on verified soil properties, bearing pressure, settlement, bending, and shear checks.

H. Overall interpretation

The results show that the ACI-based design uses approximately 27.13% more total reinforcement. The increased quantities in beams, columns, and footings outweigh the reduction reported for slabs.

The principal observations are summarized in Table 7.

Table 7. Summary of the comparative findings

Observation	Engineering interpretation
Higher total steel under ACI	The combined reinforcement quantities of the frame and foundations exceed the slab saving.
Increased beam steel	Differences in stirrup requirements and detailing contribute substantially.
Reduced slab steel	Wider spacing and different bar arrangements are reported in the ACI design.
Increased column steel	Minimum reinforcement, longitudinal bar selection, and strength provisions influence the result.
Increased footing steel	Different footing dimensions and reinforcement layouts affect the total quantity.
Overall design economy	IS uses less reported steel for this building, but a full cost comparison is still required.

The study indicates that the choice of design standard can materially influence reinforcement consumption. However, reinforcement quantity alone is not sufficient to determine which design is safer or more economical in every situation. A comprehensive assessment should also consider concrete quantities, formwork, labour, construction feasibility, serviceability, and compliance with the relevant standards.

V. CONCLUSION

The present study compared the analysis and design of a G+3 RCC residential building using STAAD.Pro under IS 456:2000 and ACI 318-2008. The reinforcement quantities reported in the project demonstrate that different design-code provisions can substantially influence the steel requirements of individual structural elements.

The total reinforcement quantity was 6,914.03 kg under IS 456:2000 and 8,789.56 kg under ACI 318-2008, representing an increase of approximately 27.13%. Beam reinforcement increased by 47.86%, column reinforcement by 81.73%, and footing reinforcement by 84.93%. In contrast, the reported slab reinforcement quantity decreased by 19.50%.

These differences are associated with minimum reinforcement requirements, longitudinal bar selection, transverse reinforcement, spacing, and other detailing provisions. The findings suggest that IS 456:2000 provides a lower total steel quantity for the building and assumptions considered. However, the result does not establish the universal superiority of either standard. The structural safety and economy of each design must be verified through consistent loading assumptions, code-specific strength checks, serviceability assessment, and complete detailing verification. STAAD.Pro is useful for comparative design, provided that the model and its results are independently checked by a qualified structural engineer.

VI. LIMITATIONS OF THE STUDY

The following limitations should be acknowledged in the research paper:

1. The investigation concerns a single G+3 residential building, so the findings may not apply to buildings with different heights, layouts, or structural systems.
2. The reported comparison primarily evaluates reinforcement quantities rather than providing a complete comparison of structural reliability or life-cycle cost.
3. Differences in member dimensions and detailing between the two designs can influence the results independently of the design-code provisions.
4. A complete comparison requires documentation of material grades, load combinations, strength factors, support conditions, and the associated loading standards.
5. Some slab reinforcement values in the thesis appear in different forms in the summary and conclusion. The panel-wise quantities and aggregation should be verified before publication.
6. The reported reinforcement quantities should be checked against the final STAAD.Pro design outputs and reinforcement schedules before being treated as verified results.

VII. FUTURE SCOPE

Further research can extend this work by:

- Comparing the same building under additional international concrete design standards.
- Evaluating alternative structural systems, including shear walls and braced arrangements.
- Comparing STAAD.Pro results with ETABS or independent hand calculations.
- Assessing the influence of different concrete and steel grades on reinforcement requirements.
- Conducting a detailed cost comparison involving steel, concrete, formwork, and labour.
- Investigating structural performance under additional seismic analyses and relevant serviceability checks.

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