

Comparative Study of RCC and Steel Structures for Structural Analysis Using STAAD.PRO

Hemlata Sikarwar, Chitranjan Kumar, Praveen Verma, Mayank Chauhan, Abhishek Rana

Department of Civil Engineering, Sri Venkateshwara University, Gajraula (UP), 244236

Abstract - The increasing demand for sustainable construction practices has led to the need for evaluating the environmental impacts of different structural materials. This study presents a Comparative Study of RCC and Steel Structures for structural analysis and design. STAAD. Pro, a widely used structural engineering software, is employed to model two representative building structures-one constructed with steel and the other with concrete-focusing on aspects such as material efficiency, load-bearing capacity, and performance. With consideration for wind, seismic loads, and other environmental factors, it can offer a thorough analysis of a structure's static and dynamic responses. Comparative evaluation of the seismic performance of a steel-concrete composite building frame located in earthquake zone III, Wind Speed 44m/s and a (G+2) storey RCC building. First, a 3D model of the structure is created. This model may then be analyzed using the robust finite element analysis program found in STAAD Pro.

Key Words: RCC & Steel structure, STAAD Pro software & RCDC, Loads, Maximum bending moment, Maximum shear force, Structural Optimization.

1 INTRODUCTION

1.1 Background of the study

The construction industry plays a vital role in shaping the built environment, and one of the most crucial decisions in the design of any structure is the choice of materials. Among the materials commonly used for building and infrastructure projects, Reinforced Cement Concrete (RCC) and Steel are two of the most widely employed options, each offering distinct advantages and challenges. RCC structures are known for their durability, cost-effectiveness, and ease of construction, while steel

structures are valued for their strength, flexibility, and lightweight properties. However, the choice between

these two materials is influenced not only by material properties but also by factors such as cost, performance, constructability, and sustainability.

With the growing complexity of modern buildings, the demand for efficient and reliable structural designs has increased. Engineers must carefully analyse the structural performance of different materials under various loading conditions to ensure that they meet both safety and serviceability requirements. The advent of structural analysis software like STAAD.Pro has revolutionized the way engineers model, analyze, and design structures. STAAD.Pro is one of the most widely used tools for analyzing both RCC and steel structures, offering advanced capabilities in simulating the behavior of materials under various load scenarios, optimizing designs, and evaluating performance against various standards and codes.

While both RCC and steel structures have been extensively studied and used in the industry, a comprehensive comparative study focusing on their structural behaviour, design efficiency, and performance under realistic loading conditions is essential for making informed material selection decisions. This study **Aims** to provide such a comparison by using STAAD.Pro to analyse both RCC and steel structures, focusing on key factors such as:

- **Load-Bearing Capacity:** How both materials respond to different types of loads (dead load, live load, wind load, seismic load, etc.).
- **Deflection and Stability:** Comparative evaluation of deflections, lateral stability, and overall safety of RCC and steel structures.
- **Material Efficiency:** The amount of material used, design optimization, and overall cost-effectiveness of the two materials.
- **Constructability and Time Efficiency:** Evaluation of construction timelines, complexity, and ease of implementation for RCC and steel structures.

1.2 Objectives of the study

The primary objective of this study is to conduct a comparative structural analysis of RCC and steel structures using STAAD.Pro. The study will aim to:

1. **Analyse the Structural Behavior** of both RCC and steel structures under various load conditions, focusing on performance factors such as deflection, stress distribution, and stability.
2. **Evaluate the Design Efficiency** of RCC and steel, including material optimization, structural adequacy, and cost-effectiveness.
3. **Compare the Safety and Serviceability** of both materials, based on industry standards and codes.
4. **Assess the Construction Feasibility** of each material in terms of construction time, labour, and complexity.

1.3 Scope of the study

This study will involve the modelling and analysis of two representative structures: one designed with Reinforced Cement Concrete (RCC) and the other with Steel. The structural analysis will focus on the following aspects:

- **Material Properties:** Standardized material properties for RCC and steel as per national or international codes.
- **Load Combinations:** Incorporation of different load types and their impact on structural performance.
- **Deflections and Stresses:** Evaluation of deflection limits and stress distribution across the structure.
- **Optimization:** Optimization of material usage and design for both RCC and steel, considering safety factors and serviceability criteria.

1.4 Theoretical framework and Research questions

This investigation is grounded in the principles of structural mechanics, with a particular emphasis on the fundamental differences in material behavior between concrete and steel. Concrete is characterized by its high compressive strength but limited tensile capacity, which necessitates reinforcement, while steel exhibits uniform strength in both tension and compression, along with significantly higher strength-to-weight ratios. These inherent material properties give rise to distinct structural behaviours, which this research seeks to quantify under controlled conditions.

This research seeks to provide evidence-based recommendations for selecting the appropriate structural system, tailored to specific project requirements and constraints.

2 LITERATURE SURVEY

2.1 Introduction to RCC and Steel Structures

The use of **Reinforced Cement Concrete (RCC)** and **Steel** as primary building materials has a long history in civil engineering.

- **RCC Structures:** RCC is widely used in construction because of its affordability, versatility, and durability. Concrete offers good compressive strength, while reinforcement (typically steel bars) enhances its tensile strength. RCC is commonly used for foundations, slabs, beams, and columns.
- **Steel Structures:** Steel is known for its high tensile strength, flexibility, and lightweight nature. Steel is typically used in high-rise buildings, bridges, and large-span structures. It offers faster construction due to prefabrication and reduced construction time.

2.2 Structural Analysis Methods in Civil Engineering

Structural analysis is a key aspect of designing building or infrastructure. It involves determining the effects of loads and forces on structural elements, ensuring safety and performance under various conditions. The two primary categories of structural analysis are:

- **Classical (Manual) Methods:** These include analytical solutions, matrix methods, and beam theory used for simple structures.
- **Computational Methods:** With the advent of computer software, complex structures can now be modeled more accurately. STAAD.Pro is one such advanced software that provides comprehensive structural analysis solutions for both RCC and steel structures.

2.3 Use of STAAD.Pro for Structural Analysis of RCC and Steel Structures

The application of **STAAD.Pro** in analysing both RCC and steel structures has been the subject of several studies. STAAD.Pro allows engineers to model complex structures, perform detailed analyses, and optimize designs for both materials.

1. Application to RCC Structures:

○ **Reddy and Rajasekaran (2015)** used STAAD.Pro for analysing multi-story **RCC frames** subjected to **seismic loads** and **dead loads**. Their study showed that STAAD.Pro could predict **deflection**, **bending**, and **shear stresses** with high accuracy, ensuring compliance with **IS codes**.

2. Application to Steel Structures:

○ In the study by **Sharma and Gupta (2018)**, STAAD.Pro was used to model and analyse **steel high-rise buildings**. The authors demonstrated how STAAD.Pro could handle **dynamic analysis** to evaluate the building's response to **earthquake** and **wind loads**. The software's ability to model **steel frames**, including connections and joints, was highlighted as one of its key strengths.

3. METHODOLOGY

3.1 General

The methodology adopted for this project involves the structural analysis and design of a G+2 utility building using two different structural systems, namely Reinforced Cement Concrete (RCC) frame and Steel frame, with identical plan dimensions and loading conditions. The objective is to ensure a fair comparison between both systems in terms of structural behaviour, member forces, economy, and suitability.

The building is analysed and designed using **STAAD.Pro software** in accordance with **Indian Standard Codes**.

3.2 Selection of Building Parameters

The basic building parameters are selected based on practical utility building requirements.

Criteria for Selection:

- **Building Type:** An Industrial Utility building is selected as the representative structure for the analysis. This is a common type of construction, where both RCC and Steel can be used effectively.
- **Dimensions and Layout:** The buildings will have certain dimensions and additional area for Staircases and load requirements, ensuring a fair comparison.
- **Number of Floors and Heights:** The building will have certain no. of floors at some heights.

- **Floor Area:** Each floor will have a specific floor area
- **Structural System:** The RCC building will be designed using a **frame system** (beams and columns), while the steel structure will be designed using a **steel frame system** with similar load distribution and floor layout.

3.3 Material Properties of the Structures

Two different Structural systems is considered.

1. RCC Structure:

- **Material Properties:**

- **Concrete Grade:** M25/M30 (Compressive Strength: 25 MPa/30 MPa)
- **Reinforcement:** TMT Steel (Fe500 grade)
- **Unit weight of Concrete:** 25KN/m³

2. Steel Structure:

- **Material Properties:**

- **Steel Grade:** IS 2062 (Structural Steel)/IS 800
- **Yield Strength:** 250 MPa/350 MPa
- **Unit weight of Steel:** 78.50KN/m³

3.4 Loads Considered

To evaluate the performance of the RCC and steel structures under realistic conditions, various **loads & load combinations** will be applied. These combinations simulate different **live loads**, **dead loads**, **wind loads**, and **seismic forces** that the structures may experience.

3.4.1. Dead Load:

Dead load including self-weight of various materials relevant to the design work is considered as per IS: 875 (Part – 1) latest revision. Water load & suspended loads, if any, such as false ceiling, ducts etc. are also considered as dead loads and are applied wherever applicable.

Basic densities of building materials:

- Reinforced Concrete: 25 KN/m³
- Plain Concrete: 24 KN/m³
- AAC Blocks: 10 KN/m³
- Red clay Bricks: 20 KN/m³
- Structural Steel: 78.50 KN/m³

Other Dead loads:-

- Floor finishes 50 – 75 mm grade slab (IPS Flooring) on the main slab for earthing Strip and other utility passes through below flooring: 1.5 KN/m²
- False ceiling: 1.5 KN/m²
- Grating Floors: 1.5 KN/m²
- External brick walls (230 mm): 5.5 KN/m² (including plaster)
- External AAC block wall (250mm): 3.75 KN/m² (Including plaster)
- Internal latest revision block wall (100 / 150mm): 2.0 KN/m² (Including plaster)
- Internal brick walls (115 mm): 3.1 KN/m² (Including plaster)
- Waterproofing (Integral cement-based surface- 200mm average): 4.0 KN/m²

3.4.2. Live Load:

Appropriate equipment / machinery load will be considered as per manufacturer's detail

The loads assumed as imposed loads are applied in accordance to provisions given in IS 875 (Part 2) latest revision.

- First Floor: 5.0 KN/m²
- Second Floor: 5.0 KN/m²
- Terrace Floor: 5.0 KN/m²
- Undefined Partition wall load (equivalent): 1.5 KN/m²
- Staircases, corridors & canteen: 4.0 KN/m²
- Toilets & accessible false ceilings: 2.0 KN/m²
- Live Load on accessible Roofs with installation of Solar Panels: 2.5 KN/m²

3.4.3. Wind Load:

• **Wind Load Calculation:** Wind loads will be applied according to the **IS 875 (Part 3)** code for wind loads in India. Wind pressures will be calculated based on the building's location, height, and exposure category.

- Basic wind speed = 44 m/s
- Terrain category = 2
- Risk coefficient = 1.0

• **Load Direction:** Wind load will be applied in both the **x-direction** (along the length) and the **z-direction** (along the width) for both RCC and steel buildings.

3.4.4. Seismic Load:

• **Seismic Analysis:** The structures will undergo **seismic analysis** based on the **IS 1893 (Part 1)** code for earthquake-resistant design. The building will be considered located in **Seismic Zone III** (moderate seismic risk).

- Zone factor (Z): 0.16
- Importance factor (I): 1.0
- Response reduction factor (R): 5.0

3.4.5. Load Combinations:

The following load combinations will be considered to check the **strength** and **stability** of both RCC and steel structures:

Strength

- 1.5 (DL + LL)
- 1.2 (DL + LL + WL/EL)
- 1.5 (DL + WL/EL)
- 0.9 DL ± 1.5 WL/EL

Serviceability

- (DL + LL)
- (DL + 0.8LL + 0.8WL/EL)
- (DL + WL/EL)

Load combinations are applied with the factors mentioned above. These Primary load cases are applied on the structure with different load combinations to arrive at most critical cases of design of the structural members

3.4.6. Deflections

Deflections are to be checked for load combinations of service loads and are checked in accordance to IS 800:2007 for steel structure members/components & IS 456:2000 for R.C.C. members/components.

Deflections for Steel structure members/components:

a. Permissible Vertical Deflection

- Purlins & Girts for Live Load/ Wind Load: Span/150
- Roof Rafter (supported & cantilever span) under Live load / wind load: Span/180
- Floor Beams (supported & cantilever span) : Span/300

b. Permissible Lateral Deflection

- Column height / 300

Deflections for R.C.C. members/components:

Calculated vertical deflections for structural members shall not exceed the following:

- For cantilever beams 7
- For simply supported beams 20
- For continuous beams 26

The calculated Vertical deflections due to load combinations for building shall not exceed the following:

- Beam & slab = $L/250$ or 20 mm whichever is less

The calculated lateral deflections due to load combinations for building shall not exceed the following:

- Column = $h/250$ or 20 mm whichever is less

3.5 Performing Structural Analysis

Once the models and load combinations are set, the next step is to perform a structural analysis to evaluate the behaviour of both the RCC and steel structures under the applied loads.

1. Types of Analysis:

- **Linear Static Analysis:** To determine the **deflections, stresses, and internal forces** (bending, shear, axial forces) under the applied loads.
- **Seismic Analysis:** To assess the structure's behaviour under earthquake loading (**Static loading**).
- **Wind Load Analysis:** To evaluate the effect of **wind forces** on the structural stability.

STAAD.Pro will be used to obtain results for various **internal forces**, including:

- **Bending Moments**
- **Shear Forces**
- **Axial Forces**
- **Deflections**

3.7 Software Tools

- **STAAD.Pro:** Used for structural modeling, analysis, and optimization of both RCC and steel structures.
- **RCDC :** Used for designing footings, columns and beams

- **Microsoft Excel:** Used for calculating additional parameters, optimizing designs, and preparing the cost comparison.

- **Staad Advanced Foundation:** Used for designing Raft combined footings, Pile Raft foundations.

4. CASE STUDY AND ANALYSIS

4.1 Introduction

This chapter presents a case study of a mid-rise Utility building modeled with both RCC (Reinforced Cement Concrete) and Steel materials. The analysis of these two structures is carried out using the structural modeling and analysis methodology described in Chapter 3. The building is designed for a total of Three floors, with a typical floor area of 1250 m² per floor. The results obtained from STAAD.Pro will be compared in terms of structural behavior, material usage, deflections, stresses, and overall cost-effectiveness.

The case study aims to evaluate the structural performance of both materials under dead load, live load, wind load, and seismic load. The comparison will help assess which material (RCC or Steel) is more suitable for different types of building construction based on performance and cost-effectiveness.

4.2 Structural Model and Design Parameters

Both RCC and Steel structures are modeled with the following parameters:

- **Number of Floors:** 3 floors
- **Floor Area:** 1250 m² per floor
- **Total Height of Building:** 14 meters
- **Column Spacing:** 6 meters and 5 meters (in both directions)
- **Live Load:** 5kN/m²
- **Dead Load:** Self-weight of structural elements plus floor finishes and partitions
- **Wind Load:** Based on **IS 875 Part 3-2015** for wind load calculation
- **Seismic Load:** Based on **IS 1893 (Part 1)-2016** for earthquake design, with the building located in **Seismic Zone III**

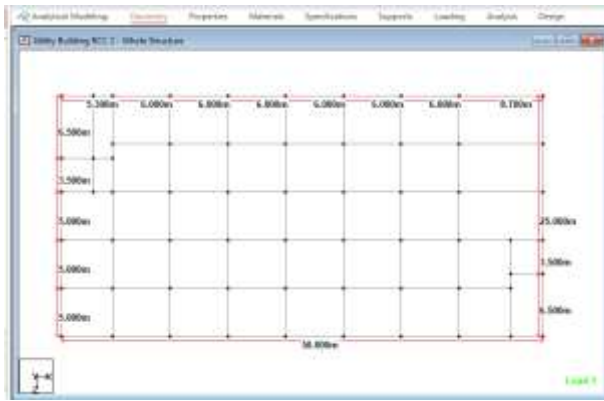


Fig:1 - Plan of Utility Building

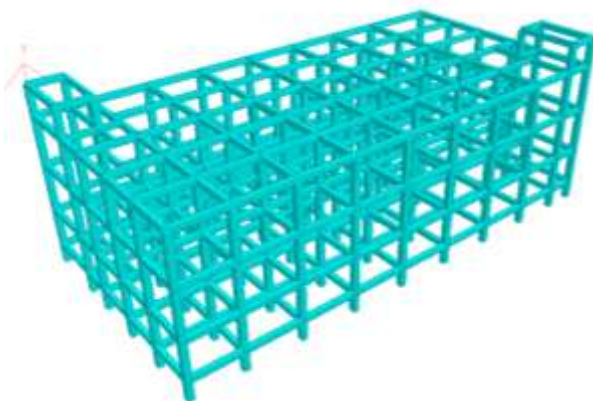


Fig:2 - 3D View of RCC Structure

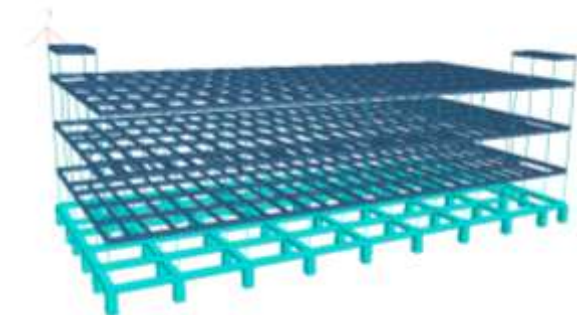


Fig:3 - 3D View of Steel Structure

The following **material properties** are used for the modeling:

- **RCC Structure:**
 - **Concrete Grade:** M30 (Compressive Strength = 30 MPa)
 - **Steel Grade:** Fe500 (Yield Strength = 500 MPa)
 - **Slab Thickness:** 150 mm
 - **Beam Dimensions:** 450mm x 600 mm
 - **Column Dimensions:** 600 mm x 600 mm

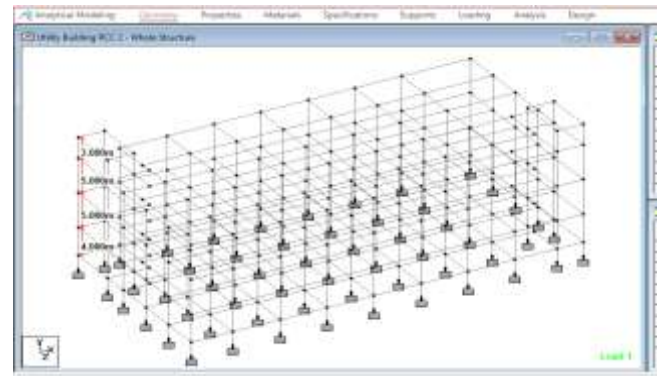


Fig:4 - STAAD.Pro Analytical Model – RCC

- **Steel Structure:**
 - **Steel Grade:** IS 2062 (Yield Strength = 250 MPa/350MPa)
 - **Beam Section:** NPB 400X180X66.31/ NPB 450X190X92.4(for larger span)
 - **Beam Section:** NPB 300X150X49.32 (For chequered plate supporting)
 - **Column Section:** Star 400/Star 450
 - **Floor System:** Composite floor (steel deck with concrete topping)

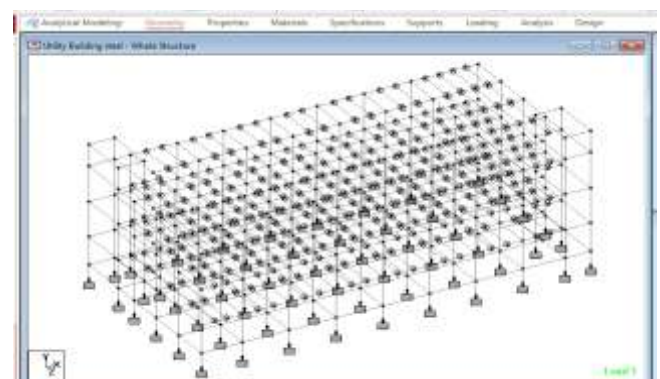


Fig:5 - STAAD.Pro Analytical Model – Steel

4.3 Loading and Analysis Procedure

The following loading conditions and analysis procedures were applied to both RCC and Steel structures in **STAAD.Pro**:

4.3.1. Dead Load:

- The dead load includes the self-weight of all structural elements such as beams, columns, slabs, and floor finishes.
- STAAD.Pro calculates the self-weight automatically based on the material density and dimensions of the members.

Table 1 Dead Load

a)	First Floor slab	:	5.25 KN/m ²
b)	Second Floor	:	5.25 KN/m ²
c)	Terrace Floor	:	5.25 KN/m ²
d)	Brick wall load based on different heights		23 kn/m
e)	Staircases & corridors	:	4.0 KN/m ²
f)	Toilets & accessible false ceilings.	:	2.0 KN/m ²

4.3.2. Live Load:

The loads assumed as imposed loads are applied in accordance to provisions given in IS 875 (Part 2) latest revision.

Table 2 Live Load

a)	First Floor	:	5.0 KN/m ²
b)	Second Floor	:	5.0 KN/m ²
c)	Terrace Floor	:	5.0 KN/m ²
e)	Staircases & corridors	:	4.0 KN/m ²
f)	Toilets & accessible false ceilings.	:	2.0 KN/m ²

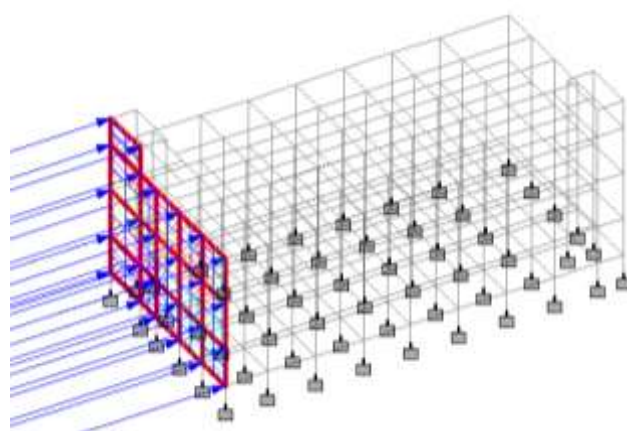
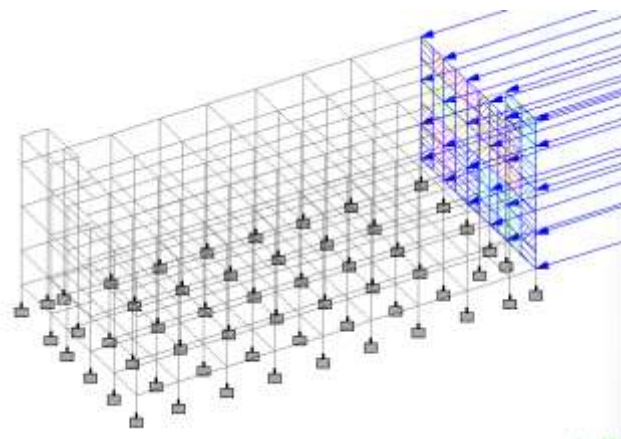
4.3.3. Wind Load:

• **Wind Load Calculation:** Wind loads will be applied according to the **IS 875 (Part 3)** code for wind loads in India. Wind pressures will be calculated based on the building's location, height, and exposure category.

- Basic wind speed (V_b) : 44 m/s
- Design wind speed (V_z) : $V_b \times k_1 \times k_2 \times k_3 \times K_4$
- K_1 (for 50 years of design life factor): 1.0 As per IS 875 pt. 3: 2015
- K_2 (for terrain type factor) : 1.05 Variable As per IS 875 pt. 3: 2015
- The Value of K_2 is used as constant for height up to 10m. Height above 10 m the k_2 value increases linearly

conforming to IS 875 pt. 3: 2015

- K_3 (land topography factor) : 1.0 IS 875 pt 3: 2015
- K_4 (importance factor for the cyclonic region): 1.5 IS 875 pt 3: 2015
- The pressure coefficient for clad building based on the height, length and breadth of the building will be taken conforming to clause no. 6.3.2.1 of IS 875 (Part 3): 2015.
- **Load Direction:** Wind load will be applied in both the **x-direction** (along the length) and the **z-direction** (along the width) for both RCC and steel buildings.


Fig:6 - Wind load Acting on (+)X Direction

Fig:7 - Wind load Acting on (-)X Direction

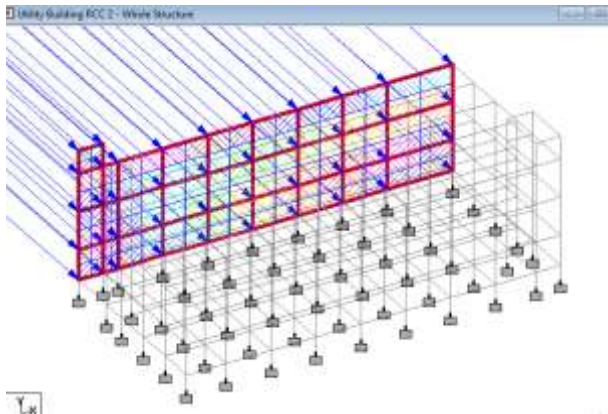


Fig:8

- Wind load Acting on (+)Z Direction

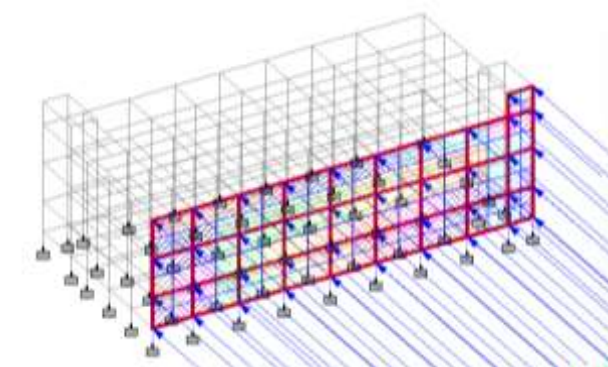


Fig:9 - Wind load Acting on (-)Z Direction

4.3.4. Seismic Load:

• **Seismic Analysis:** The structures will undergo seismic analysis based on the **IS 1893 (Part 1)** code for earthquake-resistant design. The building will be considered located in **Seismic Zone III** (moderate seismic risk).

- Zone factor (Z): 0.16
- Importance factor (I): 1.0
- Response reduction factor (R): 5.0

4.3.5. Effect of Wind Load And Earthquake Load on Foundation:

The effect of wind / earthquake loads will be considered in limit state with load factors as per provision given in IS 456:2000 for R.C.C. structure. The permissible bearing capacity of Soil / Hard Rock will be increased as per IS code while considering the effect of earthquake/ wind.

4.3.6. The wind and earthquake are considered to act on the structure separately and not simultaneously as per IS 875 Pt 3: 2015 Code provisions.

LOAD CASES: PRIMARY LOAD CASES

1. Earthquake in X- direction (EQX)

2. Earthquake in Z- direction (EQZ)
3. Dead Load
4. Live Load
5. Wind Load X- direction
6. Wind Load Z- direction

4.3.7. Load Combinations:

The following load combinations will be considered as per IS 456:2000 & similarly partial load factors should be considered as per IS 800:2007 including for IS 1893 pt 1: 2016 for seismic loads combinations with static loads and IS 875 latest revisions for wind load combinations with static loads,

Few of usual load combinations are mentioned below and all load combinations will be applied in STAAD software as per above mentioned latest code provisions as applicable,

FOR LIMIT STATE OF SERVICIBILITY (RCC & STEEL BUILDINGS)

1. $1.0 * DL + 1.0 * LL$
2. $1.0 * DL + 1.0 * EQX(+VE)$
3. $1.0 * DL + 1.0 * EQX(-VE)$
4. $1.0 * DL + 1.0 * EQZ(+VE)$
5. $1.0 * DL + 1.0 * EQZ(-VE)$
6. $1.0 * DL + 0.8 * LL + 0.8 * EQX(+VE)$
7. $1.0 * DL + 0.8 * LL + 0.8 * EQX(-VE)$
8. $1.0 * DL + 0.8 * LL + 0.8 * EQZ(+VE)$
9. $1.0 * DL + 0.8 * LL + 0.8 * EQZ(-VE)$
10. $1.0 * DL + 1.0 * WX(+VE)$
11. $1.0 * DL + 1.0 * WX(-VE)$
12. $1.0 * DL + 1.0 * WZ(+VE)$
13. $1.0 * DL + 1.0 * WZ(-VE)$
14. $1.0 * DL + 0.8 * LL + 0.8 * WX(+VE)$
15. $1.0 * DL + 0.8 * LL + 0.8 * WX(-VE)$
16. $1.0 * DL + 0.8 * LL + 0.8 * WZ(+VE)$
17. $1.0 * DL + 0.8 * LL + 0.8 * WZ(-VE)$

FOR LIMIT STATE OF STRENGTH

(RCC & STEEL BUILDINGS)

1. $1.5 * DL + 1.5 * LL$
2. $1.5 * DL + 1.5 * EQX(+VE)$
3. $1.5 * DL + 1.5 * EQX(-VE)$
4. $1.5 * DL + 1.5 * EQZ(+VE)$

5. $1.5*DL + 1.5*EQZ(-VE)$
6. $1.2*DL + 1.2*LL + 1.2*EQX(+VE)$
7. $1.2*DL + 1.2*LL + 1.2*EQX(-VE)$
8. $1.2*DL + 1.2*LL + 1.2*EQZ(+VE)$
9. $1.2*DL + 1.2*LL + 1.2*EQZ(-VE)$
10. $0.9*DL + 1.5*EQX(+VE)$
11. $0.9*DL + 1.5*EQX(-VE)$
12. $0.9*DL + 1.5*EQZ(+VE)$
13. $0.9*DL + 1.5*EQZ(-VE)$
14. $1.5*DL + 1.5*WX(+VE)$
15. $1.5*DL + 1.5*WX(-VE)$
16. $1.5*DL + 1.5*WZ(+VE)$
17. $1.5*DL + 1.5*WZ(-VE)$
18. $1.2*DL + 1.2*LL + 1.2*WX(+VE)$
19. $1.2*DL + 1.2*LL + 1.2*WX(-VE)$
20. $1.2*DL + 1.2*LL + 1.2*WZ(+VE)$
21. $1.2*DL + 1.2*LL + 1.2*WZ(-VE)$
22. $0.9*DL + 1.5*WX(+VE)$
23. $0.9*DL + 1.5*WX(-VE)$
24. $0.9*DL + 1.5*WZ(+VE)$
25. $0.9*DL + 1.5*WZ(-VE)$

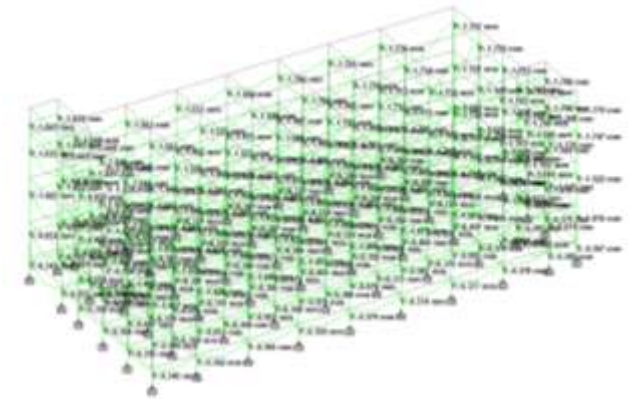


Fig:10 - RCC Deflection

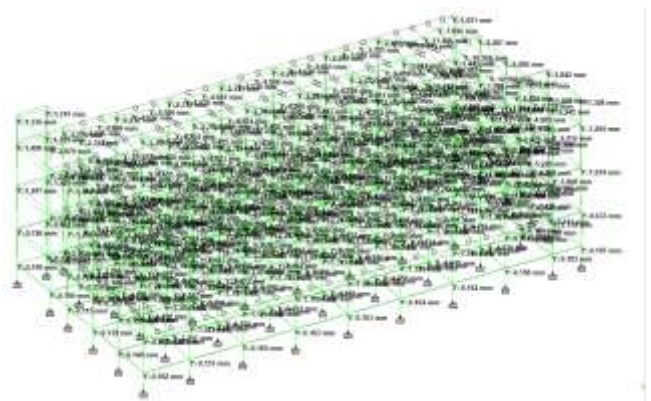


Fig:11 - Steel Deflection

The analysis results include deflections, stresses, bending moments, shear forces, and axial forces for both RCC and Steel structures.

4.4 Structural Behavior and Results

The following results were obtained from the structural analysis of both RCC and Steel buildings in STAAD.Pro:

4.4.1. Deflections

- **RCC Structure:** The maximum deflection observed for the RCC building was 3.9mm under the dead load and live load combination. The deflection remained within the permissible limits defined by IS 456:2000 (which allows a maximum deflection of $L/250$ for beams).
- **Steel Structure:** The maximum deflection observed for the steel building was 18.2 mm, which is also well within the permissible limits. Steel's higher strength-to-weight ratio contributed to lower deflections compared to RCC. As per above details figures are given below:

4.4.2. Stress Distribution

- **RCC Structure:** The maximum bending stress in RCC beams was observed to be 17 MPa, while the shear stress in columns was 3 MPa. The axial stress in the RCC columns did not exceed the design limits for the material.
- **Steel Structure:** In the steel structure, the bending stress in steel beams was found to be 180 MPa, while the shear stress in the steel columns was 10 MPa. Both values are well within the allowable stress limits for IS 2062 steel.

4.4.3. Internal Forces

- **RCC Structure:** The internal forces, including bending moments and shear forces, were higher in the RCC structure, especially in the columns and slabs. This is due to the heavier self-weight of the RCC structure compared to steel.
- **Steel Structure:** The bending moments and shear forces in the steel structure were relatively lower due to the lighter weight of the steel frame. The axial forces in the steel columns were higher compared to the RCC columns, but the steel structure was able to handle these forces more efficiently due to its high tensile strength.

Bending Moment Diagram of RCC & STEEL Structure

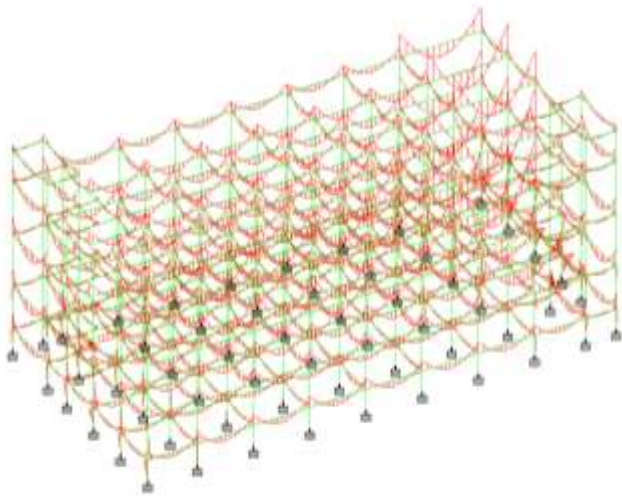


Fig:12 - Bending Moment Diagram of RCC Structures

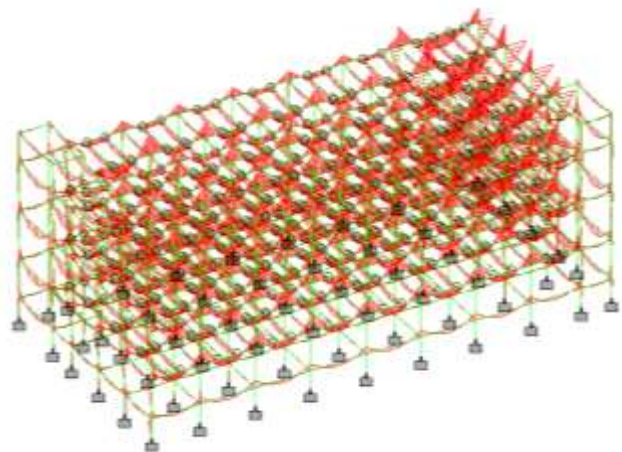


Fig:13 - Bending Moment Diagram of Steel Structures

4.4.4. Displacement of RCC and Steel Structures

Storey displacement Table are given below:

Table 3 Storey Displacement Chart of RCC & Steel

Storey	RCC displacement (mm)	Steel displacement(mm)
Terrace	9	19
2nd	7	13
1st	4	4.5

4.4.5. Material Usage and Efficiency

- **RCC Structure:**
 - The total **material volume** of concrete used for the RCC building was **1665 m³**.
 - The total **weight of reinforcement steel** used was **180 tons**.
- **Steel Structure:**
 - The total **material weight** of steel used was **360 tons** including composite deck slab reinforcement steel
 - The **material efficiency** of the steel structure was higher in terms of strength-to-weight ratio, even though the material cost was higher.

4.4.6. Cost Comparison

A preliminary cost estimate for both RCC and Steel structures was conducted based on typical material prices and construction costs.

- **RCC Structure:**
 - **Cost of Concrete (M30):** ₹5500 per m³
 - **Cost of Reinforcement Steel:** ₹65,000 per ton
 - **Total Cost for RCC Structure:** ₹2,10,00,000(only concrete and steel)
- **Steel Structure:**
 - **Cost of Structural Steel (IS 2062):** ₹95,000 per ton
 - **Total Cost for Steel Structure:** ₹3,42,00,000

The steel structure is more expensive initially due to the high cost of steel. However, this higher cost is offset by reduced construction time, lighter foundations, and faster assembly compared to RCC.

5. RESULTS AND DISCUSSION

5.1 Introduction

This chapter presents and analyzes the results obtained from the structural modeling and analysis of RCC (Reinforced Cement Concrete) and Steel structures using STAAD.Pro. The goal of this analysis is to evaluate the structural performance, material efficiency, cost implications, and overall feasibility of both types of structures when subjected to various loading conditions, including dead load, live load, wind load, and seismic load. The results are then compared to highlight the relative advantages and disadvantages of RCC and Steel in different structural applications.

The analysis will cover several key parameters such as deflections, stresses, internal forces, material usage, and costs, providing a comprehensive comparison between the two structural systems.

5.2 Summary of Results

The following table summarizes the key results obtained from the structural analysis of both RCC and Steel structures for the three-story office building model.

Table 4 Structural Analysis of Both RCC And Steel Structures/ Performance Comparison Between RCC And Steel Structures

Parameter	RCC structure	Steel Structure
Deflection (Maximum)	3.9 mm	18.2 mm
Maximum Bending Stress	17 MPa	180 MPa
Maximum Shear Stress	3 MPa	10 MPa
Axial Stress (Columns)	7 MPa	115 MPa
Material Usage (Concrete)	1665m ³ Concrete	570m ³ (composite deck slab)
Material Usage (Steel)	180tons Reinforcement Steel	360tons Structural Steel
Construction Cost	₹ 2,10,00,000	₹ 3,42,00,000
Construction Time	Longer	Shorter
Seismic Performance	Moderate	High
Wind Load Resistance	Higher (due to mass)	Higher (due to light weight)

5.3 Discussion of Results

5.3.1. Structural Performance: Deflections and Stresses

• Deflections:

○ The RCC structure exhibited a maximum deflection of 3.9 mm under the combined load cases, while the Steel structure exhibited a deflection of 18.2 mm. Both values are well within the permissible deflection limits specified in the relevant codes (e.g., IS 456:2000 for RCC). The lower deflection observed in the Steel structure is attributed to the higher stiffness of steel members relative to concrete. This result highlights the superior structural rigidity of steel, which can be beneficial in cases where minimizing deflection is critical for aesthetic or functional reasons.

• Bending and Shear Stresses:

○ The maximum bending stress in the RCC structure was 17 MPa, while the Steel structure experienced a much higher bending stress of 180 MPa. This significant difference is due to the higher tensile strength of steel, which allows it to resist bending moments more efficiently. Similarly, shear stresses in the Steel structure were found to be 10 MPa, compared to 3 MPa in the RCC columns. The Steel structure's higher shear capacity makes it a better candidate for handling high shear forces in high-rise buildings or areas subjected to heavy live loads.

5.3.2. Material Efficiency and Usage

• RCC Structure:

○ The RCC structure required 1665 m³ of concrete and 180 tons of reinforcement steel. Concrete, being a dense material, contributes significantly to the dead load of the building. The large volume of concrete used for structural elements like columns, beams, and slabs indicates that RCC is well-suited for low-rise buildings or buildings with simpler designs. While RCC is cost-effective, its material efficiency is lower compared to steel due to the volume of concrete needed for structural strength.

• Steel Structure:

○ The Steel structure required 570 m³ of concrete for composite deck slab and 360 tons of structural steel, which is lighter than the concrete used in the RCC structure. Despite the higher weight of steel (compared to concrete), Steel's higher strength-to-weight ratio means that less material is needed to achieve similar or superior performance. The material efficiency of the Steel

structure is superior because of its ability to support greater loads with less material.

5.3.3. Cost Analysis and Economic Feasibility

- **Initial Construction Cost:**

- The RCC structure was found to be significantly less expensive than the Steel structure in terms of the initial material cost. The total estimated cost for the RCC structure was ₹2,10,00,000, while the Steel structure cost ₹3,42,00,000. The higher cost of steel is due to steel material prices, welding, fabrication, and transportation, which increase the cost of a steel-frame structure. However, this higher initial cost can be offset by several factors, such as faster construction time and the increased durability of the steel structure.

- **Construction Time:**

- The RCC structure required a longer construction period because of the time-consuming process of formwork, casting, and curing of concrete. This process may extend the construction timeline by several months compared to a steel structure. On the other hand, the Steel structure benefits from prefabrication in factories, which allows for faster on-site assembly. The Steel structure can be assembled much quicker, reducing overall construction time by 30-40%, depending on the complexity of the design.

- **Long-Term Durability and Maintenance:**

- Over the long term, Steel structures may require less frequent maintenance compared to RCC structures, which can be more susceptible to cracking and corrosion in harsh environments. RCC structures, particularly in coastal areas or regions with high humidity, may suffer from reinforcement corrosion, leading to increased maintenance costs. While Steel structures are prone to corrosion if not properly maintained, they can be easily treated with protective coatings and galvanization to prolong their lifespan.

5.3.4. Seismic and Wind Load Resistance

- **Seismic Load Resistance:**

- Steel structures outperform RCC structures in terms of seismic resistance due to their ductility and ability to undergo plastic deformation without failing catastrophically. The inherent flexibility of steel allows it to absorb and dissipate seismic energy, reducing the risk of structural collapse during an earthquake. In contrast, RCC structures are generally more brittle and have lower seismic resistance unless carefully designed with seismic reinforcements. Thus, Steel is typically preferred for

buildings in seismic zones, as it offers better earthquake resilience.

- **Wind Load Resistance:**

- Both types of structures are designed to resist wind loads, but they perform differently due to their respective material properties. The RCC structure, due to its heavier mass, is less affected by wind-induced forces, which means it provides better resistance to wind uplift. However, the Steel structure, being lighter, performs better in terms of wind load distribution and wind-induced deflections due to its higher strength-to-weight ratio. Steel structures are often preferred in high-rise buildings exposed to significant wind forces because they are more efficient in handling dynamic loads.

6. CONCLUSION

6.1 Overview of the Study

This study has presented a comparative analysis of RCC (Reinforced Cement Concrete) and Steel structures for a mid-rise office building using STAAD.Pro for structural analysis. The primary objective was to evaluate the performance, material efficiency, cost implications, and overall suitability of each structural system under various loading conditions, such as dead load, live load, wind load, and seismic load. The study has provided a thorough comparison of the deflections, stresses, material usage, costs, and construction time for both types of structures, with a focus on their strengths, weaknesses, and optimal usage in different building types.

6.2 Key Findings

Based on the results and discussion presented in Chapter 5, the following key findings were made:

1. **Deflection and Structural Behavior:**

- Steel structures exhibited deflections (18.2 mm) compared to RCC structures (3.9 mm) under similar loading conditions. This result highlights the higher stiffness and strength-to-weight ratio of steel, making it more suitable for buildings where minimizing deflections is critical, such as in high-rise or aesthetic-sensitive projects.

2. **Material Usage and Efficiency:**

- RCC structures required a significantly larger volume of concrete (1665 m³) and 180 tons of steel compared to Steel structures which used 570 m³ of concrete and 360 tons of steel. Despite steel's higher cost, its higher strength-to-weight ratio means it is more material-

efficient, reducing the need for bulky elements like large beams and columns, which is beneficial for high-rise buildings.

3. Cost Implications:

○ The RCC structure was much more cost-effective in terms of initial construction cost, with an estimate of ₹2,10,00,000, compared to the Steel structure's cost of ₹3,42,00,000. However, the higher upfront cost of steel can be offset by faster construction time, reduced maintenance costs, and better performance under dynamic loads such as wind and seismic forces.

4. Construction Time:

○ Steel structures have the advantage of faster construction times, thanks to the use of prefabricated elements and quicker on-site assembly. In contrast, the RCC structure requires longer curing times and more on-site labor for formwork, casting, and concrete curing.

5. Seismic and Wind Load Resistance:

○ Steel structures offer superior performance in seismic zones due to their ductility and ability to absorb and dissipate seismic energy. This is a crucial advantage for earthquake-prone areas where earthquake resistance is a priority.

○ RCC structures, being heavier, offer higher wind load resistance due to their mass, but steel has a superior strength-to-weight ratio, which makes it more efficient in handling **wind-induced forces** in high-rise buildings.

6.3 Conclusion and Recommendations

The comparative study between RCC and Steel structures demonstrates that each material has its own set of advantages and disadvantages. The choice of material depends largely on the type of building, site conditions, budgetary constraints, and the required performance characteristics.

1. RCC Structures:

○ Advantages:

- Lower initial cost makes it an attractive option for low-rise buildings or projects with budget constraints.
- Massive strength and static load resistance are ideal for low-rise structures.
- Easier to design and construct in areas with limited access to skilled labor and equipment.

○ Disadvantages:

- Longer construction time due to the curing process.
- Lower seismic and dynamic load resistance, making it less ideal for high seismic risk areas.

2. Steel Structures:

○ Advantages:

- Superior seismic resistance and ductility, making them ideal for earthquake-prone regions.
- Faster construction due to prefabrication and ease of assembly.
- Lighter weight results in smaller foundation sizes and better performance under dynamic loads such as wind and seismic forces.

○ Disadvantages:

- Higher initial cost due to material costs and fabrication processes.
- Requires more maintenance over time, particularly in corrosive environments if not properly treated.

6.4 Recommendations for Future Research

While this study provides a comprehensive comparative analysis of **RCC** and **Steel structures**, there are several areas where further research and investigation could enhance our understanding of structural performance:

1. Long-Term Performance Analysis:

○ Future studies could focus on the long-term durability of both materials, including the effects of corrosion, fatigue, and maintenance costs over the building's lifecycle.

○ Investigation into the life-cycle costs (LCC) of RCC and Steel structures could provide a clearer picture of the total cost of ownership over time.

2. Advanced Structural Systems:

○ Future research could explore the use of hybrid structures that combine RCC and Steel for certain parts of the structure (e.g., using RCC for foundations and Steel for the superstructure) to optimize both cost and performance.

○ Exploring new materials and technologies, such as composite materials, may offer even better material efficiencies and sustainability.

3. Seismic and Wind Load Performance:

○ Further research could be done on the performance of RCC and Steel structures under combined seismic and wind loads, especially in regions with extreme weather and seismic activity.

○ Studies on retrofit techniques for improving the seismic performance of RCC buildings would also be valuable.

4. Sustainability and Environmental Impact:

○ As sustainability becomes a greater focus in construction, future research could evaluate the environmental impact of both materials, considering

aspects such as carbon footprint, recyclability, and resource availability.

6.5 Final Thoughts

In conclusion, both RCC and Steel structures have distinct advantages depending on the type of construction and design requirements. RCC continues to be the preferred choice for low-rise buildings and projects with budget constraints, whereas Steel is increasingly favored for high-rise buildings and projects requiring faster construction and higher seismic and dynamic load resistance.

The decision to choose between RCC and Steel should consider not only the initial construction cost but also the lifetime performance, construction timelines, and maintenance requirements. By balancing these factors, structural engineers can make informed decisions that best meet the design goals, budget, and functional needs of any project.

REFERENCES

1. Mustafa M. Wagh, Ankita. M. Sukhija, [2016] - "A Review on comparative study of composite RCC and steel structure". International Journal of Advanced Innovative Technology in Engineering (IJAITE), ISSN: 2455-6491, Vol. 1, Issue 5, Sept-2016.
2. Gorakh Vinit, Nishit Kadia, Kiranmoy Samanta, [2018] - "Comparative study of RCC and steel structures for different floor heights". International Journal of Innovative Research in Advanced Engineering (IJIRAE) ISSN: 2349-2163 Issue 10, Volume 5, October-2018
3. Jyothi D N, [2018] - "Comparative analysis of RCC and steel structure". International Research Journal of Engineering and Technology (IRJET) e-ISSN: 2395-0056 Volume, 05 Issue 02, Feb-2018
4. Sumit Shah, S. Saranya, [2018] - "Comparative Study of Reinforced Cement Concrete (RCC) and Steel Structure". International Journal of Science and Research (IJSR) ISSN: 2319-7064.
5. G. Hemalatha, Uma. S. G, Muthulakshmi. S, [2020] - "Comparative Analysis of Steel and RCC Frame

Structure of a Commercial Building". International Journal of Constructive Research in Civil Engineering (IJCRCE) Volume 6, Issue 4, 2020, PP 10-13, ISSN 2454-8693.

8.Design of reinforced concrete structures –N Subramanian,Oxford University press, New Delhi

9. SK Duggal- Limit state Design of Steel Structures

AUTHOR'S BIOGRAPHIES



Hemlata Sikarwar holds a B.Tech in Civil Engineering from the SR Group of Institution (India), Jhansi. She is currently pursuing her M.Tech in Structural Engineering from Shri Venkateshwara University (SVU), Gajraula, Uttar Pradesh.

Her research includes detailed study on RCC and Steel Structures. Her current research work focuses on the **"Comparative Study Of Rcc And Steel Structures For Structural Analysis Using Staad.Pro"**, with emphasis on enhancing durability, strength, and service life of structures.