

A COMPARATIVE SEISMIC & COST ANALYSIS OF RCC AND STEEL FRAME STRUCTURES OF RESIDENTIAL BUILDING: A CASE STUDY FOR KABUL, AFGHANISTAN

¹Hedayat Ullah Safi, ¹Mohammad Hashim Ayaz, ¹Shir Zaman Sahak and ¹Muhammad Shafiq Haibat

¹Department of Civil and Industrial Construction, Faculty of Construction Engineering, Kabul Polytechnic University, 1006, Kabul, Afghanistan.

ORCID: 0009-0003-2403-3616

e-mail: hedayatullah.safi92@gmail.com

Received: 1st July

Accepted: 27th October

ABSTRACT

The building materials choice and construction methods are critical to ensure the urban infrastructure's safety, sustainability, and pliability. This study presents a comprehensive comparative seismic analysis of steel and reinforced cement concrete (RCC) frame structures for a residential building in Kabul, Afghanistan. Owing to the seismic vulnerability of the area and shifting construction trends, the performance of the two structural systems is compared using a 3D ETABS model for the most dominant seismic parameters. The study aims to enlighten planners, engineers and policy makers with evidenced-base facts to guide appropriate choice of structural systems that enhance sustainable city development. The key findings show that the Steel buildings, exhibit improved seismic performance due to their lightness, increased ductility, and stiffness-distributed uniformly. In addition, steel frames had significant cost benefits, with this study reporting up to 41.28% greater cost-effectiveness over RCC. The conclusion shows that, although both systems are feasible, steel frame buildings are more efficient and durable for seismic areas and Kabul city.

Keywords: Comparative Study, Seismic & Cost Analysis, RCC & Steel Frame, Residential Building

1. INTRODUCTION

The building materials choice and construction methods are critical in the Civil engineering and structural design professional process, to ensure urban infrastructure safety, sustainability, and pliability [1], [2]. In Afghanistan, cities particularly its capital city Kabul go through noteworthy growth in both their human resources and economy, in which the construction projects play a vigorous role in ensuring their intended purposes [3]. Kabul experiencing a minus temperature in the cold season and 69.5% of buildings are reinforced cement concrete (RCC), while 30.5% are brick structures [4]. This means that residential, commercial, and industrial constructions traditionally rely on RCC, whereas the percentage of steel structures is not considerable. However, the steel structures have recently apprehended the structural engineering attention, and we are witnessing some of its under-construction samples.

Various factors hinge on RCC and steel structure selection, comprising the construction site, building materials availability, and construction techniques efficiency, to hunt the preeminent results [5], [6]. Concrete with embedded steel bars is used in RCC structure frames, while steel structure frames consist of freestanding steel elements with a frank cross-sectional design [7], [8]. Steel is considered a lightweight and high-strength construction material alternatively usable for RCC [9], [10].

During the structural design and its construction process safety, efficiency, and cost-effectiveness are the main concerns [11]. RCC structures due to their high dead loads, greater stiffness, span limitations, seismic condition, time consideration, and complexity in formwork installation often face extreme challenges [12], [13]. Conversely, steel structures by displaying higher ductility, rigidity, and ductility are more resilient, particularly when the seismic and wind forces are under consideration [14], [15].

Easy materials accessibility, durability, enduring properties, and resistance to fire are the most common advantages of RCC structures [16], but the material wastage, high weight, necessity for formwork, and skilled labour are its drawbacks [17]. In contrast, high strength, elasticity, and uniformity are the known characteristics of steel structure [18]. However, it mandates constant maintenance, suffers from lower fire resistance, requires fireproofing costs, and rust threats appear when exposed to ecological conditions [19]. A study shows that the drift, deflections, and stiffness of the RCC structure are greater than the steel structure, and catch more torsion, which constrains the structure from being constructed in small spans [20]. Furthermore, another study declares that the steel structure has less dead load, and shear force with more bending moment and less construction cost than the RCC. Additionally, the steel structure saves more time in the construction process [21]. Moreover, the RCC structure experienced 12.7% more seismic load than the steel structure. Besides, the steel structure has 18% lower story shear, and 43.54% more story drift than the RCC structure [22]. In addition, a comparative study reveals that the steel structure is 83.5% more cost-effective than the RCC structure [19].

This study aims to comparatively analyse the essential seismic parameters of RCC and steel structure through a 3D ETABS model to ensure its suitability and cost-effectiveness for Kabul, the capital city of Afghanistan, and worldwide which has similarity with the case.

2. MATERIALS AND METHODS

This research is a software base study, which conducts a comparative structural analysis of steel and reinforced cement concrete (RCC) structures by using ETABS 19. 3D models of both types of structures were created and analysed using the ETABS platform to identify significant performance parameters.

Structural models were developed under the same architectural plan for consistency. The analysis verifies various parameters like the structure's total weight, the lateral forces, base shear, story displacement, story shear, story drift, overturning moment, the centre of mass, the centre of rigidity, and approximated frame cost. The data to be used for analysis are presented in Tab.1, Tab. 2, Tab. 3, and Tab. 4.

For accurate cost and force control, each structural member was subjected manually to a controlled design instead of utilizing the automatic features offered by ETABS. ETABS results were exported to Microsoft Excel for further analysis. Results were then presented in tables and figures to enhance transparency and facilitate comparisons.

2.1. Load Combination

The following load combinations are used to ensure the safety and stability of both structures under different possible loading scenarios.

1. $1.4DL+1.4LL$
2. $1.2DL+1.2SDL+1.6LL+0.5SL$

2.2. Details for Structural Model

As shown in Fig. 1, the structural model is a 7-story residential building that contains a basement floor and only two towers on the top story over the stairs. The plan area is (17x16m) for both RCC and steel structure. The RCC building consists of columns, beams, and slabs, while the steel structure includes the braces too. Moreover, as illustrated in Fig. 2, the plan area includes five spans in the X direction, each measuring 3.5m, except for the middle span which is 3m, and four spans in the Y direction with an equal distance of 4m.

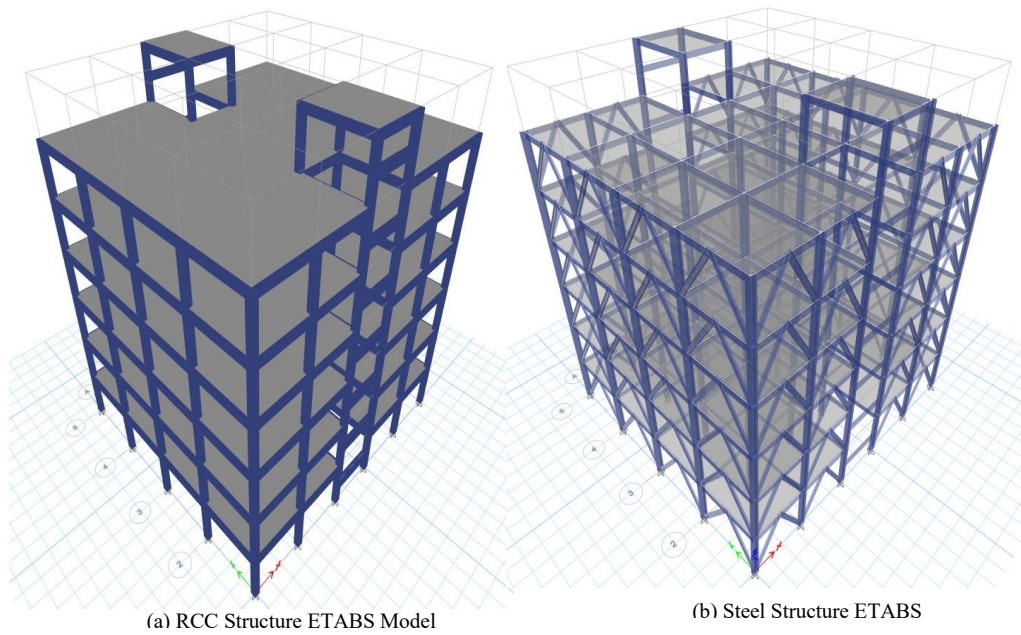


Figure 1. RCC and Steel Structure Buildings 3D ETABS Models

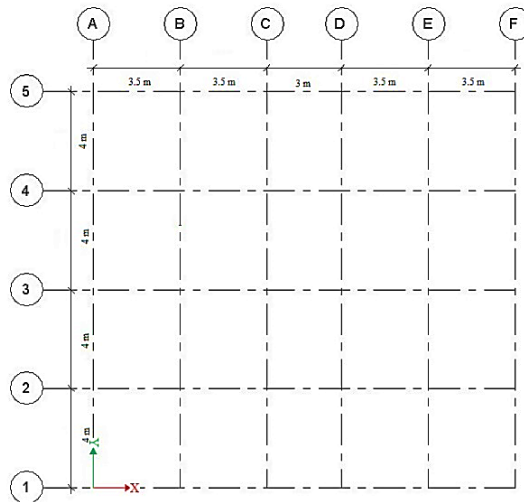


Figure 2. Building plan for Both RCC and Steel Structure

Table 1. Structural Properties for both RCC & Steel Structure

No	Frame Sections	RCC	Steel	Density of Concrete	Density of Steel
1	Column	M25, 350x350 mm	ASTM A572, W Shape	23.5631 KN/m ³	7849.047 Kg/m ³
2	Beam	M25, 350x400 mm	ASTM A572, W Shape		
3	Secondary beams		ASTM A572, W Shape		
4	Slab	M25, 150 mm	M25, 150 mm		

Table 2. Physical Data for both RCC & Steel Structure

Height of the Building	21m
Each Story Height	3m
Plan area	272m ²

Table 3. Load Acting Details for Both RCC & Steel Structure

Residential building				
No	Type of structural elements		Load Type	Rate
1	Floor	Slab	Live Load	2 KN/m ²
			Super Dead Load	2 KN/m ²
		External beams	Super Dead Load	12.9 KN/m
		Internal beams	Super Dead Load	8 KN/m
2	Roof	Slab	Live Load	2 KN/m ²
			Super Dead Load	2 KN/m ²
			Snow Load	1KN/m ²
			Ice Load	0.05 KN/m ²
		External beams	Super Dead Load	4 KN/m
		Internal beams	Super Dead Load	4 KN/m
3	Tower	Slab	Super Dead Load	2 KN/m ²
			Snow Load	1KN/m ²
			Ice load	0.05 KN/m ²
		Beams	Super Dead Load	2 KN/m

Table 4. Seismic Load Data for RCC & Steel Structure

Building Type	Residential
Short Period (S _s)	1.13
Long Period (S ₁)	0.53
Site Class	D
Occupancy Factor (I)	1
Response Modification (R)	8

3. RESULTS AND DISCUSSION

In this research, we have found out the perilous factor inducing the strength and durability of RCC and Steel structure. These aspects are vivacious for their important task in structural performance and resilience.

3.1. Structure Weight

The structure’s weight gives rise to its seismic performance and cost. Heavier structures bring about higher base shear, which demands strong foundations and a lateral load-resisting system.

Enhancing material selection and structural design can reduce unnecessary weight, improving efficiency without compromising safety. Proper weight distribution enhances stability and minimizes seismic vulnerabilities in RCC and steel structures.

As illustrated in Tab. 5, The RCC structure weighs more than the Steel structure, which is 72.22% heavier than the steel structure. The heavier weight of RCC structures is due to the dense nature of concrete and the inclusion of additional dead loads from the structure. While this added mass provides stability and resistance to wind or seismic vibrations, it increases the foundation load and overall material usage. In contrast, the steel structure’s lighter total weight makes it more suitable for high-rise buildings and seismic zones, where minimizing dead load is critical for performance and cost efficiency.

Table 5. The RCC & Steel Structure Weight

Structure Type	Entire Building Weight (KN)	Frame weight (KN)
RCC Structure	10666.7895	5322.6736
Steel Structure	6193.1732	849.0572

If take a look at the frame weight of the RCC structure, it is significantly higher than the steel structure’s frame. It is 4473.61 KN heavier than the Steel frame, which indicates that the steel frame is 84.05% lighter than the RCC frame. The lighter frame of the steel structure reduces the overall weight, offering flexibility and ease of construction.

As a result, the higher total weight of RCC contributes to better resistance against overturning forces from wind or earthquakes in low to mid-rise buildings but the lighter weight of steel structure reduces inertial forces during earth quack, enhancing safety and performance in seismic zones. Furthermore, high weight increases the foundation cost, but the lighter weight will reduce that cost.

3.2. Lateral Loads to Story

Lateral loads play a crucial role in stability and performance, especially in multi-story structures. High lateral loads cause excessive story drift, structure instability, and damage, leading to cracks, vibrations, or even failure. Conversely, lower lateral loads result in abridged structure deformation and stress. As indicated in Fig. 3, the RCC structure always experiences greater lateral loads than the steel structure, with the highest values being experienced on the 4th story for both structures. The highest lateral loads are approximately 587KN and 495KN for the RCC and steel structures, respectively, along the X and Y directions. This trend is consistent across all stories, in which the steel structure shows reduced lateral loads due to the implementation of bracing, which effectively enhances its resistance to lateral forces.

The result shows that; the steel structure emerges as the better option for lateral load management. Its bracing system realizes minimized story drift and increased overall stability, which makes it more suitable in locations where high lateral loads, such as those caused by wind or earthquakes, are to be encountered. On the other hand, while RCC structures inherently apprehend greater stiffness because of their weight, the higher lateral loads they carry can cause greater stress and deformation. Steel structures, thus, with sufficient bracing, prove to be more effective and safer for resisting lateral loads.

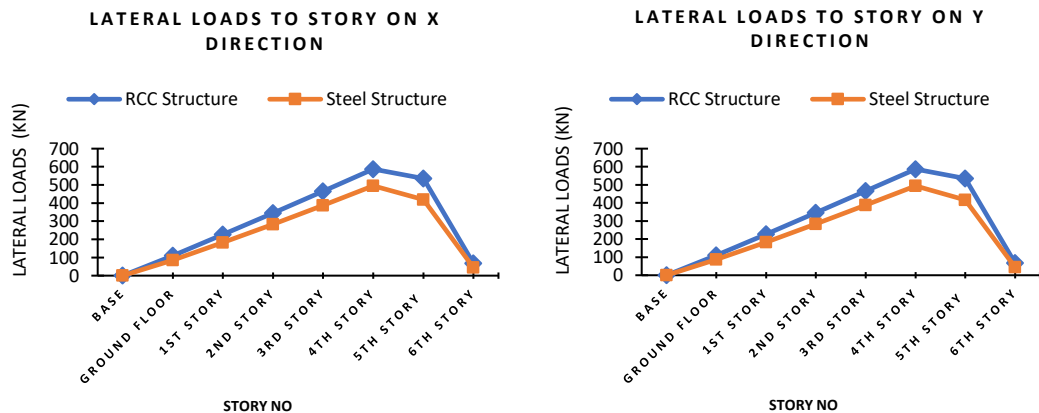


Figure 3. Lateral Loads to Story for RCC & Steel Structure

3.3. Base Shear

Base shear is the total amount of all lateral forces transferred to the foundation of a structure, which is a key parameter in structural analysis and design. A greater base shear value indicates higher forces acting on the structure, while a lesser base shear value reflects lower forces. The base shear should be within the range to offer safety and stability to the structure but should be as small as possible to ensure that excessive material costs are minimized and an economical design is achieved.

Table 6. Base shear for RCC and Steel Structure

Direction	RCC (KN)	Steel (KN)
X+Ecc.Y	2337.9859	1897.0285
Y+Ecc.X	2337.9859	1897.0285

As represented in Tab. 6, the RCC structure has a higher base shear of 2337.98 KN, while the steel structure exhibits a lower base shear of 1897.02 KN. This means the RCC structure experiences 440.95 KN, or 23.24%, more than the steel structure.

When comparing both structures, the steel structure verifies to be the more efficient choice for lateral load resistance. Its lower base shear values suggest reduced demands on the foundation and structural elements, leading to a more economical and efficient design compared to RCC.

3.4. Story Shear

Story shear as the lateral force on each story of a building caused by external loads is a fundamental aspect in the design of a structure, which determines what forces each story must be capable of resisting to remain stable and not fail. Lower values of story shear are always preferred as they reduce the demand on structural members, making the resulting structural design more economical and efficient. However, the values still need to be adequate in order to confirm the structure to resist safely against applied loads.

As clarified in Fig. 4, the maximum story shear for the RCC structure in the X and Y directions is approximately 2337.98 KN at the ground floor, gradually decreasing with height to 68.08 KN at the top. In comparison, the maximum story shear for the steel structure in the X and Y directions is about 1897.02 KN at the ground floor, reducing gradually to 45 KN at the top. These differences are primarily due to the heavier mass and higher stiffness of RCC, which generate greater lateral forces than the lighter and more flexible steel structure. If compared, the steel structure is more efficient, particularly in scenarios where minimizing lateral force demand is essential.

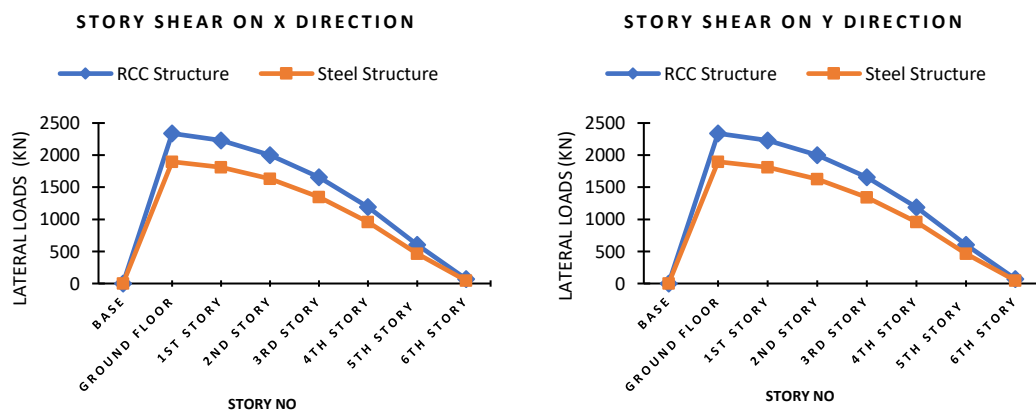


Figure 4. Story Shear for RCC & Steel Structure

3.5. Maximum Story Displacement

Story displacement which is the lateral movement of each story of a structure, when subjected to external lateral forces, occurs due to the flexibility of the structure and the deformation of its components under applied loads. It indicates the ability of the structure to withstand lateral forces without experiencing excessive deformation that could impact its safety or performance. Structures made of ductile materials such as steel experience more displacement than stiffer materials such as RCC. Nevertheless, excessive displacement could lead to damage, instability, or discomfort to occupants. Therefore, while some displacement is inevitable and acceptable, it must remain within the permissible limits defined by building codes to ensure safety and serviceability.

Fig. 5 demonstrates that the maximum story displacement for the RCC structure reaches approximately 46.78 mm at the top floor, whereas the steel structure exhibits a substantially lower maximum displacement

of about 21.09 mm in the X direction. Similarly, in the Y direction, the RCC structure again exhibits a maximum displacement of 51.81 mm, compared to the steel structure's 22.9 mm at the top story. The lower displacement of the steel structure is due to the bracing that is used in the structure, if the brace is removed the steel structure will experience more displacement than RCC and will reach more than 100mm for Y direction.

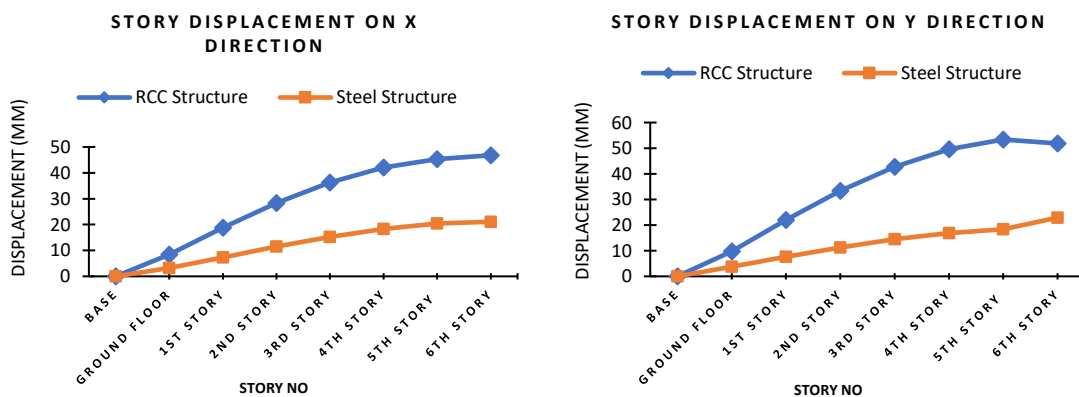


Figure 5. Maximum Story Displacement due to earth quack for RCC & Steel Structure

From this comparison, the steel structure is better in lower story displacement. Lower displacement values indicate that the steel structure can better resist lateral forces while maintaining stability and comfort for occupants. On the other hand, the higher displacement of the RCC structure may require additional measures, like stiffness increase, to control deformation, which may raise construction costs.

3.6. Maximum Story Drift

Story drift is the horizontal movement between two consecutive stories of a structure because of the lateral loading, i.e., wind or earthquake forces. It defines, how much a floor moves relative to the floor below it. Story drift occurs due to the deformation and flexibility of structural members under the influence of lateral loads. Large drift can result in structural damage, non-structural damage like windows or walls cracking, and discomfort to occupants at the time of the event. More flexible buildings like steel buildings can exhibit more drift compared to stiffer buildings like RCC buildings. Fig. 6 provides the story drift variation for X and Y direction for RCC as well as steel buildings.

In the X direction, the RCC structure experiences a maximum drift value of approximately 0.0034 at the 1st story, while the steel structure experiences a lower peak value of approximately 0.00139 at the 2nd story. Similarly, along the Y direction, the RCC structure experiences a peak value of 0.004, while the steel structure experiences a peak value of 0.00129. These trends indicate that the RCC structure experiences greater values of drift than the steel structure due to its greater mass and stiffness, which increase the effect of lateral forces.

From the above discussion, the steel structure shows improved performance in resisting story drift through the use of braces. Lower drift values indicate higher resistance to deformation and less risk of damage to structural and non-structural elements. Nevertheless, the higher drift in the RCC structure may require additional design measures, such as higher stiffness or the addition of bracing, to keep drift within acceptable levels, which may lead to increased cost. Thus, the steel frame is the better choice to ensure stability and minimize drift and is hence more effective and economical for resisting lateral loads with protection of safety and comfort of occupants.

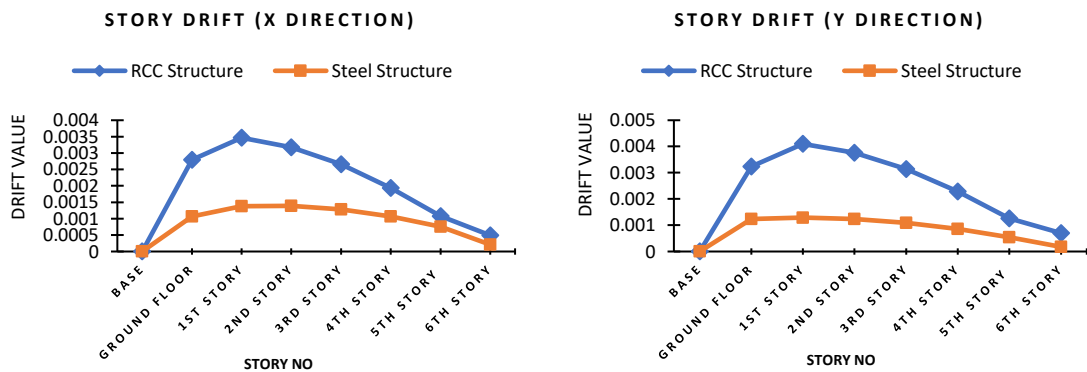


Figure 6. Story Drift for RCC & Steel Structure

3.7. Over Turning Moment

The overturning moment is the rotation moment that is applied on a building due to lateral loads, which are imposed at a definite distance from the building base, creating a torque that tries to turn the building over. A higher overturning moment may destabilize a foundation and cause tilting or failure of the building.

As shown in Fig. 7, At a base level, the RCC structure experiences a moment of around 30257.8 KN-m in the X-to-Y direction, while the steel structure experiences slightly less moment of around 24466.9 m KN-m. This would mean that the RCC structure is experiencing more forces of rotation at the foundation level. Rising to the 6th floor (top), overturning moments in both structures decrease significantly and are equal to 0 KN-m, showing reduced torque as lateral forces are introduced near the building top.

When both structures are compared, the RCC structure always registers slightly higher over turning moments than the steel structure. For instance, at the base level in the X-to-Y direction, the overturning moment for the RCC structure is approximately 5790.9 KN-m, or 23.66% greater than the steel structure. These raised values suggest that the RCC frame is subjected to higher stress by lateral loads, which can mean higher demands placed on its base and stability system. The steel frame, as opposed to it, has less overturning moment, suggesting increased resistance to it and lower structure demands.

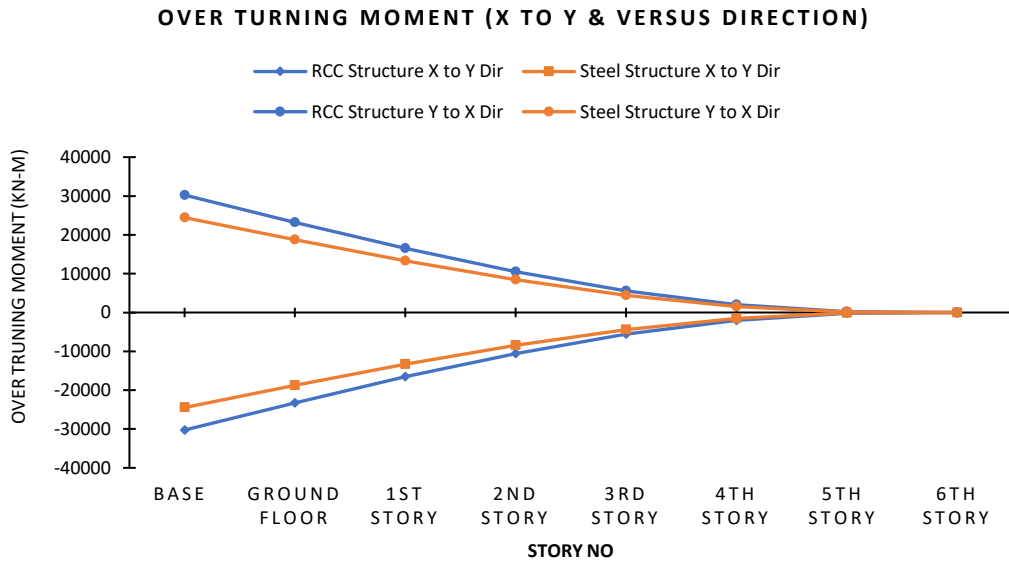


Figure 7. Overturning Moment for RCC & Steel Structure

3.8. Story Stiffness

Story stiffness is the resistance of a structure to lateral deformation or displacement under applied forces such as wind or seismic loads. Higher stiffness values indicate that a structure is more resistant to lateral deformation, whereas lower stiffness implies greater flexibility.

Fig. 8 indicates story stiffness in X-to-Y direction and Y-to-X direction for RCC and steel structure for different story levels. The steel structure indicates very high values of stiffness at all levels as compared to the RCC structure. For instance, on the ground floor, the steel structure has a maximum stiffness of approximately 535895.17 KN/m in the X to Y direction, while the RCC structure is just about 263563.13 KN/m. In this case, the RCC structure is 272332.03 KN-m or 49.18% lower in stiffness compared to steel structure on ground level. This is consistent throughout all story levels since both structures have very low stiffness on the sixth story when the lateral force resistance is minimal due to the light structural mass and stiffness at the higher levels.

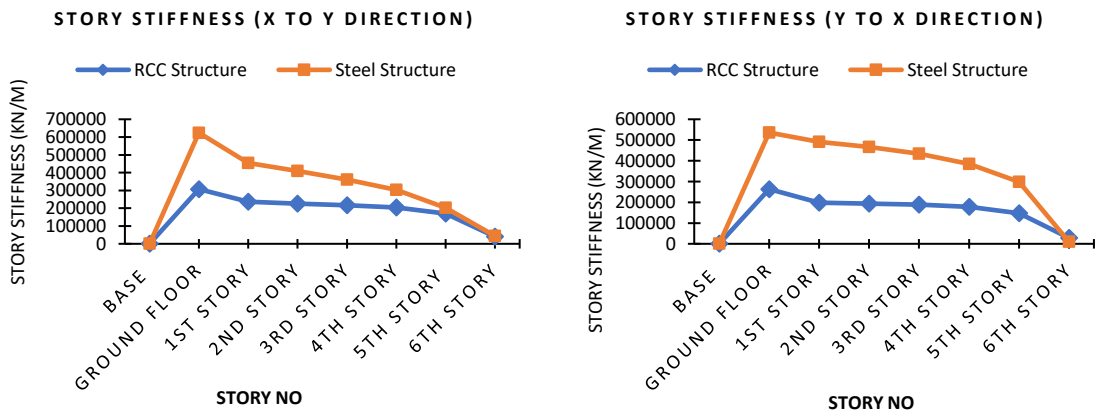


Figure 8. Story Stiffness for RCC & Steel Structure

3.9. Centre of mass

The centre of mass is a hypothetical point in a structure where the combined mass may be assumed to act for analysis. It is the mass distribution over the structure and depends on the geometry and weight of structure components. A well-aligned centre of mass minimizes structural torsion and ensures a balanced response to lateral loads.

As shown in Tab. 7, the centre of mass for the RCC structure in the X direction starts at 8.49m at the ground floor and adjusts to 8.5 m at the fifth story in the X direction. Whereas, In the Y direction, the centre of mass starts from 8.008 m on the ground floor and approaches 8 m at the sixth story. For the steel building, the centre of mass remains constant at 8.5 m in the X direction and 8 m in the Y direction for every story.

If compared, The RCC structure exhibits minute variations in the centre of mass at different stories, particularly in the Y direction. These are due to the material distribution and stiffness variation at different levels of the RCC structure. Regarding the steel structure, there is no variation and this suggests uniform mass distribution and symmetry. In summary, while both buildings are operational, the uniform centre of mass of the steel building on all floors ensures improved performance under dynamic loads and makes it a more reliable and efficient option compared to the RCC building.

Table 7. Center of mass of the RCC and Steel Structure

Story No	RCC Structure (m)		Steel Structure (m)	
	X Dir	Y Dir	X Dir	Y Dir
5th Story	8.5	8	8.5	8
4th Story	8.4929	8.0613	8.5	8
3rd Story	8.4968	8.0279	8.5	8
2nd Story	8.4979	8.0181	8.5	8
1st Story	8.4985	8.0134	8.5	8
Ground floor	8.4988	8.0106	8.5	8
Base	8.499	8.0088	8.5	8

3.10. Centre of rigidity

Centre of rigidity is a term that describes the location within a structure that denotes the distribution of stiffness where structural resistance to lateral loads such as wind or seismic loading is focused. It is affected by how the structural members like walls, braces, beams, and columns are arranged as well as the characteristics of structural elements. The centre of rigidity plays an important role in structural analysis because its coincidence with the centre of mass minimizes the torsion effects, achieving a more orderly and effective lateral force resistance. The well-aligned and regular centre of rigidity minimizes asymmetrical deformations and additional stresses, thus making the structure more stable overall.

Analysing Tab. 8 indicates that, both the RCC and steel structures exhibit identical and consistent centre of rigidity values in both the X and Y directions which are 8.5 m and 8m respectively. This uniformity indicates balanced stiffness distribution and symmetry in the design of both structures. Since the centre of rigidity values remain the same from one story to another, neither structure has any other weakness to torsional effects caused by non-uniform stiffness distribution. This coincidence of the centre of mass and centre of rigidity gives effective performance under lateral loads for both structures.

Table 8. Center of Rigidity for RCC and Steel Structure

Story No	RCC Structure (m)		Steel Structure (m)	
	X Dir	Y Dir	X Dir	Y Dir
6th Story	8.5	8	8.5	8
5th Story	8.5	8	8.5	8
4th Story	8.5	8	8.5	8
3rd Story	8.5	8	8.5	8
2nd Story	8.5	8	8.5	8
1st Story	8.5	8	8.5	8
Ground floor	8.5	8	8.5	8

3.11. Cost Estimation for RCC and Steel Frame

Tab. 9 presents a comparison of material expenditure between RCC and steel frames regarding material quantity needed, their respective unit costs, and total cost. The comparison provides an idea regarding the economic implication of each frame so that the reader can gauge their financial sustainability.

For the RCC frame, the construction requires 224.32 m³ of M25 concrete and 12.315 tons of steel. The total cost for the RCC structure amounts to \$33691.8. In contrast, the steel frame exclusively uses 86.55 tons of steel. The total cost for the steel frame is calculated as \$47602.6. This also means extensive application of steel in the construction of frames, which is the direct reason for the higher cost.

On comparing the total cost, the steel frame is higher than the RCC frame. The cost of all the materials used in the steel frame with a cost of \$47602.6 is higher than that of the RCC frame with a cost of \$33691.8 by \$13910.79. This translates to about a 41.28% increase in the cost of the steel frame. The reason why the two costs differ mainly is because the steel frame requires a higher quantity of steel used for its construction and not the addition of concrete as a supporting material.

The lower cost of the RCC frame is largely due to the fact that it makes use of concrete, which is considerably less expensive per unit compared to steel. But although the steel frame is more expensive, it has advantages such as reduced structural weight, faster construction time, and better behavior under lateral loads. On the other hand, the RCC frame, while cheaper, may entail additional labor costs and time due to the complexities of casting and curing concrete in the field.

Table 9. RCC and Steel Frame Materials Cost

Frame Type	RCC Frame	Steel frame
Required materials	224.32 m ³ M25 Concrete and 12.315 Ton of steel	86.55 Ton of steel
Individual cost for each unit	550\$/ton steel and 120\$/m ³ concrete	550\$/ton steel
Total Material Cost (\$)	33691.8	47602.6

4. CONCLUSIONS

The comparative analysis between Reinforced Cement Concrete (RCC) and steel structures reveals significant differences in structural performance, weight, stiffness, and cost. The RCC structure is substantially heavier than the steel structure, weighing approximately 72.22% more, primarily due to the dense nature of concrete and the additional dead loads inherent in RCC construction. In contrast, the steel frame is 84.05% lighter than the RCC frame. This substantial weight difference results in the RCC structure experiencing a greater base shear force approximately 23.24% more than the steel structure. Additionally, the bending moment in the RCC structure is about 23.66% greater compared to the steel structure. However, when assessing stiffness at the ground level, the RCC structure shows a 49.18% lower stiffness than that of the steel structure. Despite these structural disparities, a cost analysis reveals that constructing a steel frame results in approximately a 41.28% increase in cost compared to the RCC alternative. This integrated evaluation highlights the trade-offs between weight, structural behaviour, and cost in choosing between RCC and steel structural systems.

5. ABBREVIATIONS

RCC	Reinforced Cement Concrete
3D	Three Dimensional
ETABS	Extended Three-Dimensional Analysis of Building Systems
DL	Dead Load
LL	Life Load
SDL	Super Dead Load
SL	Snow Load

REFERENCES

- [1] M. C. Gonçalves and F. Margarido, "Materials for construction and civil engineering," *Cham, Switz. Springer*, 2015.
- [2] A. K. M. Yahia and M. Shahjalal, "Sustainable materials selection in building design and construction," *Int. J. Sci. Eng.*, vol. 1, no. 4, pp. 10–62304, 2024.

- [3] H. U. Safi, M. M. Behsoodi, and W. Shirzad, "Climate-Responsive Urban Design : Innovations and Strategies for Sustainable Buildings and Construction in Afghanistan," pp. 269–273, 2024.
- [4] H. U. Safi, M. M. Behsoodi, and W. Shirzad, "Eco-Friendly Urban Design: Investigating Innovative Approaches and Sustainable Construction Practices Across Afghanistan's Diverse Climate Zones," *Urbana*, vol. 25, no. 1, pp. 1–21, 2024, doi: 10.47785/urbana.2024.1.
- [5] N. B. Gawali, S. B. Thakare, and D. P. Kambale, "OPTIMIZING STRUCTURAL PERFORMANCE: A REVIEW OF RCC, STEEL, AND TIMBER COMBINATIONS IN CIVIL ENGINEERING," *Int. J. Innov. Stud.*, vol. 9, no. 1, pp. 100–128, 2025.
- [6] A. Kumar and S. Maru, "a Review Paper on Comparative Study on Rcc and Composite Structure for Seismic Analysis Using Response Spectrum Method," *Int. Res. J. Mod. Eng. Technol. Sci. www.irjmets.com @International Res. J. Mod. Eng.*, no. 09, pp. 2582–5208, 2021.
- [7] G. Hemalatha, S. G. Uma, and S. Muthulakshmi, "Comparative Analysis of Steel and RCC Frame Structure of a Commercial Building," *Int. J. Constr. Res. Civ. Eng.*, vol. 6, no. 4, pp. 10–13, 2020, doi: 10.20431/2454-8693.0604002.
- [8] I. Thapa, A. Bhandari, and B. Subedi, "Comparative Study of Structural Analysis between Reinforced Cement Concrete Structure and Steel Framed Structure," *Int. Res. J. Eng. Technol.*, vol. 7, no. 8, pp. 3633–3637, 2020.
- [9] A. V Gurule, "Comparison Of Structural Systems For Composite Construction In High Rise Building." Institute of Technology, 2014.
- [10] D. S. AnamikaTedia, "Cost, Analysis and Design of Steel-Concrete Composite Structure RCC Structure," *IOSR J. Mech. Civ. Eng.*, vol. 11, no. 1, 2014.
- [11] R. K. Ajay Kumar, "A Review on Analysis of Steel Structure," vol. 5, no. 4, pp. 116–121, 2018.
- [12] A. R. Sabouni, "Advances in reinforced concrete integrity and failure," in *Advances in Structural Integrity and Failure*, IntechOpen, 2023.
- [13] J. Ambrose and P. Tripeny, *Simplified design of concrete structures*. John Wiley & Sons, 2007.
- [14] S. Shah and S. Saranya, "Comparative Study of Reinforced Cement Concrete (RCC) and Steel Structure," *Int. J. Sci. Res.*, vol. 9, no. 1, pp. 1548–1551, 2020.
- [15] A. Mandlik, S. K. Sharma, and S. Mohammad, "Behaviour of Symmetrical RCC and Steel Framed Structures Under Seismic and Wind Loading," *Int. J. Res. Sci. Innov.*, vol. 3, 2016.
- [16] S. A. Wagh and U. P. Waghe, "Comparative study of RCC and steel concrete composite structures," *J. Eng. Res. Appl. ISSN*, pp. 2248–9622, 2014.
- [17] N. L. Rane, A. Anand, and K. Deepak, "Evaluating the selection criteria of formwork system (FS) for RCC building construction," *Int. J. Eng. Trends Technol.*, vol. 71, no. 3, pp. 197–205, 2023.
- [18] N. S. Trahair, M. A. Bradford, D. Nethercot, and L. Gardner, *The behaviour and design of steel structures to EC3*. CRC Press, 2017.
- [19] A. Saraogi *et al.*, "A Comparison between RCC and Steel Structure," *Int. J. Res. Eng.*, vol. 1, no. 4, pp. 106–108, 2018.
- [20] R. Divya and K. Murali, "Comparative study on design of steel structures and RCC frame structures based on column span," *Mater. Today Proc.*, vol. 46, pp. 8848–8853, 2021.
- [21] M. Ayyad, R. Naik, J. Tejan, B. Naik, and S. Acharya, "Comparative Study on Analysis and Cost Estimation of RC Structure and Steel Structure under the Normal Loading Conditions," *Int. Res. J. Eng. Technol.*, vol. 9001, pp. 4141–4145, 2008.
- [22] D. R. S. Reddy, A. C. K. Yadav, and K. Srinivas, "Comparative analytical study of seismic response and cost of multi-storey (G+ 12) RCC, steel & steel-concrete composite building," 2023.