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Structural And Cost Analysis Of Reinforced Concrete And Steel Framed Structures: A Comparative Study In Lefkoşa, North Cyprus

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Abstract
The development of structural systems, materials, and analytical techniques have been used for designing different types of structures. Comparative studies of various buildings help identify the optimum choice depending on the project requirements and conditions. In this study, 8-story residential structures are designed in Lefkoşa, North Cyprus by steel and reinforced concrete frames with different load-resisting systems. Building Code Requirements for Structural Concrete (ACI 318-19) and American Institute of Steel Construction (AISC-15th edition) are both followed and the response spectrum method (RSM) is employed while ETABS and SAP2000 are used for modeling and analyzing the structures. The results obtained are the base shear, story shear, displacement, axial forces, bending moments for selected columns, the quantity of steel, the quantity of concrete, and the quantity of formwork are compared for different structures. The result shows that the cost of steel structure is higher by around 13 % as compared to RC.
Keywords: Cost estimation, steel structure, RC, construction material, response spectrum method, ETABS, SAP2000.

1. Introduction

The construction industry plays a significant role in the economic development of any country; therefore, the choice of materials and construction techniques can have an important impact on the cost, time, and sustainability of the project. Reinforced concrete and steel are the two most commonly used materials in the construction firm and the choice of the suitable material depends on various factors such as cost, strength, durability, and aesthetics. In this study, a structural and cost analysis of reinforced concrete and steel frame structures is conducted in Lefkoşa, North Cyprus. The use of RC in construction dates back to the 19th century, and it is widely used in the construction of buildings, bridges, and other structures. RC is a composite material made of concrete and steel reinforcing bars, which are used for the purpose of increasing the tensile strength of concrete. The steel reinforcing bars are arranged in a grid pattern and embedded in the concrete in order to provide additional tensile strength and improve the overall structural integrity of the concrete[1]. The construction industry in Lefkoşa is expanding, which has increased the demand for materials and construction techniques that are equally affordable and effective. A comparative study of reinforced concrete and steel structures provides valuable information on the cost-effectiveness of each material and helps architects, engineers, and contractors make an informed decision on which material to use for their projects[2]. Choosing the right materials and procurement method can have a major impact on the success of a shell construction project. In the construction industry, it is important for all stakeholders, including owners, consultants, contractors, and clients, to consider factors such as market certainty, customer satisfaction, cost, environmental impact, profitability, and employee support when making decisions[3]. This research on residential buildings aims to provide a comparative analysis between RC and Steel structures.

2. Project Location

Lefkosa, North Cyprus has been selected as the study area for this project. The project is located in Osman Örek Cd, Lefkoşa, as shown in Figure 1. Since there is a multi-story zoning permit for the mentioned point, it has been chosen as the appropriate place.

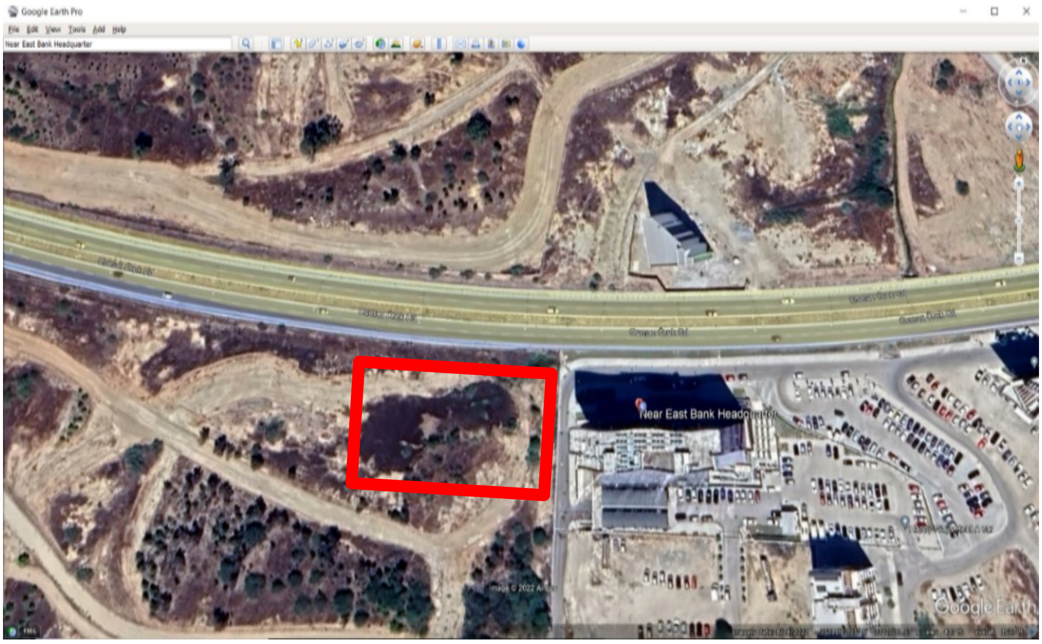


Figure 1. Site location retrieved from Google map 2022

Cyprus was affected by multiple powerful earthquakes throughout its history since it is located in one of the most seismically active areas of the eastern Mediterranean basin. The history of various earthquakes that have struck the island is depicted in Figure2

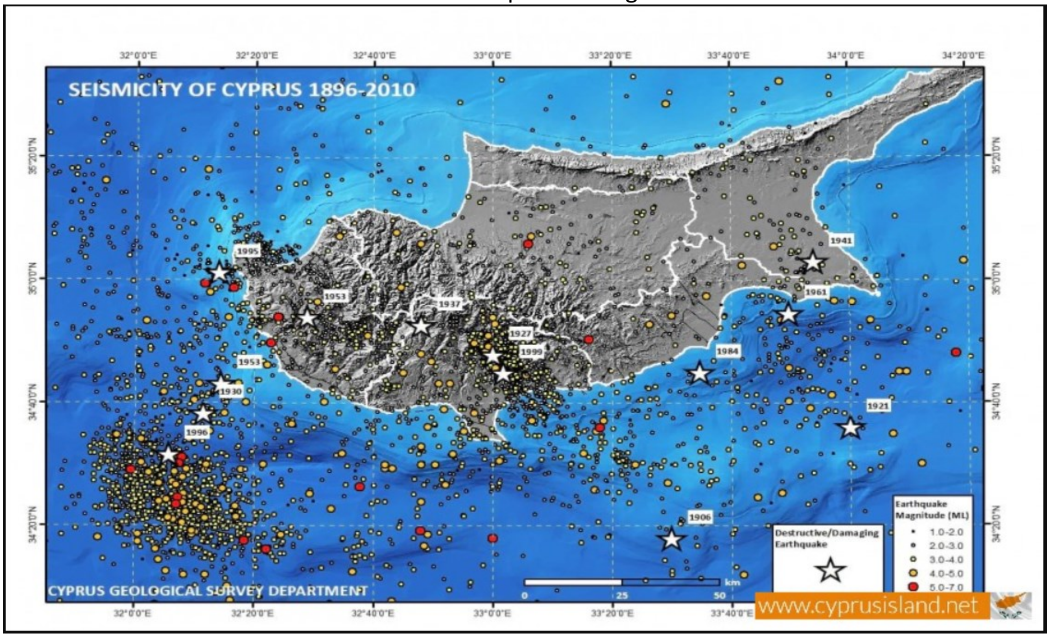


Figure 2. Seismicity of Cyprus region

https://www.cyprusisland.net/earthquakes-cyprus

Construction of Urban parcel Statistics and residential buildings has increased considerably in Northern Cyprus owing to the fact that the population is growing day by day. This increment has led to greater demand, therefore the demand led to the endeavors of choosing the right construction material. Here below in Figures 3 and 4 is depicted the information related to the construction growth and demand respectively in the city.

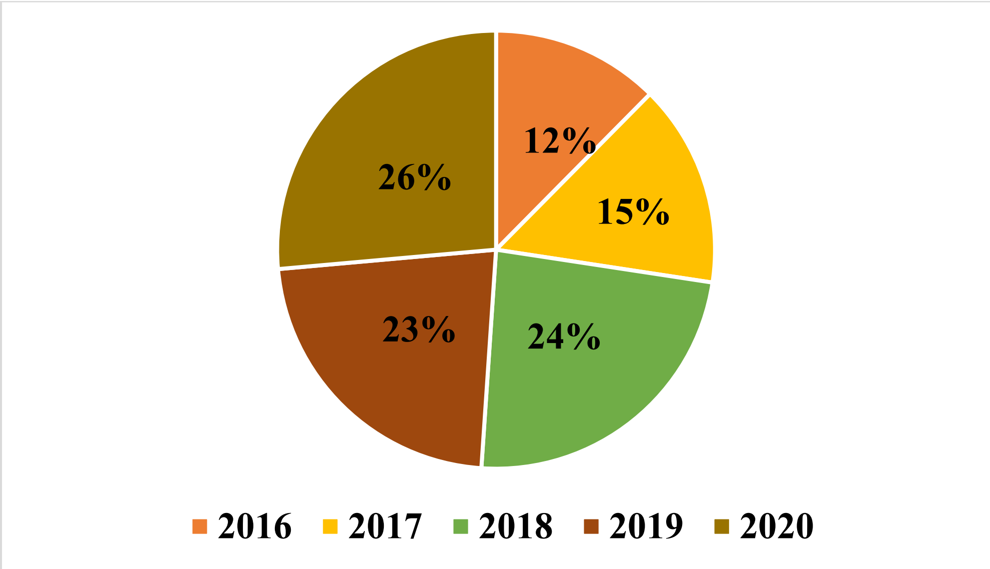


Figure 3. Urban Parcel Statistics of North Cyprus (2016-2020)

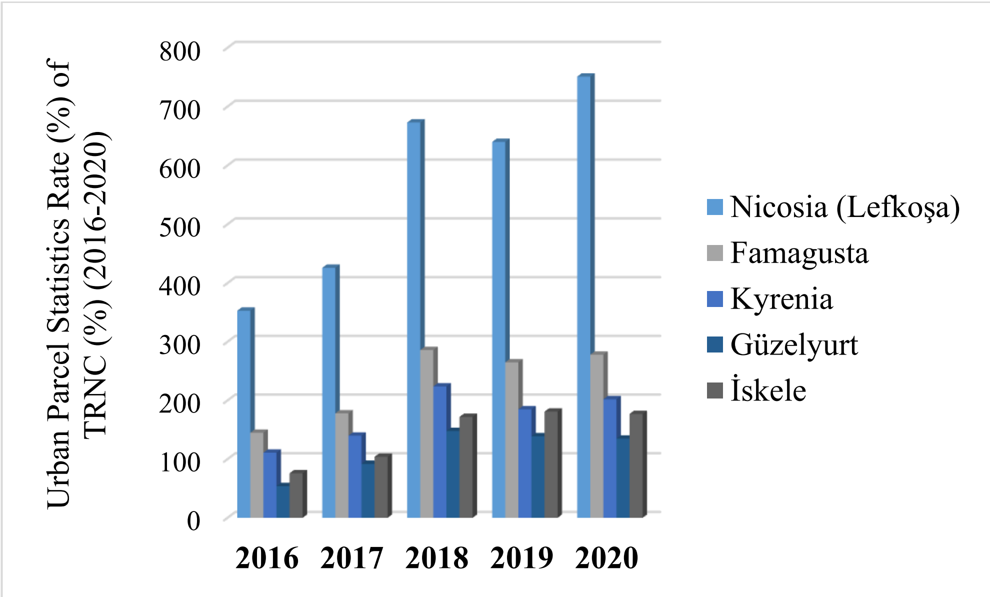


Figure 4. Residential Buildings Statistics between 2016-2020 for Lefkosa. North Cyprus.

3. Project Layout

The project layout of the floor plan of the RC and steel structure is represented in Figures 5 and 6 respectively. The shear wall and bracing have been represented on the plan in red coloration.

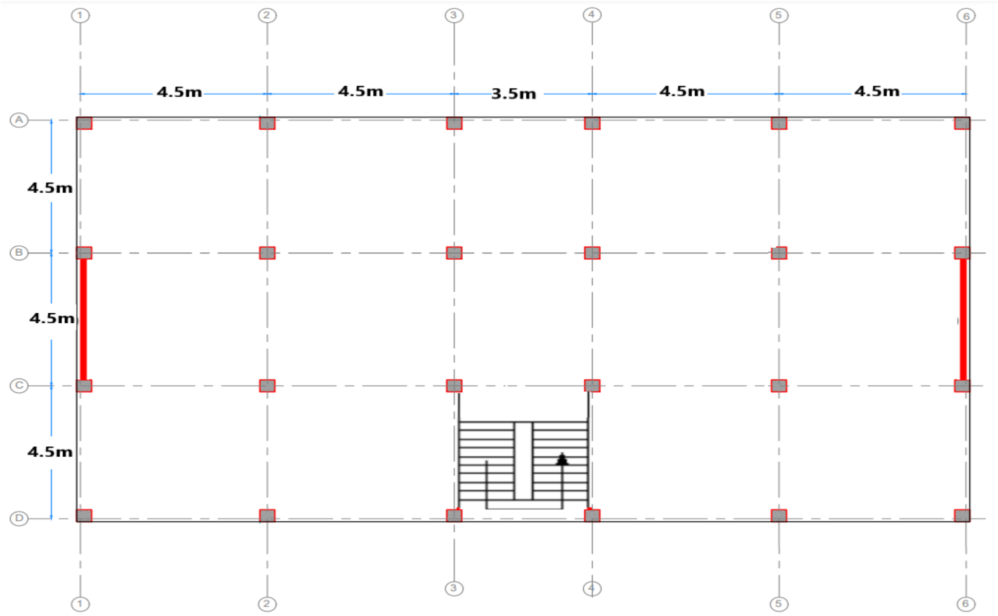


Figure 5. Floor plan for RC framed structure with shear wall

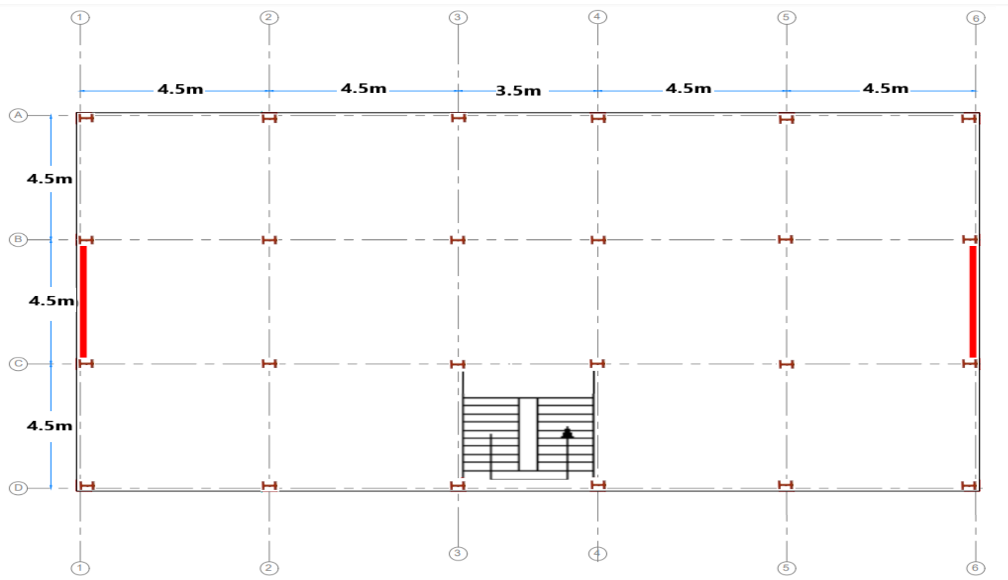
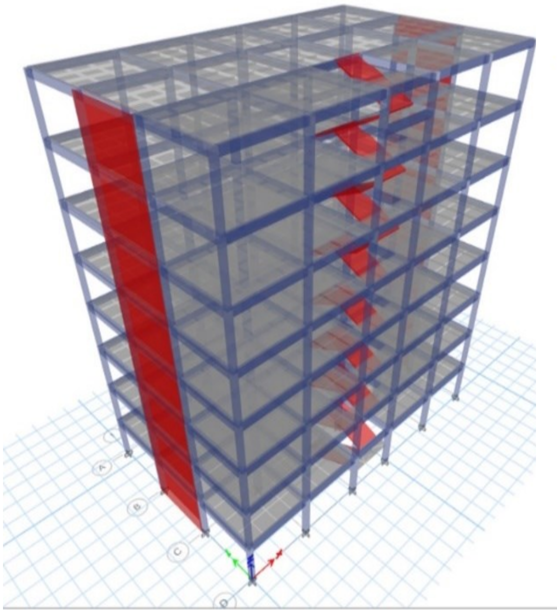


Figure 6. Floor plan for Steel framed structure with cross bracing

Figures 7 and 8 show the 3D frames that have been modeled in the two software.



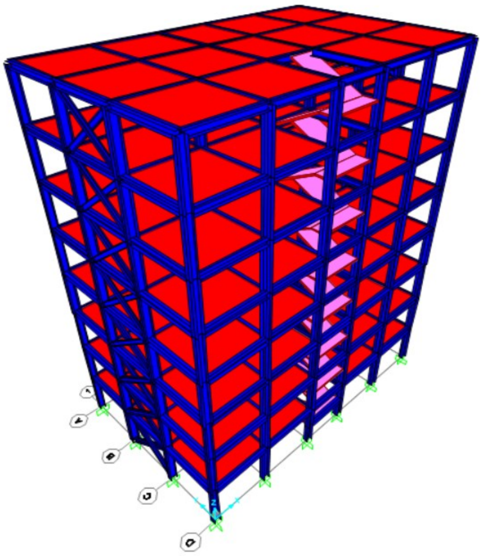


Figure 7. 3D RC with the shear wall in ETABS **Figure 8.** Steel-framed structures used for Cross bracing

3. Methodology and Material

To get conceptual clarity regarding the selection of a material, the mass material and story stiffness, base shear, story drift ratio, center of mass, the center of rigidity, and displacement are determined and compared. The software ETABS v.2022 is used to analyze the three-dimensional model of the RC and steel structure. According to the area of study, the objectives are listed below.

➢ Modeling of 8-story RC and steel frame for residential buildings, analyzing the structures, and finding base shears, story shears, displacements, axial forces, and bending moments. The structures are designed using ETABS v.20 and SAP2000 software programs as per Building Code Requirements for Structural Concrete (ACI 318-19) and American Institute of Steel Construction (AISC-15th edition). The dead load, live load, seismic load, and wind load are the type of loadings considered according to the codes mentioned above.

➢ Analyzing the RC and steel frame modeled by using response spectrum analysis.

➢ Calculating and comparing the cost of the structures based on the Northern Cyprus market including concrete, bars, and steel sections.

Table 1. Material properties and parameters used in model design .

Weight per unit volume of concrete, γ_c	25 $\mathrm{kN/m^3}$
Weight per unit volume of steel, γ_{st}	78.5 $\mathrm{kN/m^3}$
Modulus Elasticity of Steel, E_{st}	200,000MPa
Modulus Elasticity of concrete, E_c	24870 MPa
Compressive strength of concrete, f_c	28 MPa
Yield strength of Steel, f_y	420 MPa
Live Load	2.5 kN/m^2
Dead Load	5 kN/m^2
Earthquake analysis method	RSM
Soil bearing capacity	16 t/m^3
Soil unit weight	2.2 t/ m^3
Seismic zone coefficient (Ao)	0.3 g
Spectrum characteristic period (Ta/Tb)	0.15/0.4

Table 2. Date for the analysis of RC structure.

Dimension of the building, length, and width		21.5m*13.5m
Story height		3.5m
No. of story		8
Slab thickness		200mm
Shear wall		250mm
Stairs		150mm
Beam size 1-4 story		300mm*350mm
Beam size 5-8 story		280mm*300mm
Column size corner	8th Story & 7th Story	285mm*285mm
Column size corner	6th Story & 5th Story & 4th Story	300mm*300mm
Column size corner	3rd Story & 2nd Story & 1st Story	350mm*350mm
Column size exterior	8th Story & 7th Story	300mm*300mm
Column size exterior	6th Story & 5th Story & 4th Story	350mm*350mm
Column size exterior	3rd Story & 2nd Story & 1st Story	400mm*400mm
Column size interior	8th Story & 7th Story	350mm*350mm
Column size interior	6th Story & 5th Story & 4th Story	400mm*400mm
Column size interior	3rd Story & 2nd Story & 1st Story	450mm*450mm

Table 3. Date for the analysis of the Steel structure

	ACI Code	European Code
Dimension of the building, length, and width	35m*35m	
Story height	3.5m	
No. of story	8	
Slab thickness	200mm	
Stairs	150mm	
Beam size 1-4 story	W14X145mm	HEA 280mm
Beam size 5-8 story	W 14X130mm	HEA 260mm
Cross bracing	W12X50mm	HEA 320mm
Column size corner 8th Story & 7th Story	W14X233mm	HEA 340mm
Column size corner 6th Story & 5th Story & 4th Story	W14X257mm	HEB 360mm
Column size corner 3th Story & 2th Story & 1th Story	W14X283mm	HEB 400mm
Column size exterior 8th Story & 7th Story	W14X342mm	HEB 340mm
Column size exterior 6th Story & 5th Story & 4th Story	W14X370mm	HEB 360mm
Column size exterior 3th Story & 2th Story & 1th Story	W14X398mm	HEB 400mm
Column size interior 8th Story & 7th Story	W14X455mm	HEB 450mm
Column size interior 6th Story & 5th Story & 4th Story	W14X500mm	HEB 500mm
Column size interior 3th Story & 2th Story & 1th Story	W14X550mm	HEB 550mm

4. Result & Discussion

The result obtained from both RC and Steel framed structures used linear dynamic analysis, parameters such as base shear, story shear, displacement, axial force, and moments are analyzed and obtained for three selected columns using ETABS V.20. The three selected columns C1, C2, and C3 are corner, exterior and interior columns respectively. The results are in X and Y directions for RC and steel for the base shear, story shear, and displacement.

4.1 Base Shear

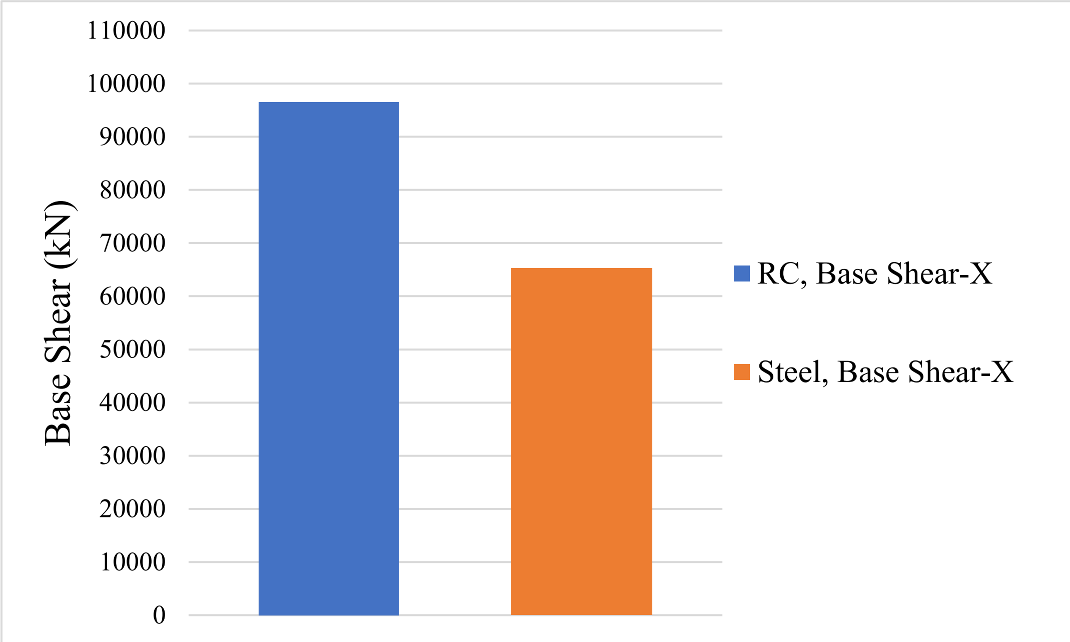


Figure 9: In X-direction for RC and Steel structure framed

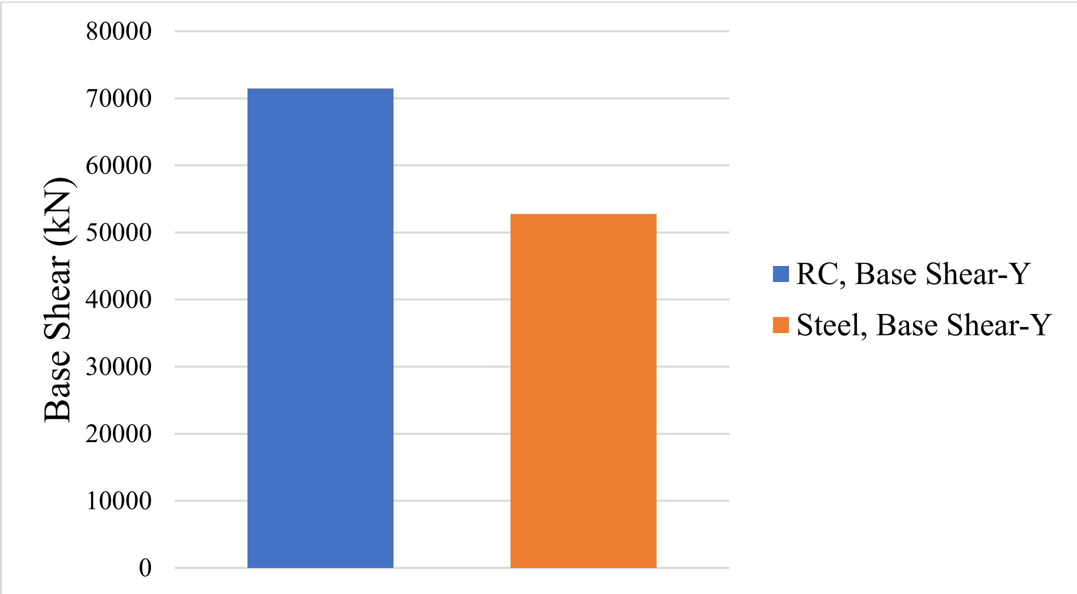


Figure 10: In the Y-direction for RC and Steel structure framed

From the result, it can be seen the maximum base shear is obtained in the case of RC framed structure, owing to its higher self-weight. The case is in base shear in RC framed structure as compared to Steel is around 27% and % 20 in X and Y directions respectively.

4.2 Story Shear

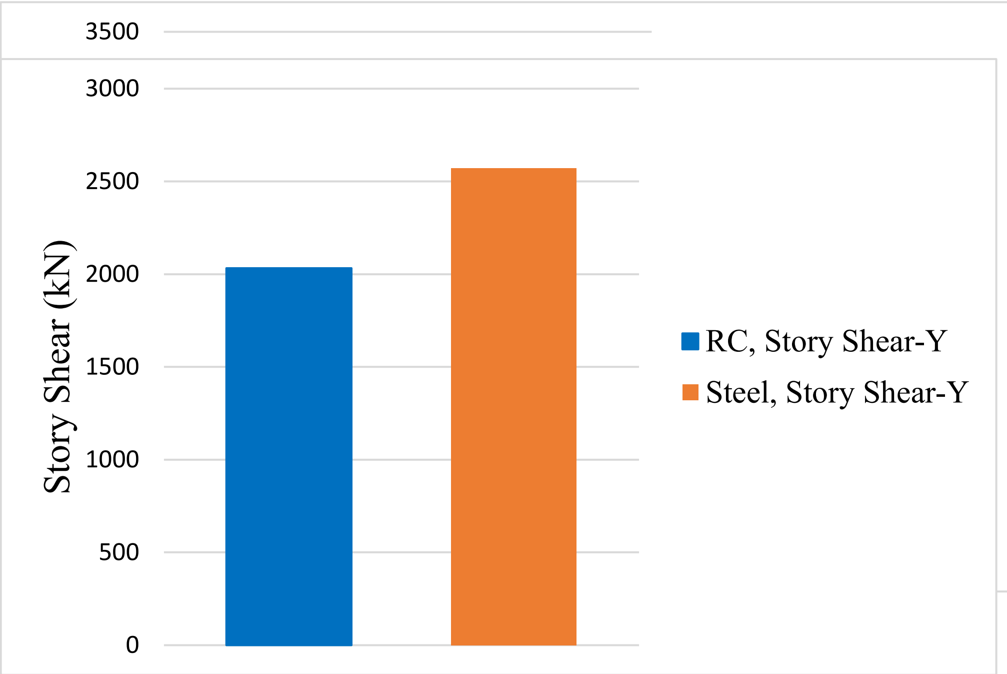


Figure 11: In X-direction for RC and Steel framed structures
Figure 12: In the Y-direction for RC and Steel framed structures
The story shear for Steel framed structure is around % 15 and % 17 greater than RC in X and Y directions respectively.

4.3 Displacement

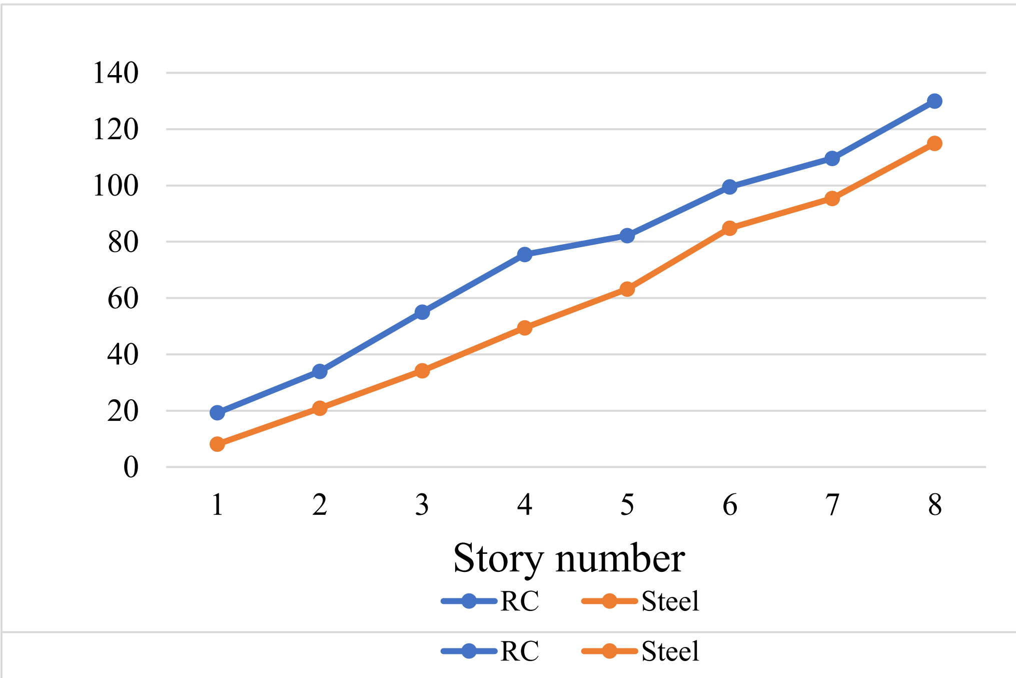


Figure 13*:* In X-direction for RC and Steel framed structures
Figure 14: In the Y-direction for RC and Steel framed structures
Story versus displacement is shown in the aforementioned line diagram, and it can be seen that as the story height is increasing, the displacement is increasing as well. The displacement for RC-framed structures is higher than Steel framed structures. The displacement of both structural systems is within the permissible limit.

4.4 Axial force

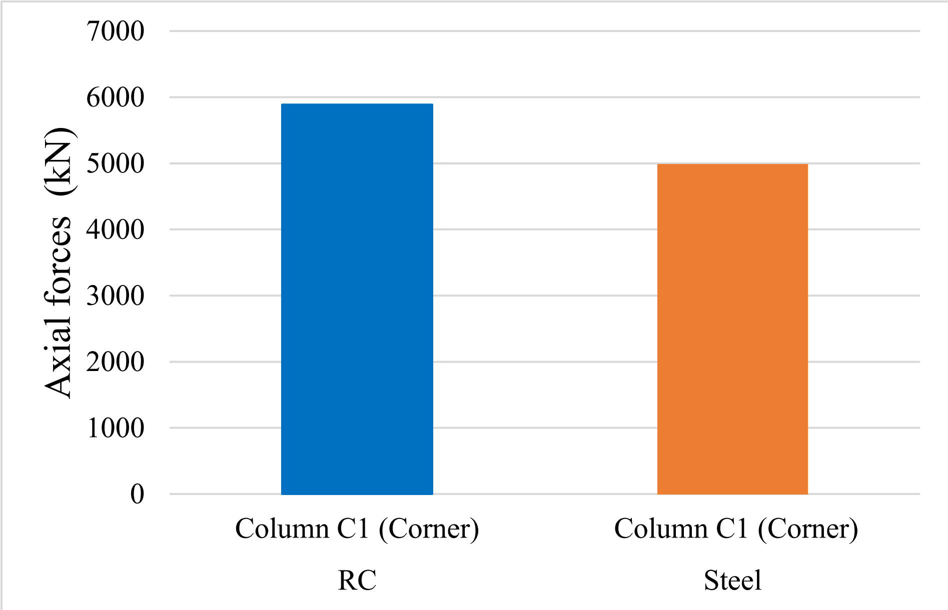


Figure 15: Axial forces for column C1 (corner)

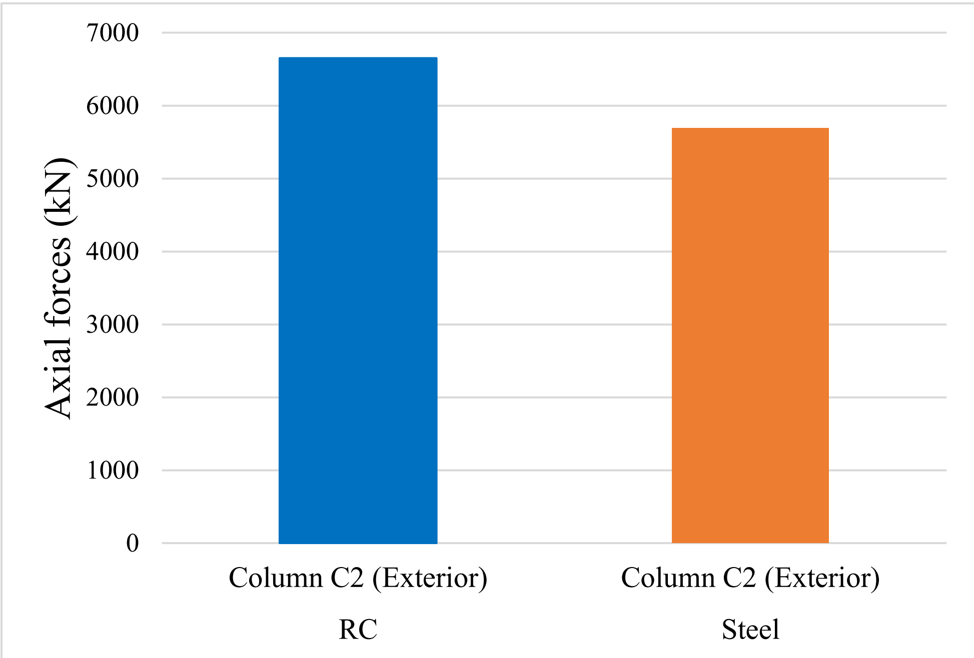


Figure 16: Axial forces for column C2 (exterior)

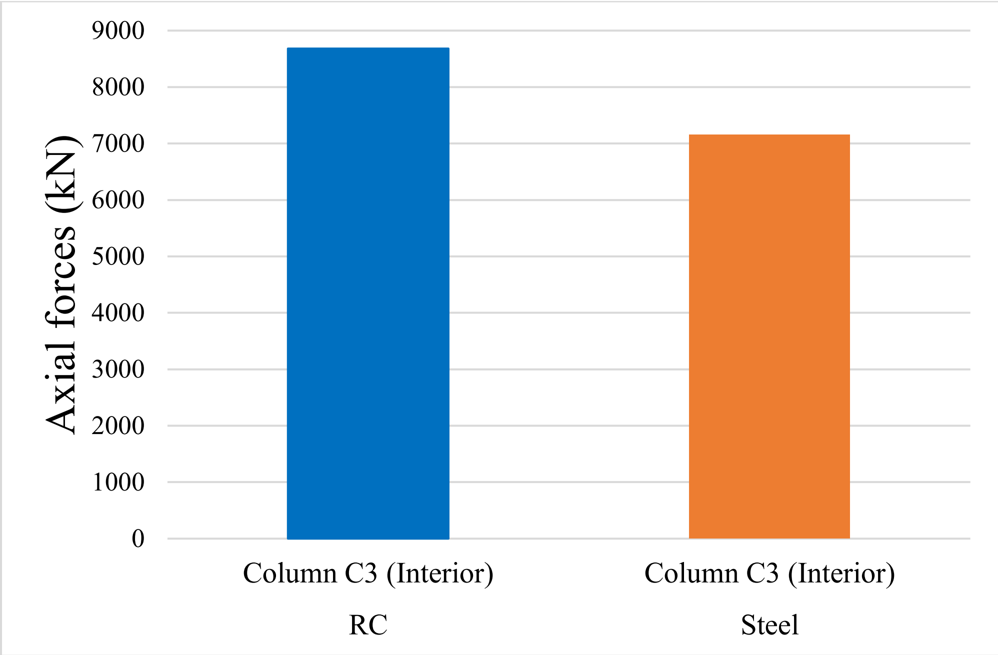


Figure 17: Axial forces for column C3 (interior)

The maximum axial forces in columns are shown in the above figures, which demonstrates that the axial forces are higher at the base of both structures. As can be seen from the above Figures an axial force for Steel framed structures is less as compared to RC framed structures.

4.5 Bending Moments in Columns

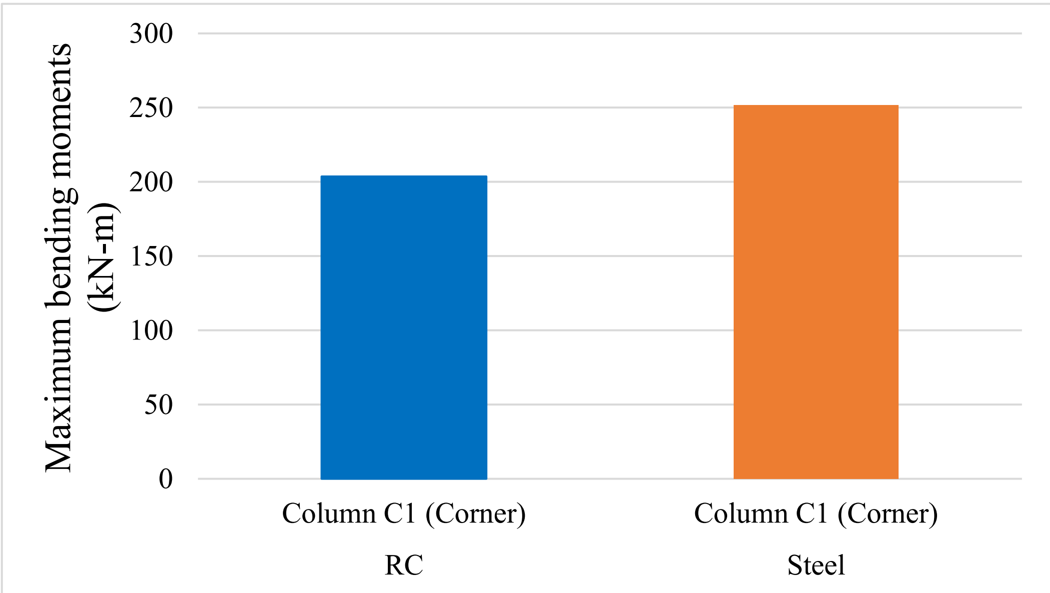


Figure 18*:* Maximum bending moments for column C1 (corner)

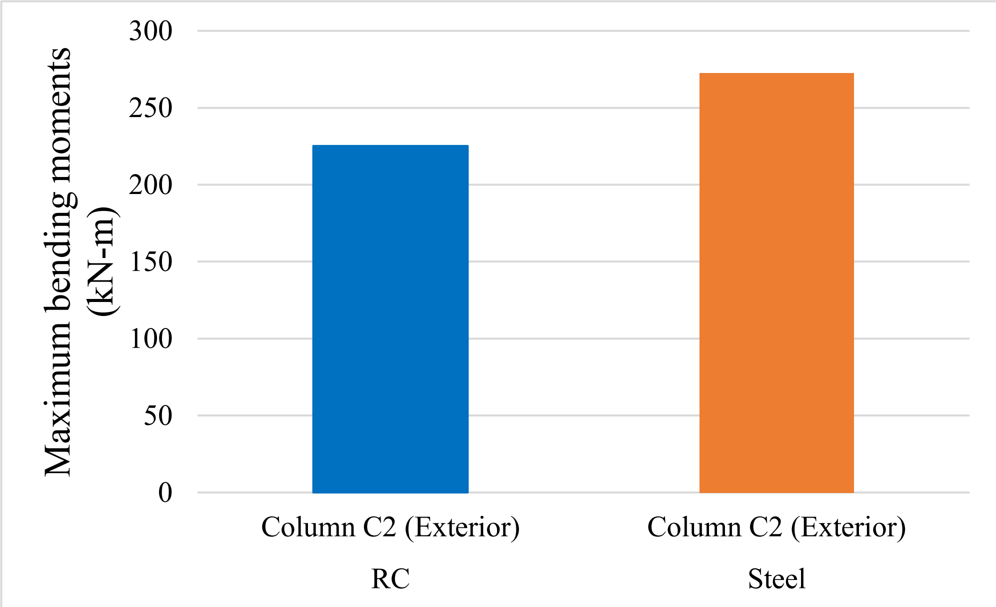


Figure 19. Maximum bending moments for column C2 (exterior)

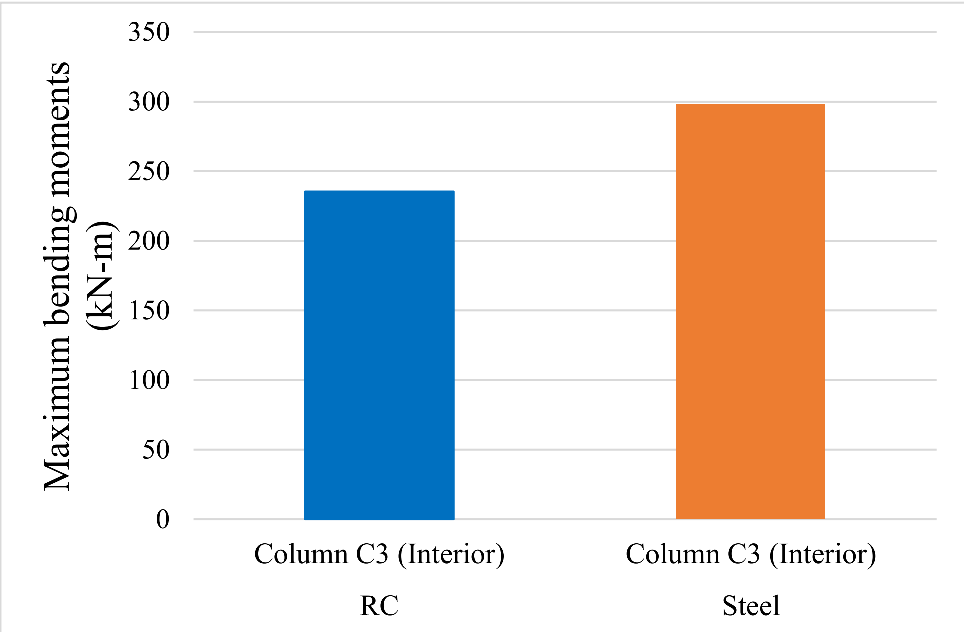


Figure 20. Maximum bending moments for column C3 (interior)

In the above Figure the maximum bending moments for the column are illustrated, which the maximum bending moments for Steel are higher than RC structural maximum bending moments for Steel are % 9 % 10 and % 12 higher than RC for C1, C2, and C3 columns respectively

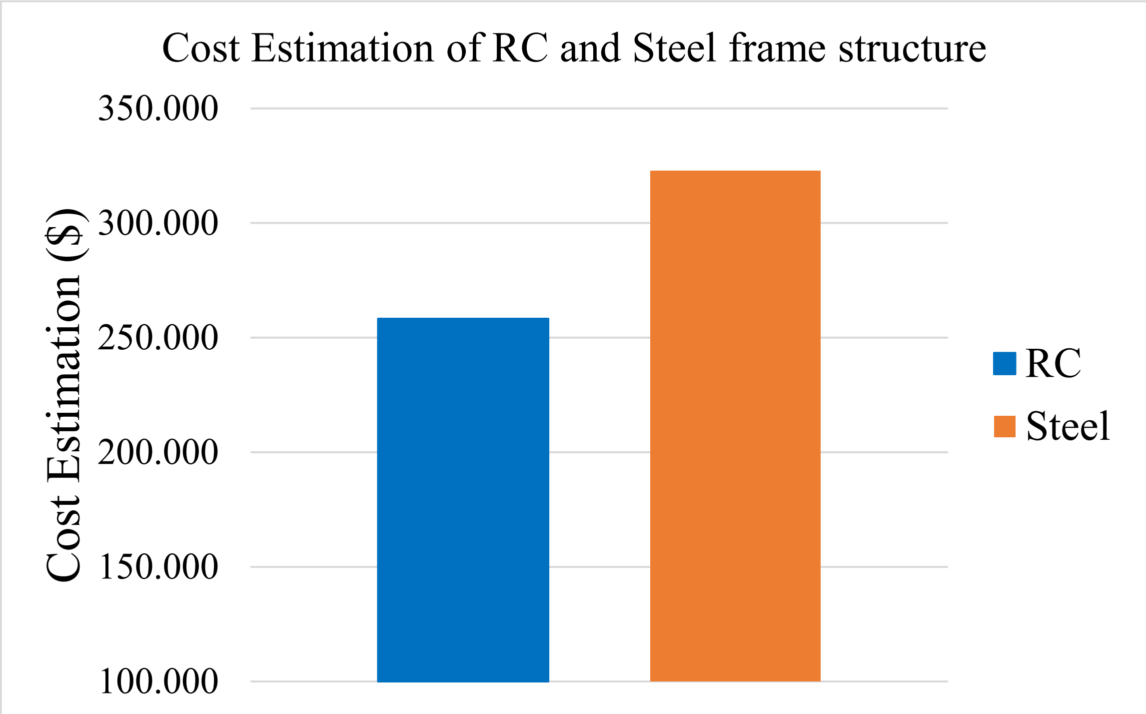


Figure 21: Cost Estimation ($)

The steel structural system is framed structurally more expensive than the RC structure. According to Figure 21, the cost of using Steel is approximately 13% higher than using RC framed structure.

Conclusion

This study presents a comparative analysis of the structural and cost aspects of reinforced concrete (RC) and steel-framed structures in Lefkoşa, North Cyprus. The analysis considered an 8-story residential building designed with both RC and steel frames. The buildings were modeled and analyzed using ETABS and SAP2000 software, following Building Code Requirements for Structural Concrete (ACI 318-19) and the American Institute of Steel Construction (AISC-15th edition).

The results revealed that the base shear, story shear, and displacement for RC structures were generally higher than those for steel structures, whereas steel structures exhibited higher bending moments in columns. Additionally, the axial force in RC columns was found to be higher than in steel columns. Despite these differences, both types of structures complied with the allowable limits for displacement.

In terms of cost, Steel framed structure is approximately %13 costly than RC framed structure. This information is valuable for architects, engineers, and contractors when deciding on the most suitable material for their projects in Lefkoşa, North Cyprus, and similar regions. The findings highlight the importance of considering factors such as cost, strength, durability, and aesthetics when choosing between RC and steel structures for construction projects. Further research could explore alternative materials and innovative construction techniques to optimize both cost and performance in different geographic and environmental contexts.

References

Al-Hussein, M., Al-Omari, I., & Al-Nawafleh, M. (2018). Comparison between Steel and Reinforced Concrete Structures. Journal of Civil Engineering and Architecture, 12(3), 237-244.

Aziz Amen, M., & Nia, H. A. (2018). The dichotomy of society and urban space configuration in producing the semiotic structure of the modernism urban fabric. Semiotica, 2018(222), 203–223. https://doi.org/10.1515/sem-2016-0141

Amen, M. A., & Kuzovic, D. (2018). The effect of the binary space and social interaction in creating an actual context of understanding the traditional urban space. Journal of Contemporary Urban Affairs, 2(2), 71–77. https://doi.org/10.25034/ijcua.2018.3672

Amen, M. A., & Nia, H. A. (2021). The Effect of Cognitive Semiotics on The Interpretation of Urban Space

Configuration. https://doi.org/doi:10.38027/iccaua2021227n9

Aziz Amen, M. (2017). The inspiration of Bauhaus principles on the modern housing in Cyprus. Journal of Contemporary Urban Affairs, 1(2), 21–32. https://doi.org/10.25034/ijcua.2017.3645

Sharma, A. S., Iyappan, G. R., & Harish, J. (n.d.2015). Comparative study of cost and time evaluation in RCC, steel & Composite high rise building. JCPS, 8(4). www.jchps.com.

Rochmanto, D. (2017). Cost of study RC structures, structural steel, and steel combination structure-concrete. International conference on coastal and delta areas (vol. 3, pp. 345- 352). Semarang, Indonesia: Instituto de Mecánica de los Fluidos e Ingeniería Ambiental (IMFIA).

Şafakli, O. (2011). An overview of the construction sector in Northern Cyprus. African Journal of Business Management. 5, 13383-13387.

Steel Construction Manual(15th ed.).(2017).Chicago, IL: American Institute of Steel Construction (AISC)

ACI: Vol. An ACI Standard: Commentary on Building Code Requirements for Structural Concrete (ACI 318R-19), (Building Code Requirements for Structural Concrete (ACI 318–19): ed.). (2019). an ACI Report. American Concrete Institute.

Jadhav, S. M., & Patankar, J. P. (2020). Comparative Study of Reinforced Concrete Frame Building and RC-Steel Composite Frame Building. International Journal of Engineering Research & Technology (IJERT) Www.Ijert.Org, 9. www.ijert.org

Cheng, M. Y., Tsai, H. C., & Sudjono, E. (2010). Conceptual cost estimates using evolutionary fuzzy hybrid neural network for projects in the construction industry. Expert Systems with Applications, 37(6), 4224–4231. https://doi.org/10.1016/j.eswa.2009.11.080

Atalar et al., 2006; Celikag & Naimi,(2011; Karimizadeh, 2015; Okan Veli ŞAFAKLI, 2011; Systems, n.d.)

Mohammed, H. J. (2012). Structural and cost analysis for several building models with different materials. International Review of Civil Engineering (I.RE.C.E.), 3(2)

Atalar, C., Durgunoğlu, H. T., Das, B. M., Hacıalioğlu, E., Akol, A., & Tozan, H. (2006). Site Investigations at Near East University - Cyprus. International Conference on New Developments in Geoenvironmental Geotechnical Engineering, November, 12.

Celikag, M., & Naimi, S. (2011). Building construction in North Cyprus: Problems and alternatives solutions. Procedia Engineering, 14, 2269–2275. https://doi.org/10.1016/j.proeng.2011.07.286

Karimizadeh, A. (2015). Comparison of Steel and Reinforced Concrete as a Sustainable Building Material in Northern Cyprus. September.

Okan Veli ŞAFAKLI. (2011). An overview of the construction sector in Northern Cyprus. African Journal of Business Management, 5(35), 13383–13387. https://doi.org/10.5897/ajbmx11.015

Sohail, M. T. (2013). Control of lateral drift of Medium to High-rise buildings using Concrete Bracings. June 2013, 184. https://doi.org/10.13140/RG.2.2.16470.04167

Systems, C. F. (n.d.). Technical Note 601 ACI318-19 CODE REQUIREMENTS FOR DESIGN OF. i, 1–29.

Fardis, M. N. (2013). Concrete Structures: Behavior and Design. John Wiley & Sons.

Alfred, C. (2014). Comparison of Structural Steel and Concrete: Advantages and Disadvantages. International Journal of Scientific and Research Publications, 4(8), 1-6.

High Quality High Strength Carbon Steel Plate 304 A36 Carbon Steel Plates Manufacturer - Buy Hot Rolled Carbon Steel Plate,Galvanized Steel Coil Carbon Steel Plate,Carbon Steel Plate Sheet Product on Alibaba.com. (n.d.). https://www.alibaba.com/product-detail/High-Quality-High-Strength-Carbon-Steel_1600618982510.html?s=p