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The Perspective on Steel After Earthquakes: The Case of Kahramanmaraş

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ABSTRACT

This study aims to comparatively evaluate the seismic performance of steel and reinforced concrete (RC) structural systems. Based on the data of existing 4-story and 12-story RC buildings located in the Taşburun neighborhood of Elbistan district in Kahramanmaraş province, the same buildings were re-modeled using both RC and steel structural systems. Performance analyses were conducted using linear and nonlinear analysis methods in accordance with the Turkish Building Earthquake Code (TBDY-2018) and the Design, Calculation and Construction Principles for Steel Structures. The analysis results indicate that steel structures exhibit lower relative story drifts, fewer plastic hinge formations, lower structural weight, and higher energy dissipation capacity compared to RC structures. Particularly in high-rise buildings, steel systems were found to reach the "Immediate Occupancy" or "Limited Damage" performance level, while RC systems could only achieve "Collapse Prevention" under the same conditions and, in some cases, "Life Safety" levels after strengthening. This difference is attributed to the ductility, lightweight nature, and controlled energy absorption capacity of steel material. The findings of this study suggest that promoting steel structural systems in earthquake-prone countries like Turkey is a strategic necessity in terms of engineering design, public safety, and post-disaster recovery processes.

1. Introduction

Since the dawn of human existence, people have required shelter and living spaces, developing various methods across different historical periods to meet this fundamental need. This evolution, which began with caves and tents in ancient times, gradually progressed to adobe and timber structures, and today to steel and reinforced concrete buildings that reach towering heights. This transformation reflects not only the development of building materials but also the advancement of construction technologies, engineering methodologies, and aesthetic expectations (Çakır, 2023).

Construction practices shaped by regional characteristics, climatic conditions, and societal needs have increasingly emphasized the importance of steel structures—particularly in buildings requiring wide spans, multiple stories, and rapid construction. Steel structures are becoming more prevalent in the modern construction industry due to their capacity to facilitate systematic quality control during both production and assembly phases (Akman et al., 2003).

The growing significance of steel structures is also influenced by the historical development of quality management. Records concerning quality date back to 2150 BCE, underscoring the enduring importance of structural safety throughout human history. One of the most striking examples is found in Article 229 of the Code of Hammurabi: "If a builder constructs a house and it is not sufficiently strong, and the house collapses and kills the owner, the builder shall be put to death" (Code of Hammurabi, 18th century BCE). Similarly, the Kanunname-i İhtisab-ı Bursa, issued by Sultan Bayezid II in 1502 during the Ottoman period, included regulations concerning construction quality. These examples demonstrate that structural safety has historically been regarded as an integral component of social order (The Bursa Ordinance of Public Inspection, 1502).

Among the greatest threats to structural safety are earthquakes, which pose serious risks to societies located in tectonically active regions. Seismotectonic movements continue globally and occasionally result in devastating earthquakes. Turkey is one of the countries most affected by this risk. Considering that approximately 95% of the population and 98% of industrial facilities are located in earthquake-prone areas, the seismic performance of buildings is of vital importance. The twin earthquakes that occurred on February 6, 2023—Mw 7.7 and Mw 7.6—centered in Kahramanmaraş, tragically reaffirmed this reality. These earthquakes caused extensive destruction and significant loss of life and property in numerous provinces, including Kahramanmaraş, Adıyaman, Gaziantep, Kilis, Malatya, Diyarbakır, Adana, Şanlıurfa, and Osmaniye (AFAD, 2023).

This study was conducted to evaluate the seismic performance of reinforced concrete buildings located in the Taşburun Neighborhood of Elbistan District, Kahramanmaraş Province, and to compare their behavior with equivalent structures constructed using steel framing systems. Following the devastating 2023 Kahramanmaraş earthquakes, the safety of the regional building stock—predominantly composed of reinforced concrete structures built without adequate engineering oversight—has come under renewed scrutiny. These buildings often suffer from poor detailing, excessive mass, and limited ductility, underscoring the need to assess alternative structural systems under local conditions.

While existing literature offers general comparisons between steel and reinforced concrete structures, this study is distinguished by its comparative performance analysis of two building typologies—a newly designed 4-story structure and an existing eleven-story building—each modeled with identical architectural and structural geometry in both reinforced concrete and steel configurations. The analyses are conducted in accordance with the Turkish Building Earthquake Code (TBDY 2018) and aim to quantify the engineering advantages of steel systems in the context of regional seismic risks and construction practices.

2. Structural Properties of Steel

2.1. Steel: Definition and Characteristics

Steel is a metal formed by combining iron (Fe) with carbon (C), typically in proportions ranging from 0.2% to 2.1%. Carbon content is a key factor in the classification of steel. While carbon is the primary alloying element, other elements such as chromium, tungsten, magnesium, and vanadium may also be added during alloying. These elements integrate into the crystal lattice structure of iron, restricting dislocation movement, and thereby increasing the material's hardness (Callister & Rethwisch, 2020; ASM International, 1990).

Steels with high carbon content are generally harder and more durable, but they exhibit lower ductility. Due to their low melting points and excellent castability, high-carbon alloys are commonly referred to as cast iron. In contrast, steels with low carbon content and those containing iron slag are known as wrought iron. This distinction enhances the weldability of steel materials and improves their resistance to corrosion (Shome, 2022; IspatGuru, 2023).

2.2. Steel Structural Components

2.2.1 Rolled Products

Rolling is a metal forming process used to shape raw materials into steel bars, wires, or profiles. In steel structures, rolled products are manufactured through hot-rolling or cold-drawing techniques, depending on the desired mechanical properties and application (Shome, 2022).

Main Types of Rolled Products:

- **Profiles:** Classified as open sections (I, C, L, T profiles) and closed sections (box and tubular profiles). These elements are commonly used in load-bearing frames and structural assemblies.

- **Flats (Lama Bars):** Rectangular cross-sectioned flat steel bars. Available in thin, wide, and flat variants, they are used in bracing, framing, and architectural detailing.

- **Sheets (Plates):** Steel sheets thinner than 10 mm, categorized as flat, domed, cylindrical, or corrugated. They are widely used in roofing, cladding, and enclosure systems.

2.2.2 Steel Connection Elements

Steel structures are formed by cutting and assembling components of various sizes. Connection elements ensure that structural members act as a unified system in terms of strength and functionality.

Main Steel Connection Elements:

- **Rivets:** Cylindrical fasteners with round or countersunk heads, applied either hot or cold. Historically common in steel bridges and early industrial buildings.

- **Bolts:** Threaded cylindrical fasteners used to join steel members. They are classified into standard-strength and high-strength bolts, depending on their mechanical properties and application.

- **Welds:** A process of joining metals through heat or pressure. Welding is divided into two main categories:

    - Fusion welding (e.g., electric arc, gas flame)

    - Pressure welding (e.g., forge welding, oxy-gas, resistance welding)

These connection methods are selected based on structural requirements, fabrication conditions, and performance expectations such as load transfer, ductility, and durability (SteelConstruction.info, 2023; AWS, 2011).

2.3 Advantages and Disadvantages of Steel

2.3.1 Advantages:

- Steel is a homogeneous and isotropic material; its mechanical properties do not vary with direction.

- It has a high modulus of elasticity, providing excellent stiffness.

- Tensile and compressive strengths are nearly equal, allowing balanced structural performance.

- It is ductile, offering flexibility against seismic and settlement-induced loads.

- Short assembly time due to off-site prefabrication capabilities.

- Easily reinforced and reused, contributing to sustainability.

- With effective planning, minimal scaffolding is required during construction.

2.3.2 Disadvantages:

- Steel is vulnerable to fire; it loses load-bearing capacity above 600°C.

- It is susceptible to corrosion, requiring regular maintenance and protective coatings.

- Due to its high thermal and acoustic conductivity, insulation is necessary.

- It is sensitive to buckling and local stability issues, especially in slender members (Callister & Rethwisch, 2020; Eurocode 3, 2005).

3. Literature Review

Kaya (2006) conducted a comparative study on the effectiveness of linear and nonlinear analysis methods defined in the Regulation on Buildings to be Constructed in Earthquake Zones (DBYBHY) in evaluating the seismic performance of reinforced concrete structures. The study included numerical analyses of buildings designed according to previous regulations and compared their seismic performance under the current code. The results indicated that nonlinear analysis methods generally yielded more accurate damage zone predictions although the differences from linear methods were not substantial. It was also found that buildings properly dimensioned according to the Regulation on Structures to be Built in Disaster Areas (ABYYHY) were sufficient in terms of the damage limits defined in the current regulation, whereas buildings designed under older codes exhibited significant design deficiencies when evaluated against the updated damage criteria.

Özmen et al. (2007) investigated the nonlinear behavior of reinforced concrete elements and how these behaviors can be modeled. The study demonstrated that nonlinear modeling approaches allow for more accurate predictions of structural behavior under seismic loads. Various modeling techniques were compared, and the research emphasized that nonlinear analyses are critical for evaluating structural performance during earthquakes.

Damcı (2008) focused on the seismic performance of buildings using nonlinear analysis methods. The study examined preferred modeling techniques for simulating the nonlinear behavior of structural elements under seismic effects. The findings highlighted that nonlinear analyses play a vital role in accurately assessing seismic performance and are essential for performance-based design approaches.

İbiş and Ulutaş (2021) analyzed the seismic performance of a reinforced concrete building designed and constructed in accordance with the Turkish Building Earthquake Code 2018 (TBDY-2018). Using the single-mode pushover analysis method, the performance level of the structure was determined. The results showed no damage in columns and shear walls, while some beams exhibited noticeable damage. These findings were compared with the target performance levels defined in TBDY-2018, and it was concluded that the building met the expected performance criteria.

The major earthquake that struck Türkiye in February 2023 has significantly raised awareness regarding structural safety. Observations from the affected region revealed that the majority of damaged and collapsed buildings were reinforced concrete structures, prompting a renewed engineering focus on their seismic resilience. In the field of structural engineering, evaluating the earthquake resistance of different load-bearing systems has become increasingly critical.

In this context, the potential performance differences between reinforced concrete and steel structures have emerged as a key research topic. This study aims to investigate the seismic performance of steel structures as an alternative to reinforced concrete buildings in earthquake-prone regions.

Two reinforced concrete buildings that survived the Kahramanmaraş-centered earthquake were selected from Taşburun District in Elbistan. Based on core samples taken from these buildings, structural models were developed and analyzed. Using the same story height and plan layout, equivalent steel structures were designed and subjected to seismic performance analysis.

The study evaluates whether steel structures offer superior earthquake resistance compared to their reinforced concrete counterparts. Among steel structural systems, Moment-Resisting Frames (MRF) and Concentrically Braced Frames (CBF) are commonly used. Literature indicates that CBF systems generally outperform MRF systems in seismic conditions. CBFs are more effective in resisting lateral forces and allow for balanced energy dissipation during earthquakes.

Therefore, the steel structures in this study were designed using the CBF system. After analyzing the reinforced concrete buildings and their steel equivalents, the observed performance differences were assessed. The findings were then discussed in terms of the potential of steel systems to reduce loss of life and property in seismic zones.

In conclusion, the study evaluates whether steel structures can serve as a viable alternative load-bearing system in earthquake-prone areas. It emphasizes the importance of material selection in structural design for seismic resilience and aims to contribute to future engineering practices.

4. Linear, Nonlinear Behavior and Analysis

4.1 Linear Analysis Methods

Linear analysis methods used to evaluate the seismic behavior of structures are addressed under two main categories in the Turkish Building Earthquake Code 2018 (TBDY-2018): Equivalent Seismic Load Method (Article 4.7) and Modal Response Spectrum Method (Article 4.8.2). The applicability of these methods, particularly in the assessment of existing buildings, is shaped by the limitations defined in Articles 15.5.1 and 15.5.3 of TBDY-2018. For example, in buildings with a Building Height Class (BYS) lower than 5, the presence of irregularity type B3 may restrict the use of linear analysis methods. Additionally, the shear forces in structural members must be considered, and the Demand/Capacity Ratio (DCR) values must comply with the specified limits to ensure structural adequacy.

4.2 Nonlinear Analysis Methods

Nonlinear analysis methods are developed to evaluate the behavior of structures beyond their elastic limits. Under the scope of the Turkish Building Earthquake Code 2018 (TBDY-2018), these analyses are categorized into two main groups: Pushover methods and Time-history dynamic analyses.

4.2.1 Pushover Methods

Pushover analysis is a technique used to determine the performance of structures under lateral loads. It is implemented in two primary forms: Displacement-controlled Force-controlled TBDY-2018 defines both single-mode and multi-mode pushover analyses. Single-mode analysis is suitable for low- to mid-rise buildings where the first vibration mode dominates. Multi-mode analysis accounts for multiple vibration modes and provides more realistic results, especially for tall or irregular structures. The resulting force–displacement curves are used to determine the seismic performance levels of buildings, which are classified as follows:

• Collapse Prevention (CP): The minimum acceptable performance level, ensuring the building remains standing after a major earthquake. Severe damage may occur, and repair is generally uneconomical. The structure is not considered reusable.

• Life Safety (LS): The building may sustain significant damage but remains stable enough to protect occupants during the event. Collapse is prevented, though repairs will be necessary. This level is widely adopted for life protection.

• Immediate Occupancy (IO): The structure experiences minimal damage and remains usable immediately after the earthquake. Only minor repairs may be required. This level is preferred for critical facilities such as hospitals and schools.

• Operational (OP): The building is expected to remain fully functional with virtually no damage. This performance level is typically required for high-importance structures, ensuring uninterrupted use post-earthquake.

TBDY-2018 incorporates these four performance levels to guide the assessment and retrofitting of existing buildings. The results of pushover analyses are used to determine which performance level a structure corresponds to. The force–displacement curves obtained from these analyses allow engineers to examine the nonlinear behavior of buildings, including the point at which the structure exceeds its elastic limit, the extent of plastic deformations, the final performance level achieved during seismic loading. These analyses are particularly useful in determining whether a building requires post-earthquake repairs or mandatory strengthening.

4.2.2 Structural Performance Assessment via Time History Analysis

Nonlinear analysis in the time domain is based on the direct integration of differential equations to track the dynamic behavior of structures under seismic motion step by step. In this method, the stiffness matrix is updated over time, accounting for both material and geometric nonlinearities. Earthquake acceleration records are directly applied to the model, allowing the calculation of internal forces and displacements at each time increment. This enables a detailed evaluation of how structures respond to earthquakes of varying magnitudes.

4.3 Nonlinear Analysis Models in Structural Systems

Traditional approaches in structural engineering assume that the stress–strain relationships of materials remain within the linear elastic range and that displacements are negligible. However, as external loads increase and structural elements approach their load-bearing capacity, elastic limits are exceeded, plastic deformations begin, and the system exhibits nonlinear behavior. This necessitates more realistic modeling of structures under extreme loads such as earthquakes.

TBDY-2018 classifies nonlinear behavior under two main categories: material nonlinearity and geometric nonlinearity.

- **Material nonlinearity** arises when structural elements exceed their elastic limits and begin to deform plastically. In reinforced concrete members, this is characterized by crushing under compression and cracking under tension; in steel members, it becomes evident when the yield point is surpassed. These behaviors play a critical role in assessing the risk of fracture, collapse, or severe damage during seismic events. TBDY-2018 recommends the use of various idealized material models to represent such behaviors.

- **Geometric nonlinearity** relates to changes in system stiffness due to large displacements. During an earthquake, the equilibrium position and stiffness distribution of the structure continuously change, rendering the small displacement assumption invalid. This is particularly significant in tall buildings or systems with irregular geometries. Geometric nonlinear models yield more accurate results in analyzing buckling, overturning, and local stability issues.

One of the key contributions of nonlinear analysis is its ability to reduce the impact of seismic loads by considering the energy dissipation capacity of the structure. Thus, even if the structure exceeds elastic limits, it can remain stable through controlled plastic deformations. Classical linear design methods overlook such behaviors, potentially leading to unexpected deformations and damage. In contrast, nonlinear analyses are indispensable for enhancing structural safety and implementing performance-based design principles.

5. Methods

In this study, linear and nonlinear analysis methods were applied to selected building models to comparatively evaluate the seismic performance of steel and reinforced concrete structural systems. The application area was based on a site located in the Taşburun Neighborhood of Elbistan District, Kahramanmaraş Province. The aim was to model 4 -story and 12-story buildings using both reinforced concrete and steel structural systems and to conduct linear and nonlinear performance analyses accordingly. All structures were designed in accordance with the provisions of the Turkish Building Earthquake Code (TBDY-2018), and comparative analyses were performed. Both the 4-story building and the existing 12-story building (ground floor + eleven stories), each with a typical story height of 3 meters, were modeled using reinforced concrete and steel structural systems. Accordingly, the total height of the 4-story building was 12 meters, while the 12-story building reached a total height of 36 meters. Their seismic performance was evaluated using this dual approach, enabling a comparative assessment of structural behavior under identical conditions.

5.1. Building Types

Two different building types were considered in this study:

- 4-story building
- Existing 12-story building (G+11)

Both structures were modeled independently using reinforced concrete and steel structural systems, based on identical soil conditions and architectural plans. The 12-story building was modeled using the data obtained from an existing reinforced concrete structure in the region. Subsequently, the same architectural plan was adapted to a steel structural system for comparative analysis. Each building was designed with a typical story height of 3 meters, resulting in total heights of 12 meters and 36 meters for the 4-story and 12-story buildings, respectively. The following sections present the floor plans, reinforced concrete elevation and design, and steel elevation and design for both building types.

5.1.1. 4-Story Building: Floor Plan, Reinforced Concrete Elevation and Design, Steel Elevation and Design

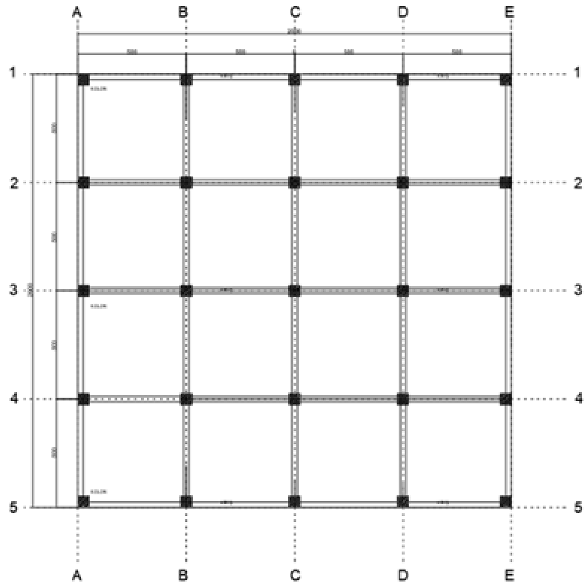

Figure 1. Floor Plan of the 4-Story Building

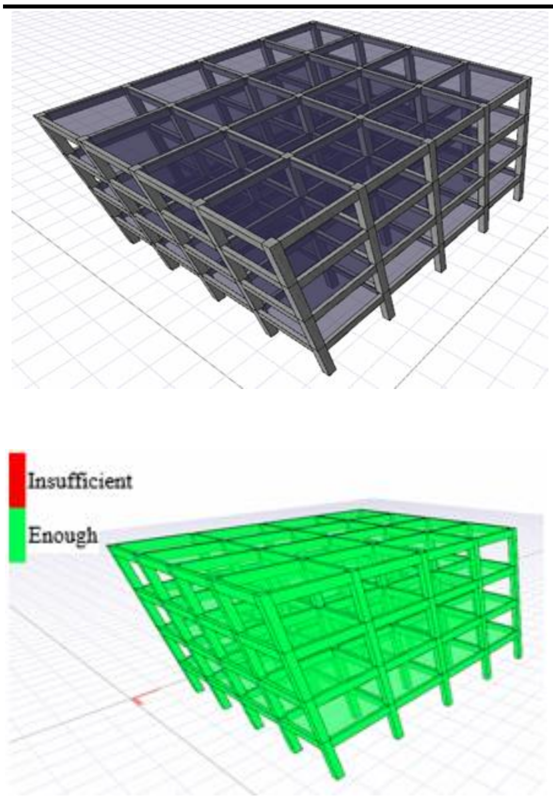

Figure 2. Elevation and Structural Design of the 4-Story Reinforced Concrete Building

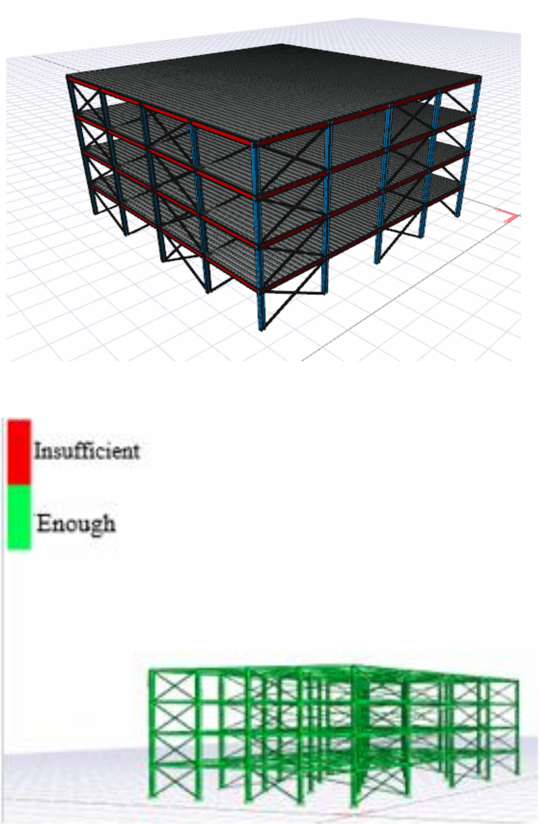

Figure 3. Elevation and Structural Design of the 4-Story Steel Building

5.1.2. 12-Story Existing Building: Floor Plan, Reinforced Concrete Elevation and Design, Steel Elevation and Design

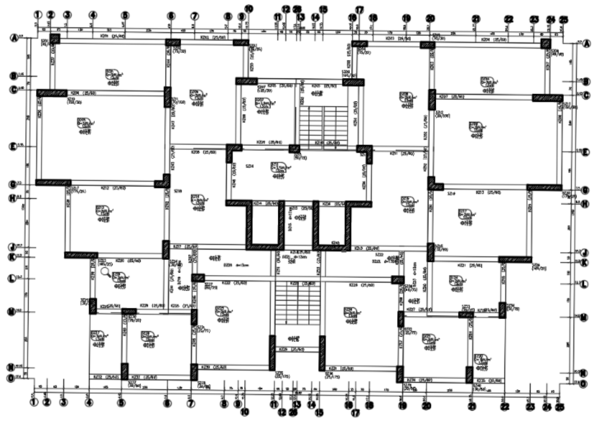

Figure 4. Floor Plan of the 12-Story Building

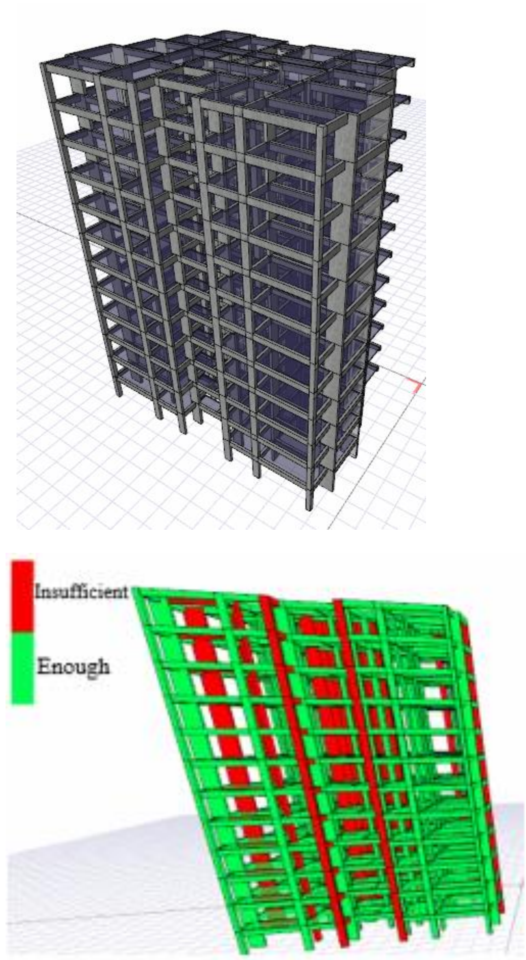

Figure 5. Elevation and Structural Design of the 12-Story Reinforced Concrete Building

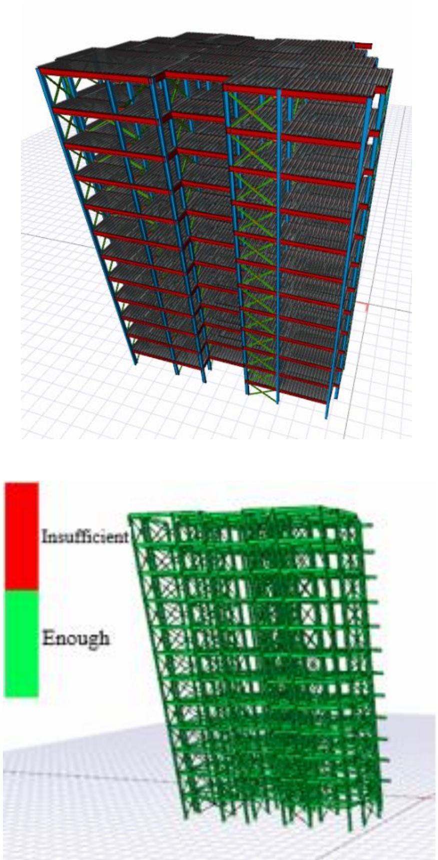

Figure 6. Elevation and Structural Design of the 12-Story Steel Building

5.2. Modeling and Material Properties

The structural models were developed in three dimensions using ideCAD and SAP2000 software. Material properties are defined as follows:

Reinforced Concrete Structures

- Concrete grade: C25 – C30
- Reinforcement steel: S420

Steel Structures

- Steel grade: S275
- Connection type: Welded joints
- Steel members:
- 4-Story Structure:
  - Columns: HE 280 B
  - Beams: IPN 340
  - Bracings: HE 140 B
- 12-Story Existing Structure (Basement + 11 floors):
  - Columns: HE 400 B
  - Beams: IPN 500
  - Bracings: HE 180 B

According to AFAD data, the site is classified as ZC soil type, and analyses were conducted based on DD-2 seismic level (10% probability of exceedance in 50 years).

5.3. Analysis Types and Parameters

All analyses were performed in accordance with Sections 5 and 7 of the Turkish Seismic Code (TBDY-2018). The following analysis types were applied:

- Nonlinear static pushover analysis
- Linear performance analysis
- Modal analysis
- Seismic overturning control
- Interstory drift and relative displacement checks
- Performance evaluation based on limit states (IO, LS, CP levels)

Load combinations were defined in compliance with TBDY-2018, and horizontal seismic effects were applied separately in both X and Y directions.

5.4. Performance Criteria

Structural performance was evaluated according to TBDY-2018 using the following criteria:

- Interstory drift ratio: ($\Delta i/h \leq 0.02$)
- Plastic hinge formation in structural members
- Post-earthquake damage states of structural elements
- Overall structural performance level:
  - Collapse Prevention (CP)
  - Life Safety (LS)
  - Immediate Occupancy (IO)

- Structural weight

For each model, both “steel” and “reinforced concrete” alternatives were analyzed under identical conditions, enabling direct comparison between systems.

6. Findings and Evaluation

In this section, the linear and nonlinear performance analysis results of steel and reinforced concrete structural systems are compared for the analyzed 4-story and 12-story buildings. The evaluation includes: Interstory drift ratios, Mode shapes, Formation of plastic hinges, Structural performance levels, Energy dissipation, Structural weight and Cost comparison. These parameters were assessed to determine the relative performance and efficiency of each structural system under identical conditions.

6.1 Cost Comparison

Structure Type	Average Cost per m²	Construction Duration	Estimated Maintenance Cost (10 Years)
Steel Structure	8,000–12,000 TRY (World Steel Association, 2025)	3–6 months (Global Construction Review, 2025)	Low (Concrete Centre UK, 2025)
Reinforced Concrete	6,000–9,000 TRY (Turkish Construction Economics Report, 2025)	6–12 months (Global Construction Review, 2025)	Medium to High (IEA, 2025)

6.1.1 Material and Labor Costs

Steel Structures: As of 2025, the price of steel per ton has increased. However, prefabricated production and rapid assembly significantly reduce labor costs.

Reinforced Concrete Structures: Although material costs may appear lower, labor-intensive processes, such as formwork, rebar tying, and concrete pouring, increase overall labor expenses (Turkish Construction Economics Report, 2025).

6.1.2 Construction Duration

Steel Structures: Since components are manufactured in factories and assembled on-site, construction time is reduced by approximately 30-50%. This shortens site-related expenses and minimizes rental losses.

Reinforced Concrete Structures: On-site production is required, which may lead to delays due to weather conditions (Global Construction Review, 2025).

6.1.3 Energy and Environmental Impact

Steel: Recyclable and environmentally friendly. However, its production phase involves high energy consumption.

Reinforced Concrete: Characterized by high carbon emissions, particularly due to cement production, which poses environmental disadvantages (IEA, 2025; IPCC, 2025).

6.1.4 Maintenance and Repair

Steel Structures: Require protection against corrosion but are not subject to issues like cracking or deformation commonly seen in concrete structures.

Reinforced Concrete Structures: Over time, problems such as cracking and reinforcement corrosion may arise, necessitating maintenance (IEA, 2025).

6.1.5 Long-Term Costs

Steel Structures: Although initial investment costs are higher, rapid return on investment, low maintenance requirements, and energy efficiency may offer overall cost advantages.

Reinforced Concrete Structures: While seemingly more affordable at the outset, long-term maintenance and energy expenses can increase total costs over time (IEA, 2025).

6.2. Analysis of a 4-Story Building

The values were obtained using the structural analysis software packages IDECAD and SAP2000.

Parameter	Reinforced Concrete Structure	Steel Structure
Maximum Interstory Drift Ratio	0.0063	0.0021
Performance Level	Immediate Occupancy (IO)	Immediate Occupancy (IO)
Number of Plastic Hinges	7	3
Energy Dissipation (kNm)	1450	980
Structural Weight (tons)	1778.81	721.46

6.3. Analysis of a 12-Story Building

In this study, the model was developed based on an existing 11-story reinforced concrete building (Z+11) located in Elbistan, and the structural analysis values were obtained using the software packages IDECAD and SAP2000.

Parameter	Reinforced Concrete Structure	Steel Structure
Maximum Interstory Drift	0.0278	0.0043
Performance Level	Collapse Prevention (CP)	Immediate Occupancy (IO)
Number of Plastic Hinges	86	7
Energy Dissipation (kNm)	4950	3200
Structural Weight (tons)	5921.43	2842.18

Comprehensive analyses and evaluations clearly demonstrate that steel structures are safer, more flexible, and more durable than reinforced concrete structures in terms of seismic performance. Especially in comparisons of buildings with identical plans, the 4-story steel structure exhibits lower drift ratios and fewer plastic hinge formations than its reinforced concrete counterpart. Both systems achieved the “Limited Damage” performance level. However, while the existing 12-story reinforced concrete building initially at the collapse threshold could only reach the “Controlled Damage (CD)” level after retrofitting, the steel structure designed with the same geometry achieved the “Limited Damage (LD)” level, quantitatively highlighting the performance gap.

This difference stems from the ductile nature of steel, its capacity for plastic deformation, its lightweight properties, and its structural behavior that allows widespread yet controlled plastic hinge formation. Numerical calculations reveal that the total weight of the 4-story reinforced concrete building is approximately 1,778.81 tons, whereas the steel structure with the same number of stories and plan geometry weighs only 721.46 tons. Similarly, the 12-story reinforced concrete building weighs about 5,921.43 tons, while its steel counterpart weighs only 2,842.18 tons, indicating that steel systems are approximately 45% lighter than reinforced concrete systems.

A lighter structure directly reduces inertial forces during an earthquake, lowering the horizontal loads on structural elements and enabling safer performance with reduced displacement values. Steel’s ability to exhibit plastic behavior beyond its elastic limit allows it to dissipate energy under sudden and repetitive loads such as earthquakes, enabling controlled energy absorption without collapse. This capacity to distribute and dampen potential damage during seismic events is a critical advantage, minimizing the risk of sudden structural failure.

In contrast, reinforced concrete structures tend to be more brittle, with lower ductility and limited energy absorption capacity, making them more vulnerable and risky. Enhancing ductility requires specialized reinforcement detailing and high-quality materials, demanding significant engineering precision to ensure seismic safety.

When analyzing the cost of structural systems, it is essential to consider not only the initial investment per square meter but also the production process, labor intensity, construction duration, and long-term maintenance requirements. According to 2025 data, although the per-square-meter cost of steel structures appears 30-50% higher than reinforced concrete, their 30-50% shorter construction time, reduced labor needs, and recyclable material advantages make them a competitive solution in terms of total cost. While reinforced concrete structures may seem more economical initially, their on-site production requirements and long-term maintenance needs can lead to cost disadvantages over time.

7. Conclusion

The selection of structural systems should not be based solely on current prices; return on investment, service life, and sustainability criteria must also be considered. In large-scale seismic disasters such as the February 6, 2023 Kahramanmaraş-centered earthquakes, many reinforced concrete buildings collapsed in a pancake mechanism due to outdated design codes, unauthorized structural interventions (e.g., column cutting), and poor material quality. In contrast, steel structures demonstrated greater resilience to such irregularities, offering safer behavior during earthquakes and significantly accelerating post-disaster reconstruction thanks to their high ductility and prefabricated modular systems. Performance analyses also show that steel systems exhibit lower lateral displacement values across all story heights, more regular modal behavior, and reduced torsional effects compared to reinforced concrete systems. As story height increases, reinforced concrete systems show a noticeable decline in performance, while steel systems maintain more stable and predictable results in terms of lateral displacement, sectional stresses, and dynamic behavior. Additionally, steel structures are approximately 34% more efficient in energy dissipation, proving that they offer not only safer but also more effective structural solutions during seismic events. All these technical advantages clearly underscore the strategic importance of steel systems in seismic design. In light of these findings, promoting steel structural systems in seismically active countries especially in high-risk regions like Türkiye is not only an engineering imperative but also a strategic necessity for life safety, post-disaster response, and sustainable urban development.

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References

Abrahamson, N. A., & Al-Atik, L. (2010). An improved method for nonstationary spectral matching. Earthquake Spectra, 26, 601–617.

Ademović, N., & Muratagić, A. (2023, June). Seismic Analysis of Buildings with a Soft Storey Using Pushover Analysis. In International Symposium on Innovative and Interdisciplinary Applications of Advanced Technologies (pp. 27–43). Cham: Springer Nature Switzerland.

AFAD. (2023). February 6, 2023 Pazarcık–Elbistan (Kahramanmaraş) Earthquakes Mw: 7.7 – Mw: 7.6 Report. Disaster and Emergency Management Authority, Türkiye.

AFAD Official Website. (2023). Retrieved from https://www.afad.gov.tr

Akman, M. S. (2003). Historical Development of Building Materials. Turkish Engineering News Journal, Issue 426, 30–36.

Altunışık, M., Genç, A., & Bayraktar, A. (2019). SAP2000 Applications in Civil Engineering (2nd ed.). DYNAMIC ACADEMY Software Construction Ltd., Trabzon.

American Society of Civil Engineers. (2022). Minimum Design Loads for Buildings and Other Structures (ASCE/SEI 7-22). Reston, VA, USA.

ASM International. (1990). ASM Handbook, Volume 1: Properties and Selection: Irons, Steels, and High-Performance Alloys. ASM International.

AWS. (2011). Welding Handbook, Volume 1: Welding Science and Technology. American Welding Society.

Bommer, J. J., Hancock, J., & Stafford, P. J. (2008). Numbers of scaled and matched accelerograms required for inelastic dynamic analyses. Earthquake Engineering and Structural Dynamics, 37, 1585–1607.

Callister, W. D., & Rethwisch, D. G. (2020). Materials Science and Engineering: An Introduction (10th ed.). Wiley.

Code of Hammurabi. (18th century BCE). Milliyet Blog.

Concrete Centre UK. (2025). Reinforced Concrete: Design, Cost, and Lifecycle Considerations. Retrieved from https://concretecentre.com

Çakır, O. (2023). Shelter Solutions Throughout Human History and the Future Search for Tradition. Yapı Journal. Retrieved from https://yapidergisi.com/insanlik-tarihi-boyunca-barinma-cozumleri-ve-gelecekte-gelenekseli-arayis/

Çevre ve Şehircilik Bakanlığı. (2016). Design and Construction Principles for Steel Structures. ÇYTHYDE, Ankara.

Damcı, E. (2008). Nonlinear Analysis of Structures and Their Earthquake Performance. PhD Thesis, Istanbul Technical University, Institute of Science.

Doğangün, A. (2021). Design and Analysis of Reinforced Concrete Structures (17th ed.). Birsen Publishing, Istanbul.

Eurocode 3. (2005). Design of Steel Structures – Part 1-1: General Rules and Rules for Buildings. CEN.

Global Construction Review. (2025). Sustainability in Steel Structures. Retrieved from https://globalconstructionreview.com

Hasol, D. (1995). Encyclopedic Dictionary of Architecture. Yapı Endüstri Merkezi Publishing, Istanbul.

IDEcad Structural Software. (2025). Retrieved from https://idecad.com.tr

IEA. (2025). Cement Technology Roadmap: Towards Low-Carbon Cement. International Energy Agency.

International Energy Agency. (2025). Cement Industry Emissions Report. Retrieved from https://iea.org

IPCC. (2025). Climate Impact of Cement Production. Intergovernmental Panel on Climate Change.

IspatGuru. (2023). Cast Irons and Their Classification. Retrieved from https://www.ispatguru.com

İbiş, T., & Ulutaş, H. (2021). Determining the Seismic Performance of a New Reinforced Concrete Building According to TBDY 2018. Bitlis Eren University Journal of Science, 10(3), 1104–1124. https://doi.org/10.17798/bitlisfen.914069

Kaya, M. P. (2006). A Numerical Study on the Comparison of Linear and Nonlinear Methods in Determining the Seismic Performance of Existing Reinforced Concrete Buildings. MSc Thesis, Istanbul Technical University.

Özmen, B. H., İncel, M., & Bilgin, H. (2007). Modeling the Nonlinear Behavior of Reinforced Concrete Elements. 6th National Earthquake Engineering Conference, Oct. 16–20, 1–10.

Özyürek, K. (2019). Evaluation of the Seismic Performance of an Existing High-Rise Reinforced Concrete Building. MSc Thesis, Kocaeli University, Institute of Science.

Özhendekçi, D. (2009). Steel Structures I Lecture Notes. Yıldız Technical University, Department of Civil Engineering, Istanbul.

SAP2000. (2008). Structural Analysis Program. Computers and Structures Inc., Berkeley, California, USA.

Shome, M. (2022). Introduction to Rolling Process. Cambridge University Press.

SteelConstruction.info. (2023). Bolted and Welded Connections. Retrieved from https://www.steelconstruction.info

Şeker, M. (2022). Theoretical Investigation of the Behavior of Multi-Story Steel Structures with Different Steel Bracing Configurations.

Şimşek, M. (1996). Quality Management. Marmara University Technical Education Faculty Publications, Istanbul.

Turkish Construction Economics Report. (2025). Annual Cost Analysis of Structural Systems.

The Bursa Ordinance of Public Inspection. (1502). Belgesel Tarih.

World Steel Association. (2025). Steel Construction: Cost and Efficiency Trends. Retrieved from https://worldsteel.org