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Research Article

Earthquake Risk Management: Failures of Modern Buildings in the 2023 Turkey-Syria Earthquakes

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Abstract

The devastating earthquakes that struck southern Turkey and northern Syria on February 6, 2023, exposed severe weaknesses in the seismic resilience of modern buildings. Despite being designed under updated seismic regulations such as the Turkish Earthquake Code (TEC-2018), many reinforced concrete structures suffered catastrophic collapse. This paper investigates the structural and regulatory failures that led to the loss of over 53,000 lives and the destruction of more than 518,000 buildings.Through a detailed analysis of forensic engineering reports, case studies, and comparisons with international collapses, the research identifies critical engineering deficiencies, such as soft-story configurations, weak concrete quality, inadequate reinforcement detailing, and poor construction practices. It also highlights systemic regulatory gaps, including construction amnesties, political corruption, and the widespread lack of independent inspections. Case studies such as Rönesans Rezidans, Isias Hotel, and Galeria Sitesi demonstrate how these failures manifested in both high-rise and mid-rise structures, with fatal outcomes.The findings reveal that code compliance alone is insufficient without robust enforcement and accountability. The study proposes actionable recommendations for improving earthquake resilience through mandatory retrofitting, stricter enforcement, independent structural audits, and public transparency. This research contributes to the growing body of evidence that earthquake-related collapses are largely preventable, and that meaningful change requires political will and engineering integrity.

Keywords: 2023 Turkey-Syria earthquake, Building collapse, Seismic code violations, Soft-story failure, Construction amnesty

Introduction

Seismic events represent some of the most destructive natural phenomena, posing significant risks to both human life and the built environment. On February 6, 2023, two major earthquakes, with moment magnitudes of 7.8 Mw and 7.5 Mw, struck southern Türkiye and northern Syria. These events resulted in one of the most devastating seismic disasters of the 21st century, leading to the extensive collapse and heavy damage of approximately 518,000 residential structures across eleven affected cities. The human toll was severe, with over 53,000 fatalities and more than 100,000 injuries reported, the majority of which were directly attributable to the collapse of reinforced concrete buildings.

A particularly alarming aspect of this disaster was the widespread failure of recently constructed buildings, many of which were expected to demonstrate higher seismic performance due to the enforcement of modern seismic design standards, particularly Türkiye's Earthquake-Resistant Design Code (TEC-2018). Despite the presence of updated regulatory frameworks aimed at enhancing structural resilience against earthquakes, the observed structural failures revealed significant shortcomings in both engineering practices and regulatory enforcement.

The extensive collapse of modern reinforced concrete structures highlights critical deficiencies not only in design and construction methodologies but also in the mechanisms of building code implementation and

oversight. These failures suggest systemic vulnerabilities that transcend individual cases, pointing to broader institutional, technical, and procedural weaknesses within the construction and regulatory sectors.

This thesis seeks to systematically investigate the principal causes underlying the extensive building collapses observed during the 2023 Türkiye-Syria earthquakes. It focuses on two primary dimensions: (1) engineering deficiencies, including inadequate design practices, poor material quality, and construction flaws; and (2) enforcement gaps, encompassing issues such as insufficient inspection regimes, regulatory non-compliance, and governance failures. Through detailed analysis of case studies, forensic investigations, and policy reviews, this research aims to contribute to a deeper understanding of the factors that compromised structural resilience. Furthermore, the study aspires to offer recommendations for improving seismic safety standards, strengthening regulatory frameworks, and enhancing disaster risk reduction strategies in earthquake-prone regions.

Material and Methods

This study uses a post-earthquake analysis to understand why many buildings failed during the 2023 Turkey-Syria Earthquakes. It looks at collapsed buildings to find common problems such as soft-story design, weak concrete, and bad reinforcement. The Turkish Earthquake Code 2018 (TEC-2018) is reviewed to see if the buildings followed the rules. Other past earthquakes and international cases are also included to compare and understand repeated mistakes in construction.

Seismic Code Review:

The Turkish Earthquake Code 2018 (TEC-2018) and Syrian building regulations are reviewed to assess gaps between theoretical design standards and observed real-world performance. Special attention is given to performance-based seismic objectives, minimum material requirements, and detailing provisions.

Case Selection Criteria

Case Selection Criteria:

- Buildings were selected based on the following:
- Collapse severity and casualty rates,
- Year of construction (primarily post-2000, including post-2018 TEC compliance),
- Public visibility and forensic access,
- Presence of known risk factors such as soft stories, weak materials, and unauthorized modifications.

Data Sources

The study uses many types of sources. Reports from groups like EERI, GEER, AFAD, and USGS were used to get expert findings. Academic articles and engineering research were helpful to understand how the buildings failed. Turkish earthquake codes and laws were used to check what the rules required. Photos, drone images, and videos helped show the damage clearly. Other collapse cases from around the world were also used to support the analysis

Results and Discussion

This section presents brief summaries of three major building collapses from the 2023 Turkey-Syria earthquakes. Each case illustrates common structural failures, code violations, and consequences of poor enforcement. All cases were built in the 2000s and were expected to comply with modern seismic regulations, particularly TEC-2018.

Rönesans Rezidans, Antakya

Collapse Details: A 12-story luxury apartment complex, fully collapsed during the Mw 7.8 quake, killing hundreds. The building housed approximately 250 apartments and had commercial units on the ground floor [1].

Key Failures:

- Inadequate column reinforcement and insufficient confinement.
- Use of substandard materials, including low-strength concrete.
- Soft-story ground floor due to commercial use.
- Possible unauthorized structural modifications

Figure 1. *Rönesans Rezidans Before and After the Earthquake Collapse.*

Galeria Sitesi, Adıyaman

Collapse Details: A mixed-use commercial-residential complex from the 1990s, collapsed instantly during the earthquake. It was one of the deadliest collapses in Adıyaman, trapping dozens inside [2].

Key Failures:

- Brittle column failure, inadequate rebar, and outdated foundation system.
- No retrofitting done despite known seismic risk.

Soft-story vulnerability [3].

Figure 2. *Galeria Sitesi Before and After the Earthquake Collapse.*

Isias Hotel, Adıyaman

Collapse Details: Originally a residential building (1991), converted into a hotel without proper permits. Collapsed fully, killing 35 volleyball team members, all of whom perished. The collapse was total and sudden, indicating a critical structural failure likely intensified by prior unauthorized structural modifications [4].

Key Failures:

- Use of river sand in concrete.
- Removal of load-bearing columns for a subterranean garage.
- Added floors without permits or structural reinforcement.
- Soft-story condition due to commercial ground level.

Figure 3. *Isias Hotel Before and After the Earthquake Collapse.*

The collapse of thousands of buildings during the 2023 Turkey-Syria earthquakes was not solely the result of natural forcesit was the result of systemic human failures. Despite the presence of an updated seismic design framework in Turkey (TEC-2018), the widespread destruction revealed the ineffectiveness of enforcement, the prevalence of corruption, and the misapplication of engineering standards.

A key contradiction exposed by the disaster was that many of the collapsed structures were built after 2000, and some even after TEC-2018 took effect in 2019. These buildings should have performed well under seismic loading, but instead, they failed catastrophically. Investigations found that 75% of collapsed modern buildings had multiple code violations, and 30% of concrete samples tested were below 20 MPa, while TEC-2018 requires 25 MPa for seismic regions.

***Table* 1.** Contemporary Construction Failures, Excluding Pre-2000 Buildings [5]

Observed Failure	Required Standard (TEC 2018/Eurocode 8)	Why It Failed	Evidence	Observed Failure
Pancake collapse	Strong-column weak-beam design required	Columns failed before beams, reversing energy dissipation hierarchy	Collapsed buildings showed intact beams atop shattered columns	Pancake collapse
Shear cracks in columns	Minimum ductility ratio of 4.0	Brittle shear failure due to insufficient transverse reinforcement	Diagonal cracks in column cross-sections	Shear cracks in columns
Soft-story collapse	Stiffness irregularity limit: <30% difference	Weak ground floors (commercial spaces) with inadequate bracing	Ground floor collapses while upper floors remained intact	Soft-story collapse

These failures were not merely design issues but also results of poor construction execution and fraudulent inspections, where crucial reinforcements were either missing or poorly anchored.

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The 2018 Construction Amnesty Law further undermined structural safety by granting legal status to millions of non-code-compliant buildings without requiring seismic upgrades. This included public infrastructure like hospitals and emergency centers that later collapsed [6].

Turkey's problem extended beyond technical errors, political corruption played a defining role. Contractors with close ties to politicians were often allowed to bypass regulations and inspections. Both ruling-party and opposition municipalities failed to enforce codes, proving the issue was systemic, not political.

Post-earthquake investigations revealed forged inspection records, unauthorized structural changes, and use of illegal construction materials (e.g., river sand at Isias Hotel). In many cases, floors were added without permits or supporting redesigns.

The situation in Turkey mirrors other deadly collapses around the world. The Champlain Towers South collapse in Florida (2021) followed years of ignored maintenance warnings. The Ikoyi Tower in Nigeria (2021) collapsed due to unapproved additional floors. The Xingfu Building in China (2022) failed after illegal renovations.

Conclusions and Recommendations

Policy-Level Recommendations:

- End the Construction Amnesty Practice: There should never be a law that allows unsafe buildings to become legal. These types of laws should be banned permanently.
- Make Structural Audits Mandatory: All buildings, especially old or large ones, should go through regular checks every few years.

- Create an Independent Inspection Authority: Inspections should be done by third-party professionals, not by local municipalities who may have connections to contractors.

Engineering-Level Recommendations:

- Ban Soft-Story Designs in Risk Areas: Buildings with commercial ground floors must include shear walls or braces to prevent soft-story collapse.
- Retrofit Old Buildings: Structures built before the 2000s should be reviewed and strengthened, especially if they don't meet TEC-2018.
- Use Better Materials: Builders must use approved concrete and reinforcement. Random sample tests should be required for every project**.**

Enforcement & Accountability:

- Prosecute Negligent Builders: If a contractor knowingly breaks the rules and people.
- Track Construction Progress Digitally: Projects should be monitored using digital tools like photos, videos, and GPS-logged progress reports.
- Publish a Building Safety Certificate: Every completed building should have a safety certificate that is visible to the public, similar to how restaurants show hygiene scores..

The 2023 Turkey-Syria earthquakes were not solely acts of nature., they became man-made catastrophes due to widespread engineering failures, weak enforcement, and governance breakdowns.

Despite having a modern seismic code (TEC-2018), thousands of buildings constructed under or after it collapsed, exposing the dangerous gap between regulation and real-world application.

Detailed analysis of structures such as Rönesans Rezidans, Galeria Sitesi, and Isias Hotel shows that common, preventable flaws, including soft-story configurations, low-strength concrete, poor detailing, and unauthorized modifications, were consistent across multiple regions.

Many of these collapses were enabled by the 2018 Construction Amnesty Law, weak municipal oversight, and systemic corruption in the construction sector.

As this paper argues, earthquakes don't kill people, buildings do. And buildings collapse not from ignorance, but from neglect, greed, and the failure to enforce existing knowledge.

The lessons from this disaster must now translate into urgent reform: enforcing existing seismic codes, penalizing non-compliance, retrofitting vulnerable structures, and involving the public in transparency and safety.

Without these changes, the next earthquake will produce the same tragic outcomes, despite all that has been learned.

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