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SEISMIC RETROFITTING PROPOSAL FOR MODERN HOUSING HERITAGE: THE CASE OF CINNAH 19 IN ANKARA (1)

Cengiz ÖZMEN*, Ceren KATİPOĞLU ÖZMEN**, Ayça ÖZMEN**,
Emre KİSHALI***, Vildan ERASLAN****, Esra Nur Eda KÜÇÜK**

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INTRODUCTION

On February 6, 2023, Southeastern Anatolia and Mediterranean regions were struck by two consecutive earthquakes with magnitudes of 7.8 and 7.7. These were the thirteenth and fourteenth earthquakes of magnitude greater than 7.0 since 1923 in a country whose metropolitan areas are either on or near major fault lines. Since the urban development of Turkish cities is a result of the rapid global economic and construction boom after World War II, a significant number of modern apartment blocks are among the affected or vulnerable structures in the existing building stock. Some of these apartments are fine examples of modernism and its quest for new forms and innovations in materials and construction techniques. Yet many are under threat of demolition, especially in Türkiye's major cities. After the catastrophic earthquakes in Kocaeli and Düzce in 1999, and Van in 2011, two important laws were enacted: Law No. 6306 on the Transformation of Areas under Disaster Risk (Resmi Gazete, 2012) and the Turkish Earthquake Code of 2018, hereafter TEC (2018). While Law No. 6306 (Resmi Gazete, 2012) establishes the procedures and principles for the improvement and renewal of areas under disaster risk, TEC (2018) regulates the design of new buildings and the seismic strengthening of existing structures. The provisions of Law No. 6306 (Resmi Gazete, 2012) and the lack of adequate protection measures in existing legislation for modern architectural heritage have encouraged rapid urban transformation through the demolition and rebuilding of residential buildings. As a result, many examples of twentieth-century buildings have already been lost or are at risk. Nevertheless, the recent Frankfurt Declaration on the protection of modern housing by DOCOMOMO Germany is promising. Article 7 promotes conservation, adaptation, renovation, and ongoing enhancement rather than demolition and construction (DOCOMOMO Germany, 2023).

One of the main options for enhancing the earthquake safety of modern reinforced concrete apartment buildings is seismic retrofitting. Although

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* *Corresponding Author;* Department of Architecture, Çankaya University, Ankara, TÜRKİYE.

** Department of Architecture, Çankaya University, Ankara, TÜRKİYE.

*** Department of Architecture, Kocaeli University, Kocaeli, TÜRKİYE.

**** Department of Civil Engineering, Kocaeli University, Kocaeli, TÜRKİYE.

the procedures and requirements for retrofitting are outlined by relevant laws and regulations, this method is often less favored due to various concerns, particularly those related to the balance between economic viability and cost-effectiveness**.** While seismic retrofitting, as defined in current codes, provides adequate seismic safety, the application of retrofitting techniques to buildings of modern heritage introduces critical debates regarding authenticity**,** a core and often controversial concept in the field of conservation. In the context of twentieth-century architectural heritage, the multidimensional nature of authenticity**,** as first mentioned in the Nara Document on Authenticity (1994), has become central to these discussions. Since seismic retrofitting requires significant alterations to spatial organization, structural systems, and construction materials, such interventions must be evaluated through the lens of conservation theories.

From this point of view, this paper, while arguing for alternative of retrofitting rather than demolition-rebuilding approach for strengthening modern housing heritage against earthquakes in Türkiye, also underlines the importance of issues of authenticity within a conservation context. It aims to contribute to the discussion by offering alternative retrofitting proposals for the Cinnah 19 building, which is considered an iconic example of 1950s modern reinforced concrete residential architecture in Ankara. These proposals are then subjected to a comparative multi-criteria evaluation and scrutinized from the point of view of preserving the original spatial design, structural system, and building materials.

MATERIALS AND METHODS

This study emphasizes that occupant safety is paramount, and measures should be taken when structures no longer meet load-bearing requirements. In this context, structures can be demolished, retrofitted, or partially-completely reconstructed. In the case of architectural heritage, however, retrofitting is recommended as the first option. As an additional note, in recent years, the consumption of non-renewable resources makes it necessary to look at the construction sector from the point of view of sustainability. In this respect, it is vital to maintain the existing building stock and consider retrofitting alternatives before any demolition. This article focuses on proposals for the retrofitting of a twentieth-century modern housing in Ankara, called Cinnah 19, which is considered a part of the city’s modern civil heritage with its architectural, aesthetic, social, and technological values.

At the outset, this study sets the contextual framework for the current state of preservation of the modern housing Türkiye. Firstly, the emergence of residential buildings in the style of Le Corbusier’s Unite d’Habitation is explained within the atmosphere of rapid urbanization and the establishment of civil housing cooperatives in Türkiye after the Second World War. Secondly, the current state of the efforts to conserve modernist architectural heritage in Türkiye is scrutinized within the framework of international and national debates on the theoretical and practical approaches to the problem. At this stage, a special emphasis is given to the existing tendencies and applications in the field regarding the modern housing under the existing earthquake codes, urban transformation legislation, economic stimuli, and public perceptions of seismic retrofitting. Thirdly, the reasons underlying the selection of the Cinnah 19 apartment block as a case study are explained in terms of this building’s status as an archetypal example of the modern housing, a noteworthy part of the architectural heritage remaining from the civil housing cooperatives era of Turkish urban development, and the result of a relatively well-documented construction history, which is not typical of many other similar buildings due to the sporadic nature of archival information from that era.

The analysis part of the study focuses on finite element modeling of the Cinnah 19 building. In this modeling process, archival documents, on-site observations, and data from scientific literature on the material properties and construction techniques of similar buildings were used. Although retrofitting methods for reinforced concrete are constantly evolving, the most commonly used methods in Türkiye are jacketing of structural elements and addition of reinforced concrete shear walls. Other methods, such as steel frame strengthening, seismic dampers, and base isolators, are less preferred due to limited expertise and high costs. When considering the preservation of modern architectural heritage, the conservation of material authenticity and the original structural system is the primary concern. It must be emphatically stated here that the modeled retrofitting proposals for the Cinnah 19 building in this study are deliberately selected among the available options not for their technically innovative character or state of the art quality but for being commonly encountered and therefore realistically applicable solutions in Turkish construction practice, which also preserve as much of the building's original character as possible. Finite element analyses of the existing building and retrofitting options were performed using ProtaStructure, a software that specializes in structural modeling and retrofitting integration. These analyses provided a detailed assessment of the existing condition of the building, and its performance after retrofit.

The evaluation stage employs a comparative value-based approach to assess the advantages and disadvantages of the two retrofitting options that meet the seismic performance requirements of TEC (2018). This evaluation is conducted through the lens of architectural conservation of Türkiye's heritage, focusing on authenticity, spatial quality, material originality, and fidelity to the existing structural system. While this study favors reinforced concrete jacketing of all columns due to its minimal impact on the building's architectural characteristics, it avoids a definitive conclusion, acknowledging the subjectivity and diversity of contemporary conservation approaches. The primary focus remains on the urgency of protecting modernist architectural heritage in Türkiye and validating seismic retrofitting as a viable alternative to demolish-rebuild approach. It should also be acknowledged that in the context of Ankara, which is located in a relatively low-risk seismic zone, retrofitting is a preferable strengthening solution in terms of cost compared to the demolition and reconstruction method.

CONSERVATION PROBLEMS OF MODERN HOUSING HERITAGE: EARTHQUAKE CODES AND URBAN TRANSFORMATION IN TÜRKİYE

Conservation of Modern Housing Heritage

The great divide between tradition and modernity is particularly clear in the debate over the conservation of modern heritage. Whilst older heritage can be evaluated simply in terms of age, historical and aesthetic value (Ahunbay, 2022), the novel characteristics of more recent heritage make assessment harder. As Canziani (2008) says, the main challenge of modern heritage conservation is the inconsistency between the concepts of modern architecture such as temporality, functionality, flexibility, and the idea of conventional conservation. This also brings the retention of experimental and short-lived materials and structural systems up for discussion. Buildings of the last century are not the same as other historic buildings and should be evaluated with an alternative approach. Prudon (2017) also supports this dichotomy by focusing on innovation and longevity and affirms the need for developing new strategies philosophically and technically. He argues that today’s construction technology differs greatly from earlier times when building traditions remained the same for centuries (Prudon, 2017). Therefore, the actors involved in the conservation of modern heritage offer different notions of conservation values. These values, cited by DOCOMOMO-US (n.d.), include technological value in leveraging innovative technology to address programmatic, aesthetic, and structural challenges; social value in reflecting modern lifestyles and working conditions; aesthetic value of form, composition, scale, proportion, detail, and material; canonic value as an exemplary artifact; referential value in inspiring later designs, along with integrity in preserving its authentic design intent despite material changes. Unlike other ICOMOS charters, the ICOMOS Madrid–New Delhi Document (2017) emphasizes the technological significance of 20th-century buildings by highlighting their innovative structural solutions, forms, construction techniques, and materials, encouraging tailored conservation methods, careful documentation, minimal replacement, and the use of compatible, energy-efficient alternatives when necessary.

Along with conservation values, authenticity is another debate surrounding modern heritage. Authenticity is related with the truthfulness and credibility of physical, oral, figurative, or written information resources which helps to understand meaning, nature, history, and specificity of the cultural heritage. These sources include substance, material, design, form, technique, tradition, setting, location, feeling, spirit, and other external and internal elements (ICOMOS, 1994). Heynen (2006) agrees that the modern architectural heritage poses various problems in the field of conservation and says that technical issues are one of the main issues. Firstly, the structures are built for a particular and transitory temporary reason, and their structures and materials are not guaranteed to stand for eternity. Secondly, the conservation of experimental materials requires expensive and in-depth interventions that are against their design aim regarding economic, functional, and rational. Therefore, as the two sides of the coin, different forms of authenticity are the issue of the conflict (Heynen, 2006). In this context, authenticity alternates between design and materiality. For instance, Sterken (2008) states that changing the structural system to preserve the structural form using contemporary methods is also a type of multifaceted authenticity, not of the material but of the concept instead. However, Ayón (2009) gives an example of the conflict for authenticity between design aim and historic fabric. During the restoration of a well-known modern building Guggenheim New York whilst the topping of the external wall was innovatively designed for the rainwater problem to preserve its design integrity, the structural system was strengthened to keep the original structural system. Also, the color and later additions were taken into consideration for the renovation of the exterior wall, showing the respect of layers that occurred in time (Ayón, 2009).

Different opinions seem to create ambiguity when deciding whether to strengthen or reconstruct the structure of a modern building. However, conservation is a case-by-case action, and it is not possible to evaluate a particular conservation method without analyzing in depth the importance and problems of each case. As the ICOMOS ISC20C Cádiz Document (2021) underlines, the conservation of modern heritage built in concrete requires a context-specific, interdisciplinary approach that includes assessing its significance, authenticity, and integrity; defining the limits of acceptable change; particularly managing alterations related to fire and structural safety, accessibility, and energy requirements; identifying responsible parties; respecting historical layers; sustaining use where possible; reviewing legal and technical frameworks; carefully documenting along with the identification of deterioration and previous interventions; conducting non-destructive sampling; simulating and evaluating repair methods; considering practical constraints such as budget and accessibility; ensuring continuous maintenance and monitoring; and promoting awareness of its cultural value.

Modern Architectural Heritage Under Risk: Earthquake Codes and Urban Transformation in Türkiye

The modern housing stock is not officially recognized as part of Türkiye’s architectural heritage. The Law on the Conservation of Cultural and Natural Property No.2863 (Resmi Gazete, 1983) is tailored for buildings constructed before the 20th century, making it difficult for the modern housing to qualify for official conservation status. The criteria for registration include being part of an archaeological site, having historical significance (often linked to the Turkish War of Independence), or possessing exceptional historical, artistic, architectural, or regional value. It is uncommon for the modern housing to meet these criteria. Even when protection status is granted, in some cases, structural deficiencies or seismic safety concerns could be asserted as a justification for demolishing the buildings.

Since the 1950s, the earthquake codes in Türkiye have undergone many updates, with the most recent major one in 2018. The seismic performance evaluation of existing buildings was first officially addressed in TEC (2007), driven by the urgent need for assessment following the 1999 Kocaeli and Düzce earthquakes. Rapid assessment studies in major cities like Istanbul, Ankara, and Izmir revealed that the seismic strengthening of the entire building stock, either through retrofitting or rebuilding, required substantial financial resources. The government prioritized strengthening public buildings, such as schools, hospitals, and critical infrastructure, and enacted Law No. 6306 (Resmi Gazete, 2012), effectively leaving the responsibility for residential buildings to the private sector. Law No. 6306 (Resmi Gazete, 2012) allows property owners to seek seismic risk evaluation services from public or private experts and decide on strengthening or rebuilding based primarily on cost-benefit considerations (Daşkıran and Ak, 2015).

The building industry is crucial to Türkiye’s economic growth, making it a priority for all governments, regardless of political alignment. Rebuilding residential buildings is often more attractive than strengthening them due to the potential profits from construction, and the increased real estate value of new buildings reflecting the latest architectural trends, materials, and standards. Strengthened buildings must comply with the latest municipal bylaws, regardless of their age, and older buildings are denied any rights granted by bylaws in force at the time of their original construction.

The Gölyaka-Düzce Earthquake Preliminary Report (2022) by the Turkish Chamber of Civil Engineers found that reinforced concrete buildings strengthened after the 1999 Kocaeli (Mw 7.4) and Düzce (Mw 7.1) earthquakes performed well during the 2022 Gölyaka-Düzce Earthquake (Mw 5.9). These buildings were originally strengthened due to issues like inadequate lateral rigidity, insufficient compressive strength, and corrosion-related bonding problems. Strengthening methods included jacketing structural members with high-strength reinforced concrete and adding shear walls. No collapses or structural damage were reported in any strengthened buildings. All Turkish earthquake codes since 1999 have required equal strength capacity and lateral displacement limits for both new and strengthened buildings. The buildings' adequate performance, despite neglect, underscores the effectiveness of seismic strengthening.

The preference for demolition and reconstruction in Türkiye appears rooted in two factors: the short-term economic stimulus from large-scale rebuilding, and the psychological belief that seismic strengthening is ineffective. This perception poses a risk to modern architectural heritage, as no residential buildings from this era in Türkiye are legally protected, leaving their fate to owners. Strengthening is often the cheaper option, with less impact on the urban environment, and it preserves modern architectural and heritage values. Additionally, it is the more sustainable choice, requiring fewer natural resources, producing less waste, and offering greater long-term economic benefits.

MODERN HOUSING IN TÜRKİYE AND CINNAH 19 BUILDING

The International Style that emerged in the first half of the 20th century and became widespread after World War II, along with the modern architectural movement, found fertile soil in Türkiye. The nation's rapid urbanization in the 1950s drove the need for housing, and some of this need was met by mass housing cooperatives. Even though they did not have very high capital, those cooperatives achieved a relatively high level of organization in the 1950s. Batuman (2017) defines this period as the Civil Cooperative Period. After the Law on the Amendment of Article 26 of Land Registry No.6217 (Resmi Gazete, 1954), the construction sector, which was dominated by actors with low capital and small companies defined as builders, rapidly increased housing production. During this period, architects working in Türkiye produced housing blocks with the characteristics of the modern architectural movement and international style, forming a valuable part of today's architectural heritage. Among these structures, many examples have survived and maintained their original usage such as Cinnah 19 (1955), Israil houses (1955), İlbank Blocks (1957), Mintrak Apartment (1957), 96'lar Apartment (1957), Maliye Houses (1957) and İş Bank Blocks (1962). (**Figure 1**).

Figure 1. Some examples of the modern housing blocks in Ankara (Authors, 2022).

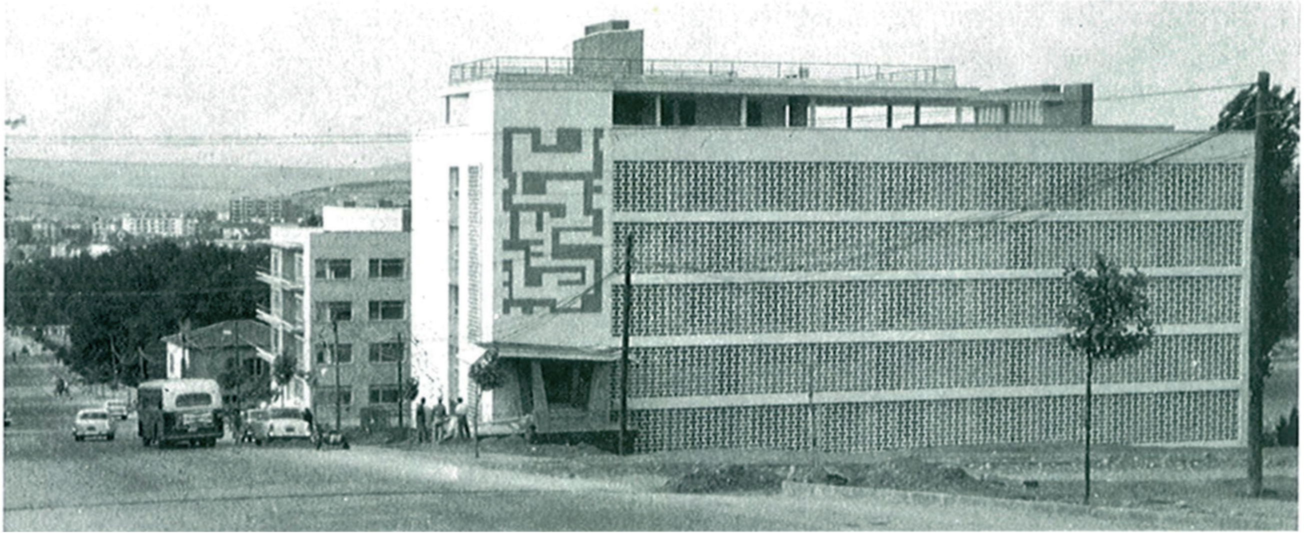
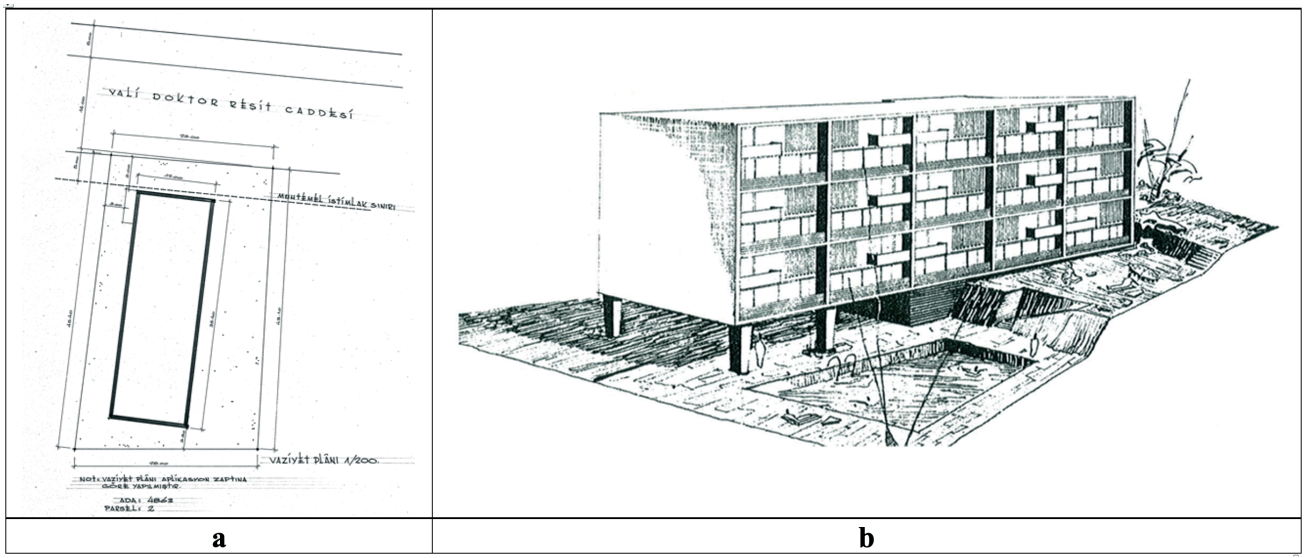


Figure 2. The southern façade of the Cinnah 19 Apartment in 1950s (Mimarlar Derneği 1927).

Modern architecture of the 1950s, which Türkiye adopted in parallel to developments in the West, differs from its predecessors not only in terms of style and form, but also through a significant improvement in the materials and technology. The rapid development of glass, steel, and reinforced concrete and their use in architecture is the most critical technological innovation in the works of this period. Alongside all the other materials and technologies that left their mark on this period and are still used, reinforced concrete is a cost-effective material, allowing the creation of all kinds of shapes, accelerating the construction process, allowing wider openings, and opening the way for mass fabrication. Such have helped it be rapidly adopted in many regions. However, the use of this new and experimental material without determining all its advantages and disadvantages caused many buildings constructed at that time to deteriorate rapidly due to the nature of the reinforced concrete. In a way, the architecture of the period is a record of experimentation with reinforced concrete as a technology and as an artistic and social tool.

As a significant example of modern architecture, the Cinnah 19 apartment (**Figure 2**) epitomizes the social life of the capital, Ankara in the 1950s and 1960s. The building, an example of reinforced concrete apartments built in the 1950s, was designed by Architect Nejat Ersin in 1955-1956 for the workers of the Directorate of *Meydanlar İş Yapı* (**2**). The structural project was prepared by Yavuz Kireç (Mimarlar Derneği, 1927). Documents in the archive of Ankara Metropolitan Municipality and the archive of the Mimarlar Derneği 1927 show the design of the building was revised and changed during the process. Based on the first proposal, the building consists of 15 duplex units, with a flat roof and a large swimming pool on the ground (**Figure 3**). The building was redesigned due to the changes in the land boundaries: on the western side (Vali Dr. Reşit Street) the pavement was widened and on the eastern side the land was expanded (**Figure 3**). In the second proposal, the building was positioned very close to the main road, and another floor consisting of two flats was added to the building above the basement floor, and the location and direction of the main stairwell were changed (**Figure 4**). The units were redesigned to be wider than the first proposal since the rotation of the stairwell created more space, and the recreation area and pool on the terrace floor were added.

2. Meydanlar İş Yapı Kooperatifi was a cooperative, initiated by the workers of State Airports Authority in Türkiye.



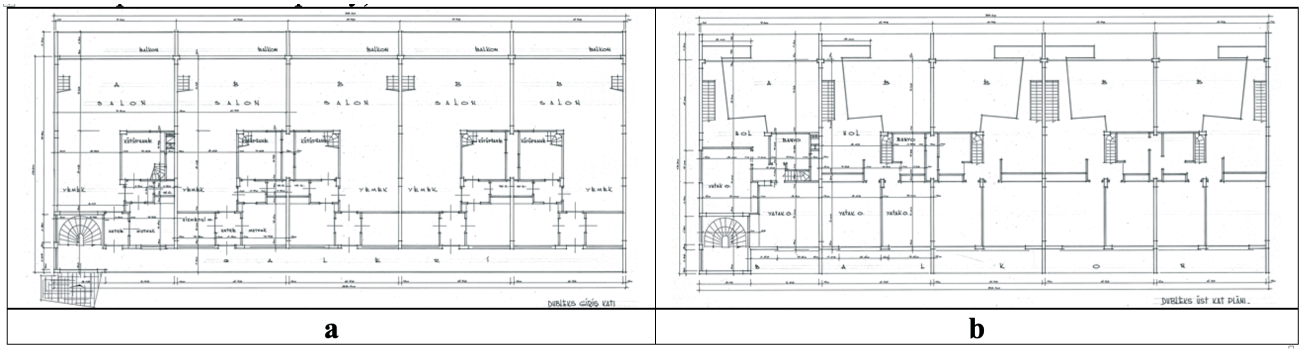
a

b

Figure 3. The first proposal prepared by Architect Nejat Ersin. a. Site plan. b. Perspective view (Archive of Ankara Metropolitan Municipality).

The building reached its current state after the third proposal. In this proposal, the area previously designed as a library and containing a second staircase to the upper floor was included in the living room, the staircase was cancelled and a wet volume consisting of a toilet and sink was added in its place (**Figure 5**).

Ersin's Cinnah 19 building was inspired by Le Corbusier's modern principles. This kind of attribution is rare in the Turkish apartment typology of the period. The partially elevated structure with pilotis, the recreation area created on the terrace floor, and the free volumes created by the gallery space in the duplex units are some of Corbusier's influences (**3**) (Mimarlar Derneği, 1927) (**Figure 6**). Besides these, Cinnah 19 also exemplifies unique modern architectural and aesthetic values. The semi-open common circulation corridor and the façade of this corridor (south façade) consisting of blocks specially designed by the architect are some such elements. Ersin specifies that the white concrete block grille façade was inspired by Edward Durell Stone's buildings (**4**) (Mimarlar Derneği, 1927). The grille façade also repeats on the stairwell part of the main street elevation (**Figure 7**). The main entrance on the south façade of the apartment is indicated with an eave, carried by four free columns. An abstracted black and white mosaic panel, designed by Ersin himself, is applied just above the entrance (Bancı, 2021). Also, the floor tiles on the corridors and the stairs are designed by the architect (Bancı, 2021) (**Figure 8**). Due to the construction material shortage in Türkiye in the 1950s, the



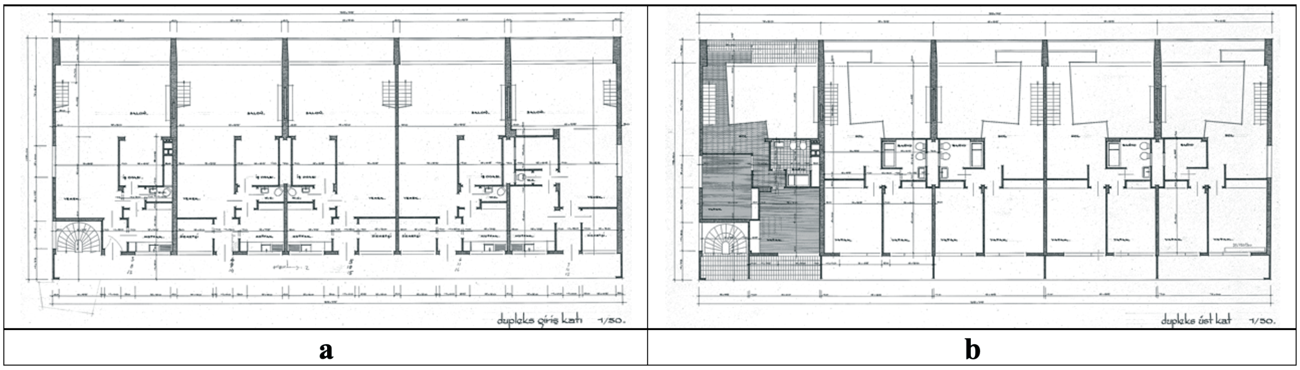
a

b

Figure 4. The second proposal prepared by Architect Nejat Ersin. a. Residential unit's entrance floor plan. b. Residential unit's mezzanine floor plan (Archive of Ankara Metropolitan Municipality).

3. In his mémoire, Ersin states that he searched for different spatial solutions for his cooperative apartment and found the Unité d'Habitation building in Marseille as an inspirational example for creating equal size units with cozy spaces.

4. The mentioned reference can be Edward Durell Stones Townshouse apartment that has a similar concrete grille façade design.



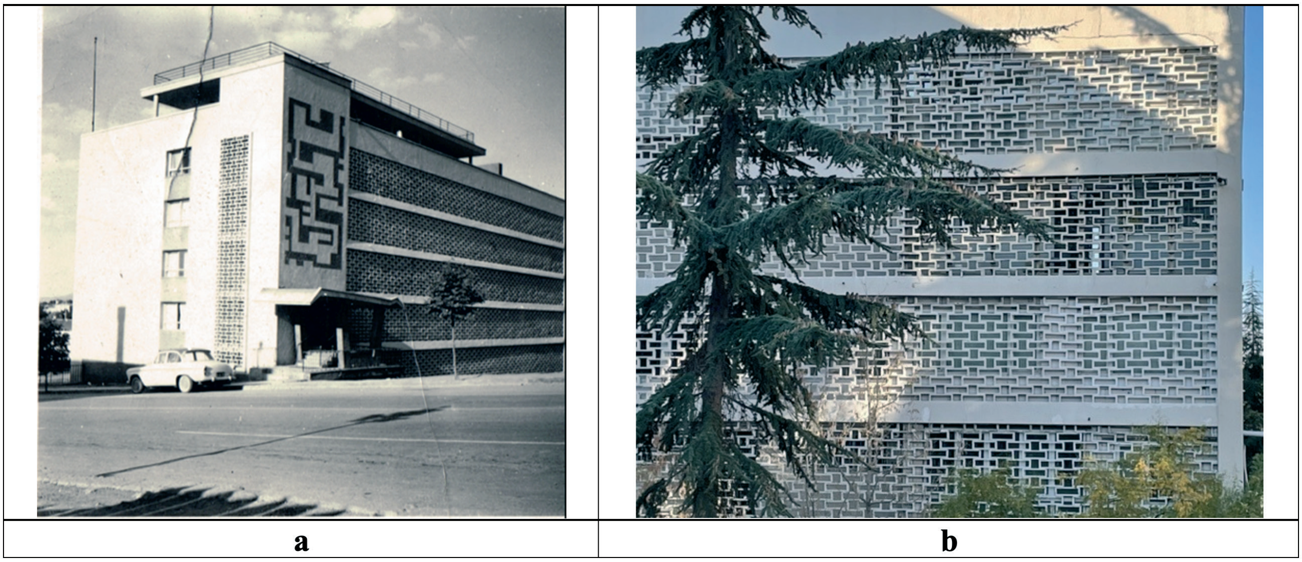
a b

Figure 5. The third proposal prepared by Architect Nejat Ersin. a. Residential unit's entrance floor plan. b. Residential unit's mezzanine floor plan (Archive of Ankara Metropolitan Municipality).

Figure 6. The north façade of the Cinnah 19 Apartment (Authors, 2022).

furnishing elements in the wet spaces were specially ordered and produced by the architect by taking on-site measurements (Mimarlar Derneği, 1927). The black marble used in the fireplaces is another specifically produced element of the building (**Figure 9**).

While most of the architectural documents of the buildings (specifically the application projects and the documents showing the details of the



a b

Figure 7. a. The southwest façade of the Cinnah 19 Apartment in 1950s. b. Detail of the grille façade of the building (Source: a: Mimarlar Derneği 1927) b: Authors, 2022).

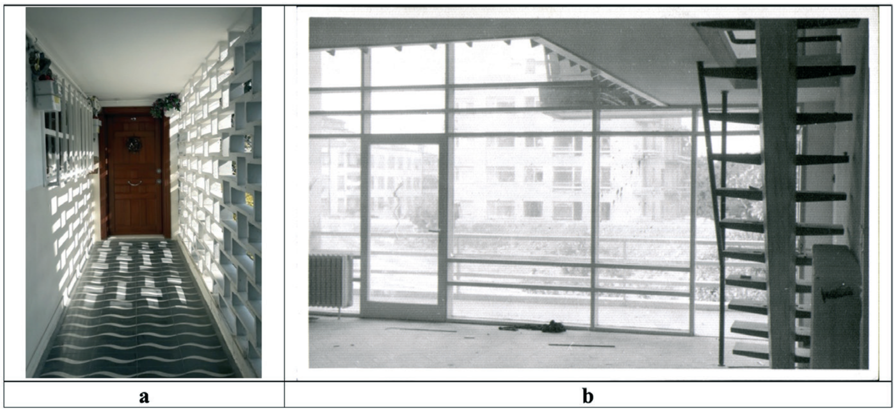
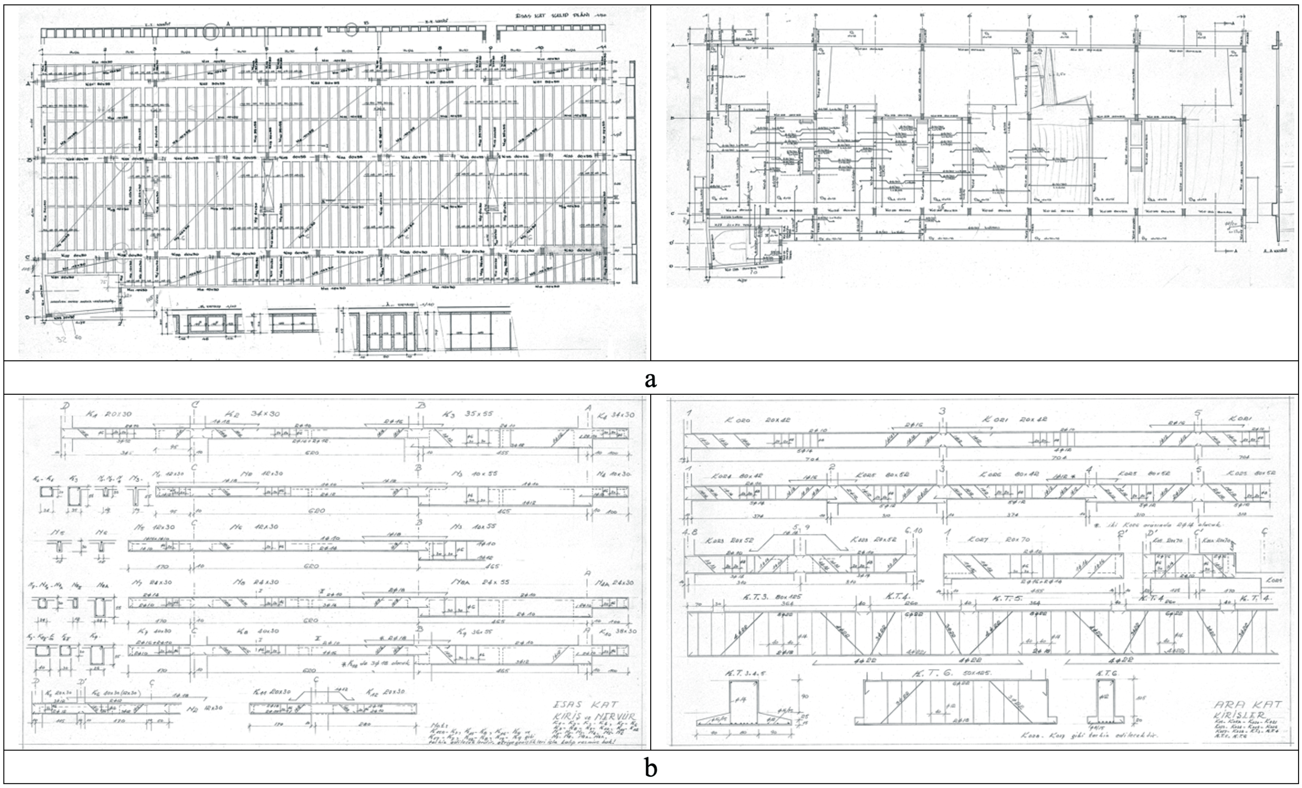


Figure 8. a. Detail from common corridors showing the original tiles. b. Interior of the apartment unit (a: Authors, 2022; b: Mimarlar Derneği 1927).

Figure 9. a-b. Detail from apartment unit showing the black marble fireplace and library (Mimarlar Derneği 1927).

construction) built in the 20th century in Türkiye cannot be found in the institutions’ archives, such documents for the Cinnah 19 building can be reached courtesy of Ersin’s family (Mimarlar Derneği, 1927). In the light of these documents (**Figure 10**), the progression of the design and

Figure 10. a. Structural plans of the first proposal. b. Reinforcement details of the first proposal (Mimarlar Derneği 1927).



construction process can be traced relatively more accurately than with other similar buildings of the era. This has been a facilitating factor in tracing the architectural authenticity of the building in terms of spatial design and construction techniques.

FINITE ELEMENT MODELS AND CALCULATIONS

The modeling and finite element analyses of the existing Cinnah 19 building and the seismic retrofitting are realized according to the following steps:

- An architectural and structural system survey of the Cinnah 19 building was performed based on the archival documents and a site visit. This site visit included complete access to all common spaces such as the roof terrace, technical spaces on the ground floor, the interior circulation areas of the building, as well as the garden. Additionally, three duplex and one single story residential units were accessed and surveyed. It was observed that although there were minor changes in the functions of the individual units, the architectural authenticity of the building in terms of both exterior appearance and interior space organization was largely preserved.
- An architectural model of the building’s current condition was created using Autodesk Revit and Autodesk AutoCAD softwares. This model includes not only the architectural features of the building, but also the complete structural system, and was instrumental in understanding the three-dimensional configuration of the reinforced concrete frame and the architectural and spatial implications of the proposed retrofitting options.
- The finite element model of the building in its current state was generated in the ProtaStructure software. Overall dimensions of the structural system as well as the heights, widths, and cross-sections of the reinforced concrete members were cross-checked between the archival documents and the observations and measurements taken on-site. Material sampling and rebar mapping from the building were not available. As the construction date of the building predates the landmark 1975 Turkish Earthquake Code, the building was accepted as a no-code building. The concrete used in the construction was accepted as C10 class and the reinforcement steel was accepted as S220 class. Such materials are typical of the reinforced concrete buildings of similar typology of that era in Türkiye (**5**). Information about reinforcement details was either obtained from construction drawings, whenever available, or accepted as configured and placed in accordance with the building codes of the era.
- The structural performance of the existing building was analyzed according to TEC (2018) and evaluated as unable to satisfy the required minimum seismic performance targets. This analysis also demonstrated that the critical weakness of the existing structural system was due to the insufficient seismic capacity of the vertical load carrying elements. In contrast, the horizontal load carrying elements such as beams, ribs, and slabs demonstrated satisfactory performance and thus no modifications to these elements were offered in the subsequent retrofitting proposals.

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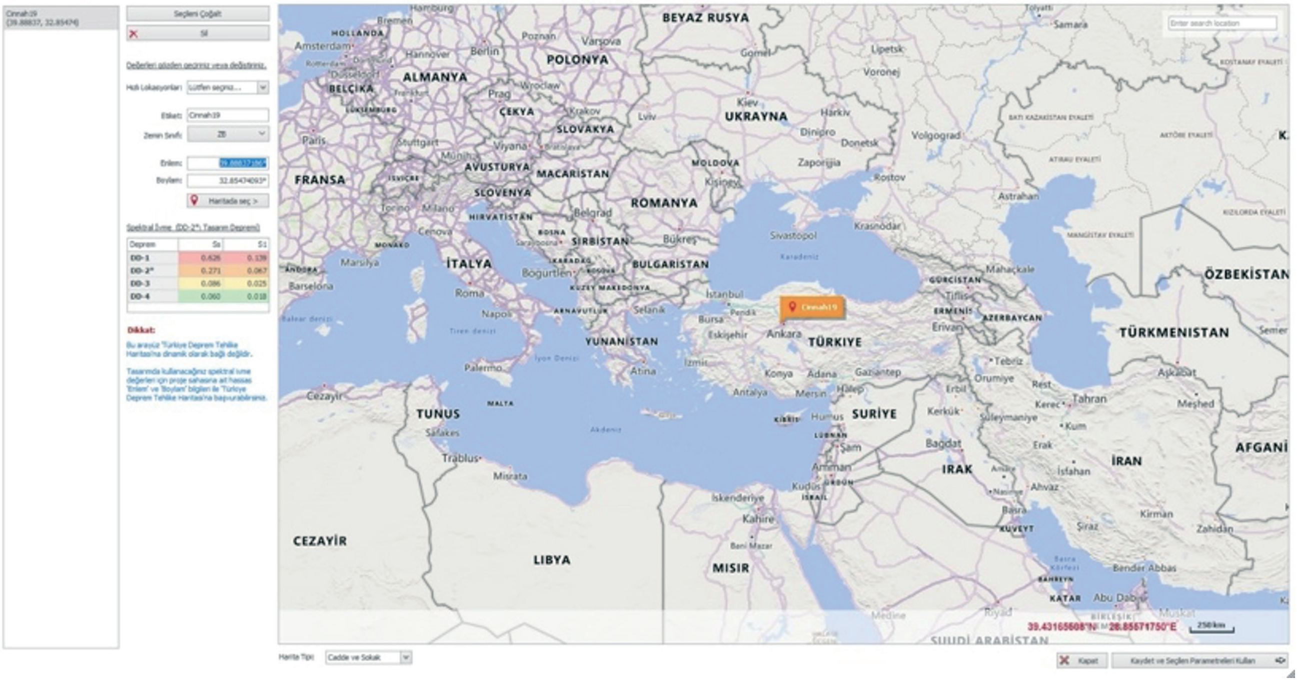
5. Over the past decade, studies on the structural strength of Türkiye’s modern architectural heritage have provided valuable insights into the construction techniques and materials used during relevant periods. For instance, tests conducted on 50 core samples extracted from 19 buildings in the Istanbul University Faculty of Science and Letters complex—designed by Sedat Hakkı Eldem and Emin Onat between 1943 and 1952 revealed an average concrete compressive strength of C12 (Kaya, 2020).

- Three retrofitting options were developed, modelled, analyzed, and evaluated based on their effects on the architectural-spatial characteristics of the building, the conservation of the originality of the building materials and the fidelity of the original construction techniques and structural system.
- The first option was the strengthening of the entire structural frame via 10 cm-thick reinforced concrete jacketing of all columns of the building using C35 class concrete and S420 class rebars. This option satisfied the required minimum seismic performance targets as designated in TEC (2018).
- The second option was the addition of 30 cm-thick in-frame shear walls surrounding the main staircase of the building on three sides using C35 class concrete and S420 class rebars. No other alterations were proposed. This option was unable to satisfy the required minimum seismic performance targets and created torsional irregularity in the building.
- The third and final option was the addition of 30 cm-thick in-frame shear walls in designated locations along both the longitudinal and transverse axes of the building using C35 class concrete and S420 class rebars. This option also satisfied the required minimum seismic performance targets as designated in TEC (2018).

Structural analyses of the Cinnah 19 building are conducted according to the requirements of TEC (2018). Turkish regulations prioritize TEC (2018) in seismic calculations, with additional compliance required for codes like TS 500 Requirements for Design and Construction of Reinforced Concrete Structures (2000) and TS 498 Design Loads for Buildings (2021, rev. 2023 and 2024). The steps taken in the modelling and analysis of the Cinnah 19 building are as follows:

- The parameters of the reference ground motion level and the corresponding horizontal and vertical elastic response spectra were determined according to Chapter 2 (Earthquake Ground Motion) of TEC (2018). In the Cinnah 19 case, the structural performance of the existing building was analyzed under Design Basis Seismic Intensity Level (DD2) which represents an earthquake with a 10% probability of being exceeded in 50 years (in other words, 475-year return period).
- The Horizontal Elastic Design Spectrum specific to the Cinnah 19 building plot and its ground properties are automatically assigned by the integral module of the Prota software (**Figure 11**) upon the selection of the specific building site (**Figure 12**).
- The classification of the Cinnah 19 building is made according to Chapter 3 (The general principles for evaluating the buildings and the design) of TEC (2018). This is a multi-step process beginning with the classification of the building according to its use (Building Occupancy Class, BKS) and assigning a constant value of parameter I (Building Importance Factor) to be integrated into calculations. As a residential building, Cinnah 19 falls under Class BKS=3 with I=1.
- The next step in classification is the Earthquake Design Class, which is done by taking into consideration the previously determined BKS and the maximum horizontal elastic design



Cinnah19 (39.88837, 32.85474)

Değerleri gözden geçiriniz veya değiştiriniz.

Hızlı Lokasyonlar: Lütfen seçiniz...

Etiket: Cinnah19

Zemin Sınıfı: ZB

Enlem: 39.88837186°

Boylam: 32.85474093°

Spektral İvme (DD-2*: Tasarım Depremi)

Deprem	Ss	S1
DD-1	0.626	0.139
DD-2*	0.271	0.067
DD-3	0.086	0.025
DD-4	0.060	0.018

Dikkat:

Bu arayüz 'Türkiye Deprem Tehlike Haritası'na dinamik olarak bağlı değildir.

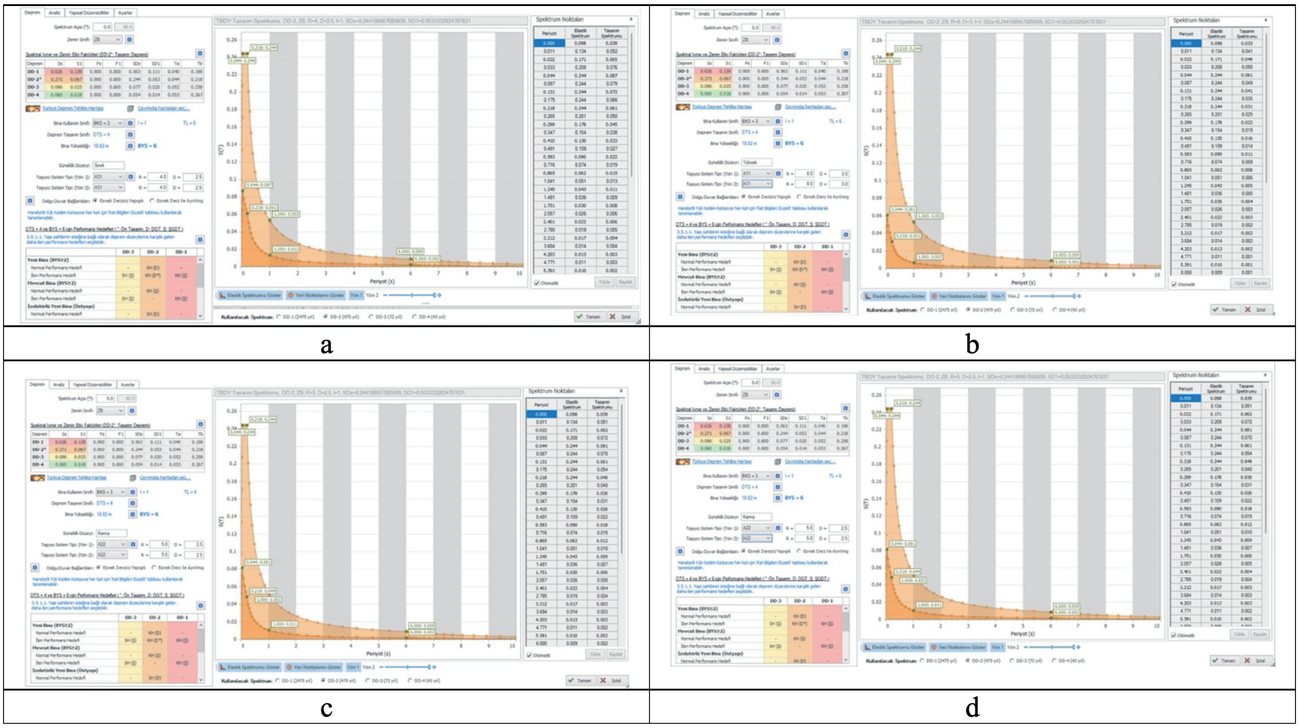
Tasarımda kullanacağınız spektral ivme değerleri için proje sahasına ait hassas 'Enlem' ve 'Boylam' bilgileri ile 'Türkiye Deprem Tehlike Haritası'na başvurabilirsiniz.

Figure 11. ProtaStructure software integrated module for the site selection.

Figure 12. a. The Horizontal Elastic Design Spectrum for the model 1. b. The Horizontal Elastic Design Spectrum for the model 2. c. The Horizontal Elastic Design Spectrum for Model 3. d. The Horizontal Elastic Design Spectrum for the model 4 (Tables are produced via ProtaStructure Software).

acceleration value taken from the axis of ordinate of the Horizontal Elastic Design Spectrum. In the Cinnah 19 case the Earthquake Design Class of the building is Class 4 (DTS=4).

- This is followed by the determination of the Building Height Class (BYS) which is determined by the Earthquake Design Class and the physical height of the uppermost structural slab of the building from the ground floor slab. As a building without a basement floor,



a

b

c

d

the Cinnah 19 falls under Class 6 representing a building with a height between 17.5 m and 28 m.

- The final step of the classification is the determination of the Design Performance Target. For an existing reinforced concrete building of Earthquake Design Class 4 (DTS=4) and Building Height Class 6 (BYS=6) the Performance Target under a DD-2 class earthquake is the Controlled Damage Performance Level. This means that a certain amount of ductile behavior and completely repairable damage is allowed in the predetermined locations of the structural system without any compromise in occupant safety.
- The evaluation and analysis of existing reinforced concrete buildings is conducted according to Chapter 15 (Special Rules for the Evaluation and the Strengthening Design of Existing Buildings under Earthquake Effect) of TEC (2018). Two different structural analysis approaches are defined to evaluate the seismic performance of existing buildings, namely the linear elastic method and the non-linear method. Linear static methods are the Equivalent Lateral Force Method (ELFM) and Modal Superposition Method (MSM), which are commonly preferred due to the time efficiency. According to Chapter 15 of TEC (2018), the prerequisite conditions are defined to follow the linear approaches. ELFM is not applied to the structure unless the BYS is higher than Class 5. Moreover, B3-Type Irregularity (Discontinuity of Vertical Structural Elements) is another limitation to follow the linear approach. Finally, Demand Capacity Ratio (DCR) is a parameter used in determining whether linear analysis methods (Equivalent Seismic Load or Modal Superposition) can be used reliably. The ratio comparing actual demand (from loads) to structural capacity is analyzed considering the code suggested.
- ELFM is not valid for all cases. Therefore, if the conditions are allowed by the code ELFM approach is applied otherwise the models are analyzed by the MSM. The models are defined according to their ductility level defined by TEC 2018 in **Table 7.1** Structural System Behavior Factor, Overstrength Factor, and Permitted Building Height Classes for Building Structural Systems
- The level of the ductility system was chosen according to the model and **Table 7.1** A11 (high ductility structural systems for the intervened models), A22 (mixed ductility system for the partially intervened model) and A31 (limited ductility structural system for the current condition). The live loads are defined according to the architectural function of spaces such as rooms, stores, etc. using the ProtaStructure Architectural Load Assignment Interface.
- Beams and columns are modelled as frame elements. Ribbed floor slabs are used in the models. Secondary beams are modelled and the spaces between the main beams and ribs are defined as slabs. Slabs are assumed to exhibit rigid-diaphragm behavior in each floor. The corrosion ratio and reinforcement realization coefficient (the ratio of the existing reinforcement in reinforced concrete elements to the reinforcement envisaged in the project) are not considered due to the limited availability of information.
- The modeling process of both the existing building and the proposed retrofitting alternatives is presented in the following

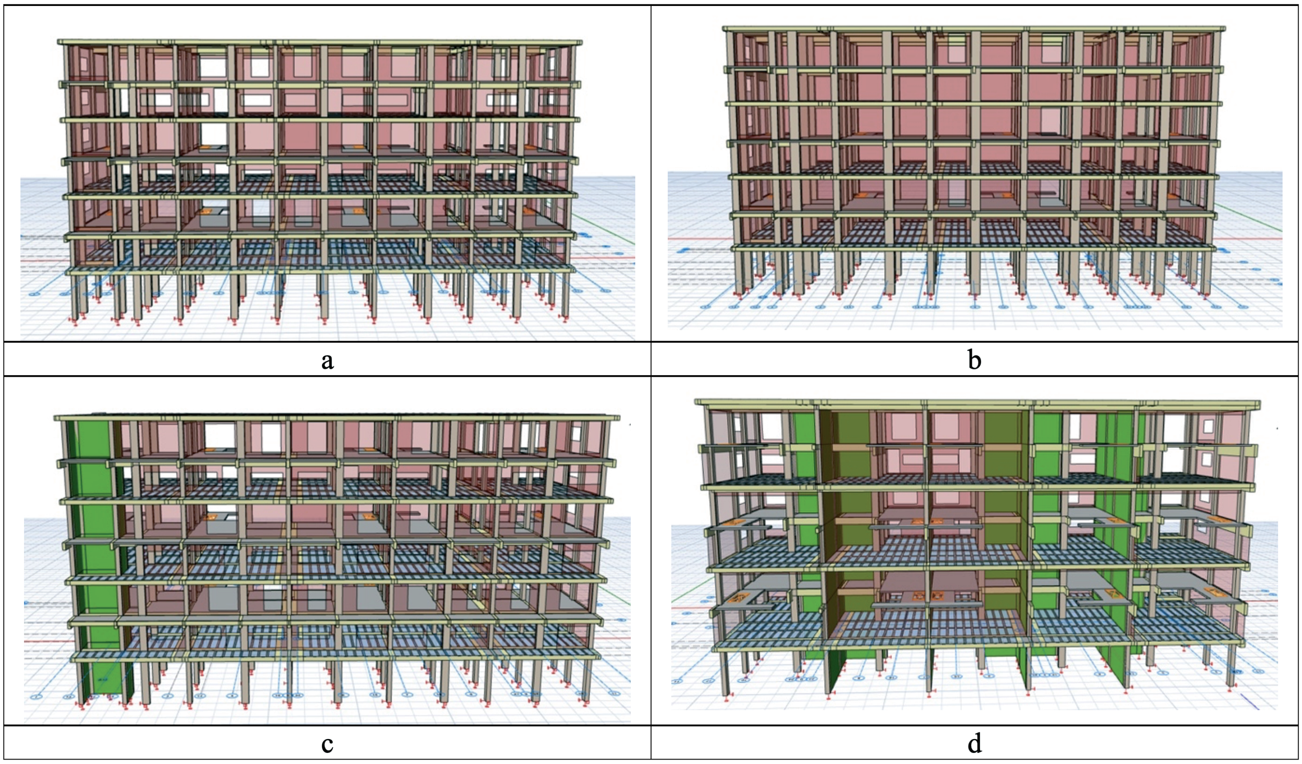

a
b
c
d

Figure 13. a. The ProtaStructure perspective view for the model 1. b. The ProtaStructure perspective view for the model 2. c. The ProtaStructure perspective view for the model 3. d. The ProtaStructure perspective view for the model 4 (3-D images are produced via ProtaStructure Software).

section, supported by 3D visuals exported from ProtaStructure (**Figure 13**).

In the first model (**Figure 14**), the building is analyzed in its current state. The concrete used in the construction is accepted as C10 class and the reinforcement steel is accepted as S220 class. Reinforcement is assigned by the software based on available construction drawings or building codes of the era. As the analyses for all four models show that columns are critical in the building's seismic behavior, beam reinforcements are placed according to building code requirements and remain unchanged in all models. Columns have standard 30x50 cm cross-sections. Column reinforcements and stirrups are assigned as plain bars in 4x 1Ø16 - 2x 1Ø16 and Ø8/19 configuration respectively (**Table 1**). In this phase, the MSM is used for the structure described in TEC (2018) (**6**). Relative story drifts do not exceed horizontal and vertical limits. The results of the structural analysis of the first model show that the Controlled Damage Performance Level is not achieved under DD-2 earthquakes with the aforementioned parameters. The structure shows no irregularities (**Table 2**). The performance level is summarized in **Table 3**.

The performance level is analyzed in four different directions (0, 90, 180, and 270). Except for +y (90) and -y (270), all directions display collapse mechanisms. In the 0 (+x) direction, 51.4% of shear forces exceed the Distinct Damage Limit in both the lower and upper sections of the second floor. In the 90 (+y) direction, this value is 36.2% at the sixth floor, and 43.2% in the second floor of the 180 (-x) direction (**7**).

In the second model (**Figure 15**), the building is analyzed with 10 cm-thick jacketing applied to all the columns —the minimum thickness allowed by TEC (2018). The original concrete is accepted as C10 class, with S220 class reinforcement steel. For the jacketing, the concrete is C35 and the

6. According to TEC (2018), the Equivalent Lateral Force Method (ELFM), which is a linear calculation method, can be used for determining the earthquake performance of existing buildings if the conditions listed below are satisfied in the models: Building Height Class (BYS) must be higher than Class 5. If there is no B3 irregularity in the structure. The linear analysis methods to be used for determining the seismic performance of buildings are the Equivalent Seismic Load Method defined in Section 4.7 and the Modal Superposition Method defined in Section 4.8.2. The additional rules specified below shall apply to these methods. In this analysis, the ELFM was not used. 15.5.3. Limitations on the Use of Linear Analysis Methods 15.5.3.1 – Linear analysis methods cannot be applied if any of the following conditions occur: (c) In reinforced concrete buildings, if—excluding the top floor—the average of the Effective Stiffness Ratios, scaled by the shear forces of ductile vertical members (columns, shear walls, and strengthened partition walls), is greater than the average Effective Stiffness Ratios value of beams in the direction of the earthquake. Average Effective Stiffness Ratios value of ductile vertical load-bearing elements (scaled by shear forces) = 0.85 > Average Effective Stiffness Ratios value of ductile beams = 0.75 (TBDY 2018 – Section 15.5.3.1(c)) Therefore, the Modal Superposition Method was applied.

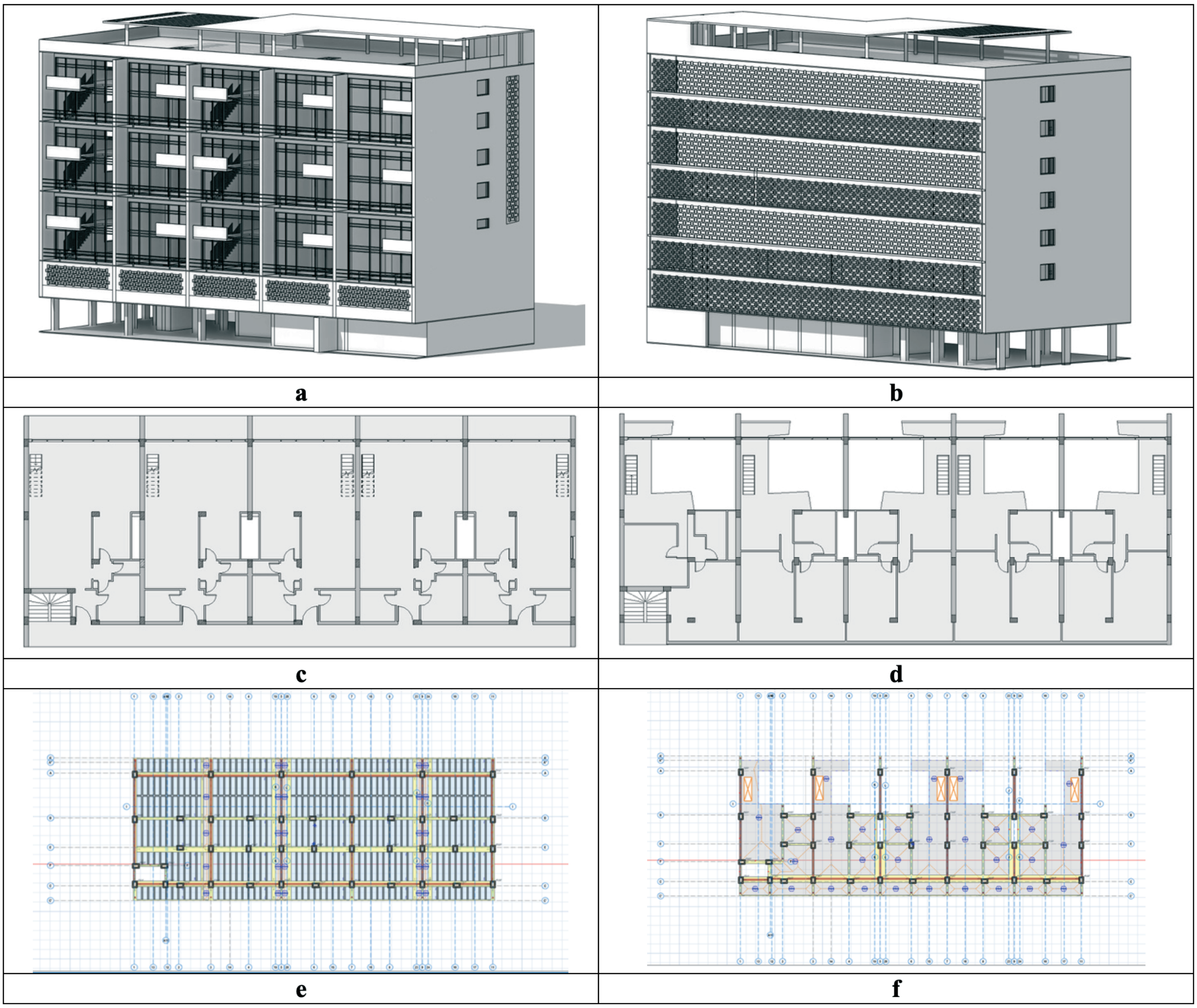


Figure 14. Model 1 – Current state: a. Perspective views from northwest façade. b. Perspective views form southeast façade. c. Residential unit's entrance floor plan. b. Residential unit's mezzanine floor plan. e. Residential unit's entrance floor ProtaStructure model. f. Residential unit's mezzanine floor ProtaStructure model (3-D images are produced by authors via Autodesk Revit Software; 2-D images are produced via ProtaStructure Software).

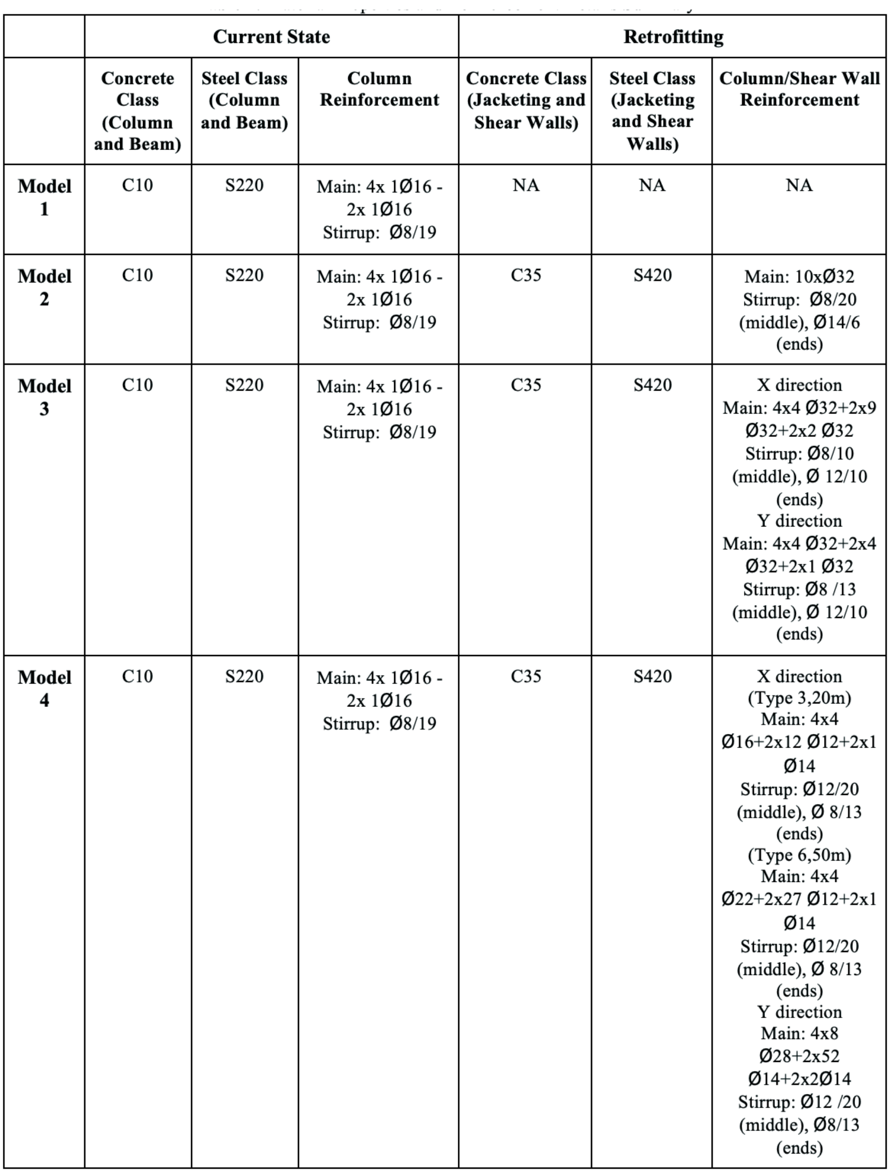
reinforcement steel is S420. The main reinforcements are 10 Ø 32, with stirrups selected as Ø 8 /20 in the middle of the column and Ø 14 / 6 at the column ends (**Table 1**).

The ELFM is eligible for the analysis of the structure. Results show that the DD-2 earthquake Controlled Damage Performance Level is satisfied in all directions (0, 90, 180, 270). The structure displays no irregularities (**Table 2**). The performance level is summarized in **Table 3**. In this case, A11 is chosen as ductility level. (Buildings where all of the effects of earthquakes are met by reinforced concrete frames with high ductility levels that transmit momentum)

In the third model (**Figure 16**), the building is analyzed with 30 cm-thick in-frame shear walls applied to three sides of the stairwell. The original construction's concrete is accepted as C10 class, with S220 class reinforcement steel. For the shear walls, concrete is C35 and reinforcement steel is S420. The main reinforcements for the X direction shear wall are 4x4 Ø32+2x9 Ø32+2x2 Ø32 with stirrups Ø 8/10 in the middle and Ø 12/10 at the ends. For the Y direction, reinforcements are 4x4 Ø32+2x4 Ø32+2x1 Ø32 with stirrups Ø 8/13 in the middle and Ø 12/10 at the ends (**Table 1**).

7. There were no irregularities in plan and in vertical direction as defined in TEC (2018) observed in Figure 12. The observed failure mechanisms were due to the inadequacies in material strength and the amount of reinforcement. As a result, two variations of Model 1 were created to explore the hypothetical seismic strength of Cinnah 19 building with better concrete strength and higher level of column reinforcement. Concrete class was assumed first as C14 and then as C18, knowing that these strength levels are unrealistic for the building's construction period in Türkiye. The column

Table 1. Material properties and reinforcement details summary.



	Current State			Retrofitting		
	Concrete Class (Column and Beam)	**Steel Class (Column and Beam)**	**Column Reinforcement**	**Concrete Class (Jacketing and Shear Walls)**	**Steel Class (Jacketing and Shear Walls)**	**Column/Shear Wall Reinforcement**
Model 1	C10	S220	Main: 4x 1Ø16 - 2x 1Ø16 Stirrup: Ø8/19	NA	NA	NA
Model 2	C10	S220	Main: 4x 1Ø16 - 2x 1Ø16 Stirrup: Ø8/19	C35	S420	Main: 10xØ32 Stirrup: Ø8/20 (middle), Ø14/6 (ends)
Model 3	C10	S220	Main: 4x 1Ø16 - 2x 1Ø16 Stirrup: Ø8/19	C35	S420	X direction Main: 4x4 Ø32+2x9 Ø32+2x2 Ø32 Stirrup: Ø8/10 (middle), Ø 12/10 (ends) Y direction Main: 4x4 Ø32+2x4 Ø32+2x1 Ø32 Stirrup: Ø8 /13 (middle), Ø 12/10 (ends)
Model 4	C10	S220	Main: 4x 1Ø16 - 2x 1Ø16 Stirrup: Ø8/19	C35	S420	X direction (Type 3,20m) Main: 4x4 Ø16+2x12 Ø12+2x1 Ø14 Stirrup: Ø12/20 (middle), Ø 8/13 (ends) (Type 6,50m) Main: 4x4 Ø22+2x27 Ø12+2x1 Ø14 Stirrup: Ø12/20 (middle), Ø 8/13 (ends) Y direction Main: 4x8 Ø28+2x52 Ø14+2x2Ø14 Stirrup: Ø12 /20 (middle), Ø8/13 (ends)

The Modal Superposition is mandatory for the analysis of the structure (**8**). Structural analysis shows that the DD-2 earthquake Controlled Damage Performance Level is satisfied in only two directions (90, 270) but not satisfied in the remaining two directions (0, 180). However, with the new structural elements the building would have A1 type irregularity (**Table 2**). The performance level is summarized in **Table 3**.

In the fourth model (**Figure 17**), the building is analyzed with 30-cm-thick in-frame shear walls applied along X direction on optimal locations within the E axis. One 3.20 m shear wall is added between the axes 2–3 and two 6.50 m shear walls are added between axes 4–6 and 8–10. This is supplemented by shear walls separating the residential units in Y direction (along axes 3,5,7, and 9). The concrete in the original construction is accepted as C10 class, and the reinforcement steels are accepted as S220 class. For the shear walls, the concrete class is accepted as C35 and the reinforcement steels are accepted as S420. The main reinforcements for the 3.20 m shear wall in X direction are configured as 4x4 Ø16+2x12 Ø12+2x1

... note 7 continued

structural design is updated with 4x 1Ø18 - 2x 1Ø18 reinforcement and Ø8/15 - Ø10/5 stirrups for both variations. The structure failed to reach the desired Controlled Damage Level performance target under DD-2 reference earthquake for C14 but satisfied it for C18 class concrete. The analysis results for these two variations of Model 1 demonstrated the critical role played by concrete quality and reinforcement level in the seismic performance of reinforced concrete architectural heritage buildings.

8. ELFM is not eligible due to the following reasons. Direction 1 Torsional Irregularity (Type A1) is present in the structure.

· Maximum Torsional Irregularity Coefficient = 1.289 ≤ 1.4

· Seismic Design Category (SDC): DTS = 4

· Building Height Class: BYS = 6 ≥ BYS = 5 (Hn = 18.82 m) (TBDY 2018 – Clause 4.6.2.2)

· The building has been reanalyzed with additional eccentricities applied. √

Direction 2 Torsional Irregularity (Type A1) is present in the structure.

· Seismic Design Category (SDC): DTS = 4

· Building Height Class: BYS = 6 ≥ BYS = 6 (Hn = 18.82 m) (TBDY 2018 – Clause 4.6.2.2)

ELFM is not eligible due to the following reasons. Direction 1 Torsional Irregularity Type A1 is present in the structure.

· Maximum Torsional Irregularity Coefficient = 1.077 ≤ 1.4

Irregularities in Plan	**Model 1**	**Model 2**	**Model 3**	**Model 4**
(A1) Torsional irregularity	NO	NO	YES	YES
(A2) Floor discontinuity	NO	NO	NO	NO
(A3) Projections in plan	NO	NO	NO	NO
Irregularities in Vertical Direction	**Model 1**	**Model 2**	**Model 3**	**Model 4**
(B1) Weak storey	NO	NO	NO	NO
(B2) Soft storey	NO	NO	NO	NO
(B3) Discontinuity of vertical structural elements	NO	NO	NO	NO
Special Irregularities	**Model 1**	**Model 2**	**Model 3**	**Model 4**
Short Column	NO	NO	NO	NO
Weak Column – Strong Beam	NO	NO	NO	NO

Table 2. Cinnah 19 building structural irregularities result according to TEC 2018.

	Ductility Level	**Hazard Level**	**Performance Target**	**Direction**	**The most critical storey in the performance level**	**Performance level**	**Condition**
Model 1	A31 (limited)	DD2	Controlled Damage	0º 90º 180º 270º	1 1 1 1	Collapse Controlled Damage Collapse Controlled Damage	X √ X √
Model 2	A11 (high)	DD2	Controlled Damage	0º 90º 180º 270º	1 1 1 1	Controlled Damage Controlled Damage Controlled Damage Controlled Damage	√ √ √ √
Model 3	A22 (mixed) Equivalent Lateral Force Method	DD2	Controlled Damage (A1) Torsional Irregularity)	0º 90º 180º 270º	1 1 1 1	Controlled Damage Controlled Damage Controlled Damage Controlled Damage	√ √ √ √
	A22 (mixed) Modal Superposition Method	DD2	Controlled Damage (A1) Torsional Irregularity)	0º 90º 180º 270º	1 4 1 4	Collapse Controlled Damage Collapse Controlled Damage	X √ X √
Model 4	A22 (mixed) Equivalent Lateral Force Method	DD2	Controlled Damage	0º 90º 180º 270º	1 1 1 1	Controlled Damage Controlled Damage Controlled Damage Controlled Damage	√ √ √ √
	A22 (mixed) Modal Superposition Method	DD2	Controlled Damage	0º 90º 180º 270º	1 1 1 1	Controlled Damage Controlled Damage Controlled Damage Controlled Damage	√ √ √ √

Table 3. The performance evaluation summary.

Figure 15. Model 2 – Column-jacketing: a. Perspective views from northwest façade. b. Perspective views form southeast façade. c. Residential unit's entrance floor plan. b. Residential unit's mezzanine floor plan. e. Residential unit's entrance floor ProtaStructure model. f. Residential unit's mezzanine floor ProtaStructure model (3-D images are produced by authors via Autodesk Revit Software; 2-D images are produced via ProtaStructure Software).

Ø14 and the stirrups are selected as Ø 12/20 in the middle of the shear wall and Ø 8/13 at the shear wall ends. The main reinforcements for the 6.50 m shear walls in X direction are configured as 4x4 Ø22+2x27 Ø12+2x1 Ø14 and the stirrups are Ø 12/20 in the middle and Ø 8/13 at the ends. The main reinforcements Y direction shear walls are configured as 4x8 Ø28+2x52 Ø14+2x2 Ø14 and the stirrups are selected as Ø 12/20 in the middle and Ø 8/13 at the ends (**Table 1**). As in the previous case MSM is mandatory for the analysis of the structure. In this case, the results show that the Controlled Damage Performance Level with DD-2 earthquakes is satisfied in all directions (0, 90, 180, and 270), with no structural irregularities (**Table 2**). The performance level is summarized in **Table 3**.

RESULTS AND EVALUATION

The first retrofitting option (**Table 7**), which includes jacketing all columns, results in a moderate change to the façades. While the window openings on the east façade are narrowed, the jacketing of the columns causes more visible columns on the north façade. Furthermore, the dimensions of the original white concrete block grille façade extending along the stairwell

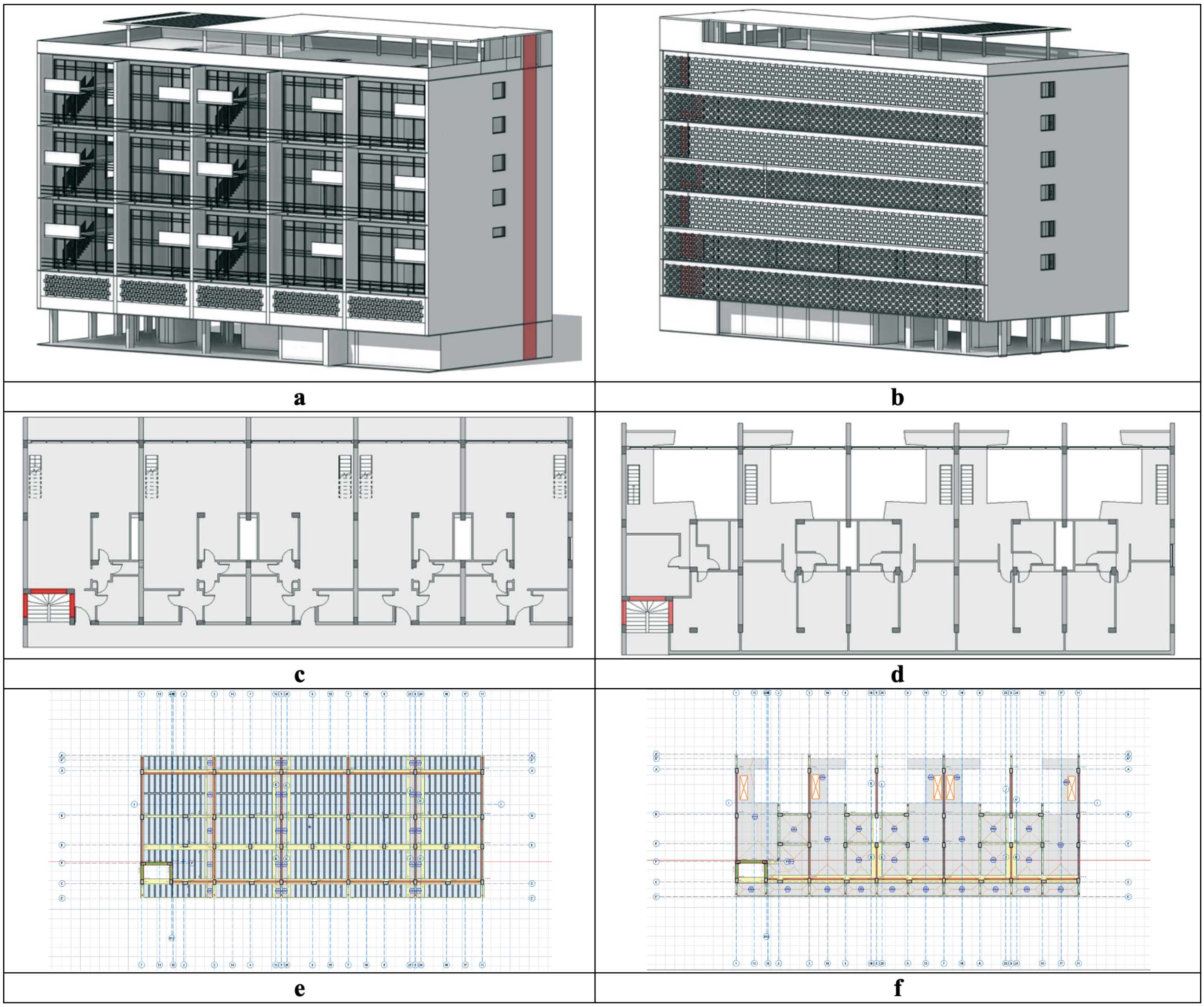


Figure 16. Model 3 – Shear walls around the stairwell: a. Perspective views from northwest façade. b. Perspective views form southeast façade. c. Residential unit's entrance floor plan. b. Residential unit's mezzanine floor plan. e. Residential unit's entrance floor ProtaStructure model. f. Residential unit's mezzanine floor ProtaStructure model (3-D images are produced by authors via Autodesk Revit Software; 2-D images are produced via ProtaStructure Software).

on the west have to be narrowed. Except for the south façade, the façade materials have to be changed.

The spatial characteristics of the private spaces are not radically affected by the jacketing option. Since the jacketing is limited to 10 cm, the walls will become thicker and the dimensions of the space will be narrowed, but the spatial layout does not change. The perception of the proportion of the thin columns has changed a little. The common spaces such as corridors and staircases are also moderately affected: the narrowing of the stairwell will make it difficult to use the staircase and there will be a narrowing in the corridors. The thickening of the columns can be perceived in the open spaces of the building: the terrace and the garden floor.

All these changes in the spaces create modifications in the building elements and the materials. The window frames on the east and north façades need to be reproduced. Since the door and window spaces will change, these elements also need to be reproduced. The floors will be partially changed due to the intervention in the places where the jacketing is applied. The original tiles of the common staircase, which were designed

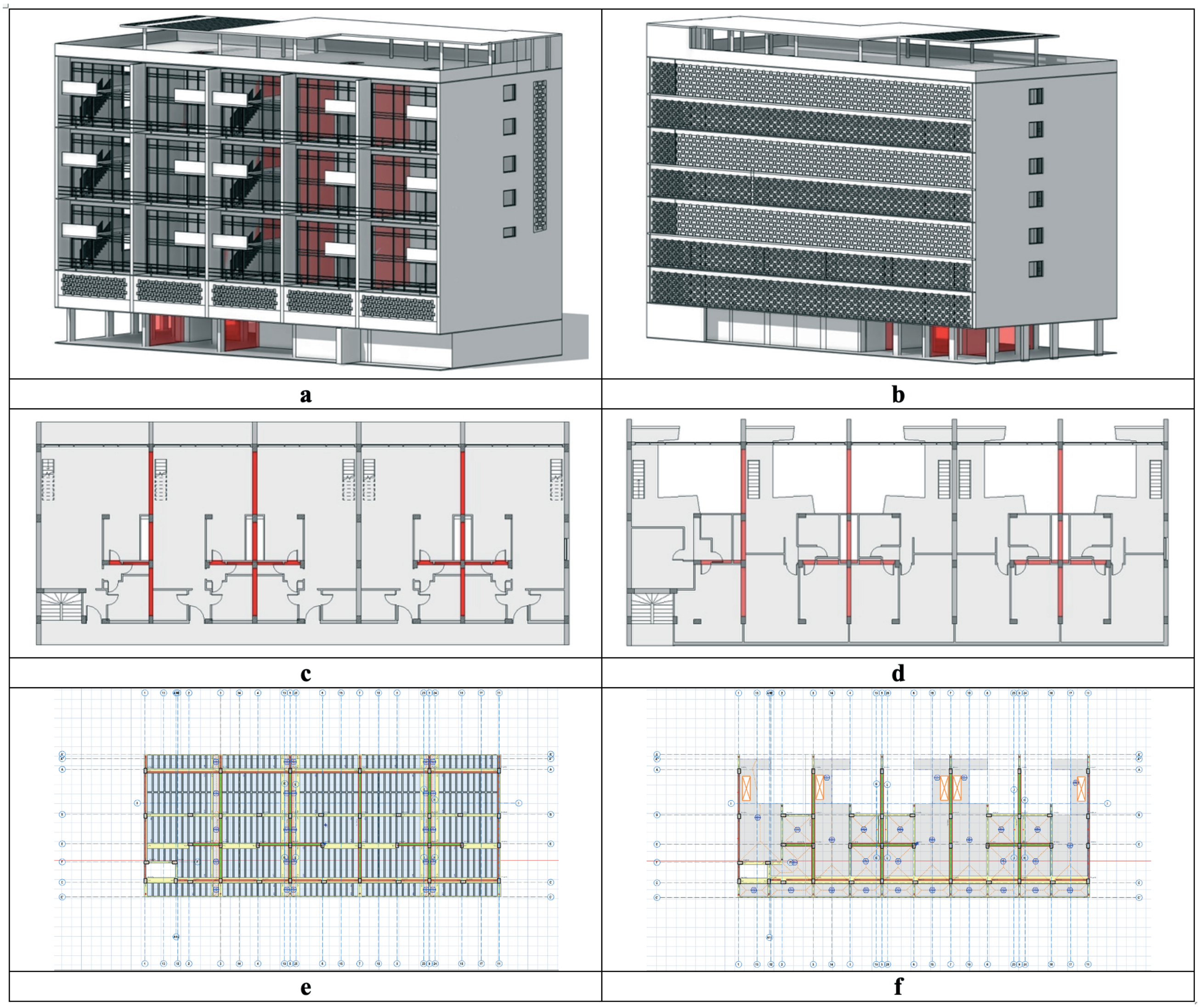


Figure 17. Model 4 – Shear walls along X and Y directions: a. Perspective views from northwest façade. b. Perspective views form southeast façade. c. Residential unit's entrance floor plan. b. Residential unit's mezzanine floor plan. e. Residential unit's entrance floor ProtaStructure model. f. Residential unit's mezzanine floor ProtaStructure model (3-D images are produced by authors via Autodesk Revit Software; 2-D images are produced via ProtaStructure Software).

and produced by the architect, will be partially damaged during the process.

The second retrofitting option, the proposed construction of shear walls fails to meet the required performance level and, while it does not affect the building's façades or common areas, it causes significant disruption to the private spaces. Shear walls added in the X direction block entrance to the wet areas. Furthermore, the shear wall in the living area closes the chimney, thus the fireplace, which is a characteristic feature of the place and is a singular interior architectural example of its period, will be removed. Also, the spatial integrity of the residences in the first basement floor, which has larger volumes, is disrupted. Additionally, on the garden floor, the added shear wall divides the empty space, which was designed to reflect Le Corbusier's principles.

In terms of authenticity of the building materials and elements, there will be some moderate changes; some of the walls will have to be rebuilt and some interior doors will have to be relocated during the retrofitting process. The reinforcements of the shear walls must be anchored to the surrounding columns, beams, and slabs, causing moderate damage to

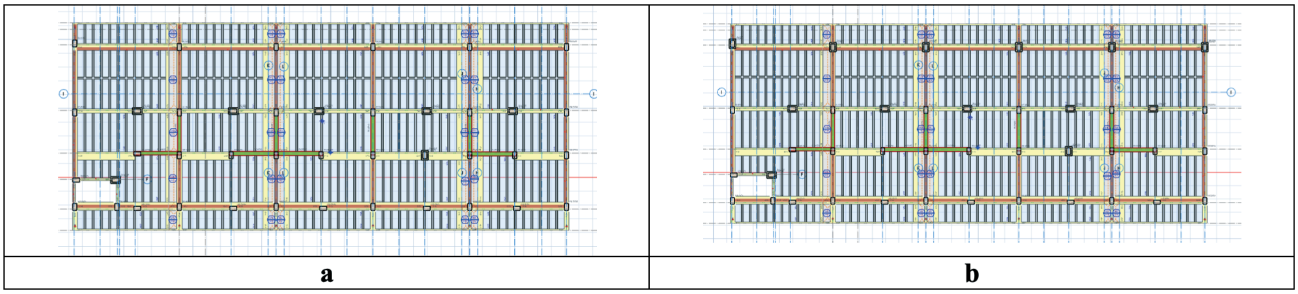
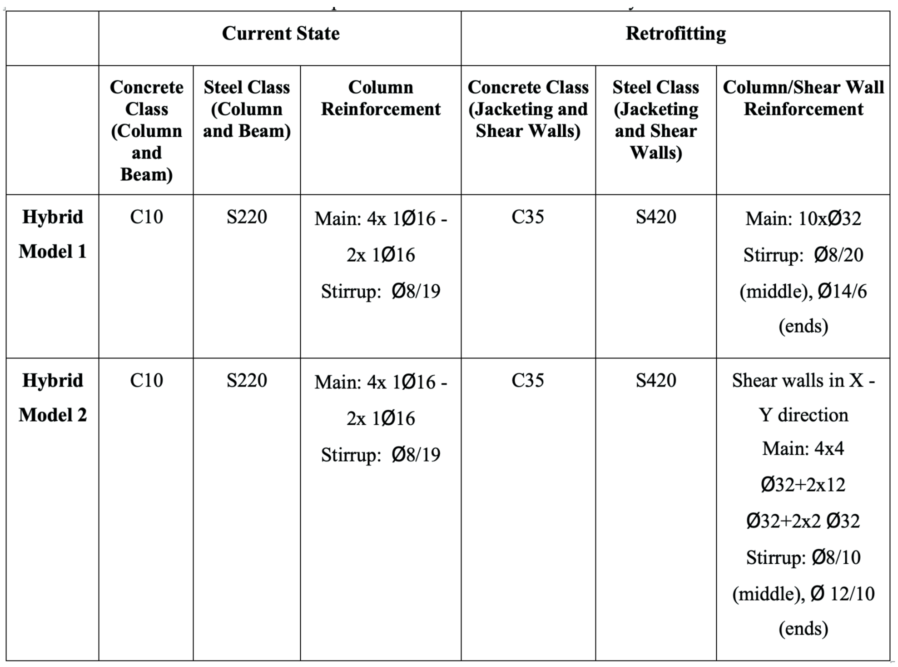


Figure 18. Hybrid Models 1 and 2 – Residential unit's entrance floor of the ProtaStructure model a. Shear walls and column jacketing are added, façades remain unaltered. b. Shear walls and column jacketing are added including the columns on the façade (Images are produced via ProtaStructure Software).

these structural elements and materials. Significant interventions are also required in the foundation of the structure, since each shear wall must be supported by its own foundation. While the structural system before the shear wall retrofitting option is categorized as A31 (Buildings where all of the effects of earthquakes are met by reinforced concrete frames with limited ductility levels that transmit momentum) according to TEC (2018), after the addition of shear walls the system should be classified as A22 (Buildings where the effects of earthquakes are met together by reinforced concrete frames with limited ductility levels and gapless reinforced concrete curtains with high ductility levels) according to the same code. Thus, there will be a change in the structural system classification.

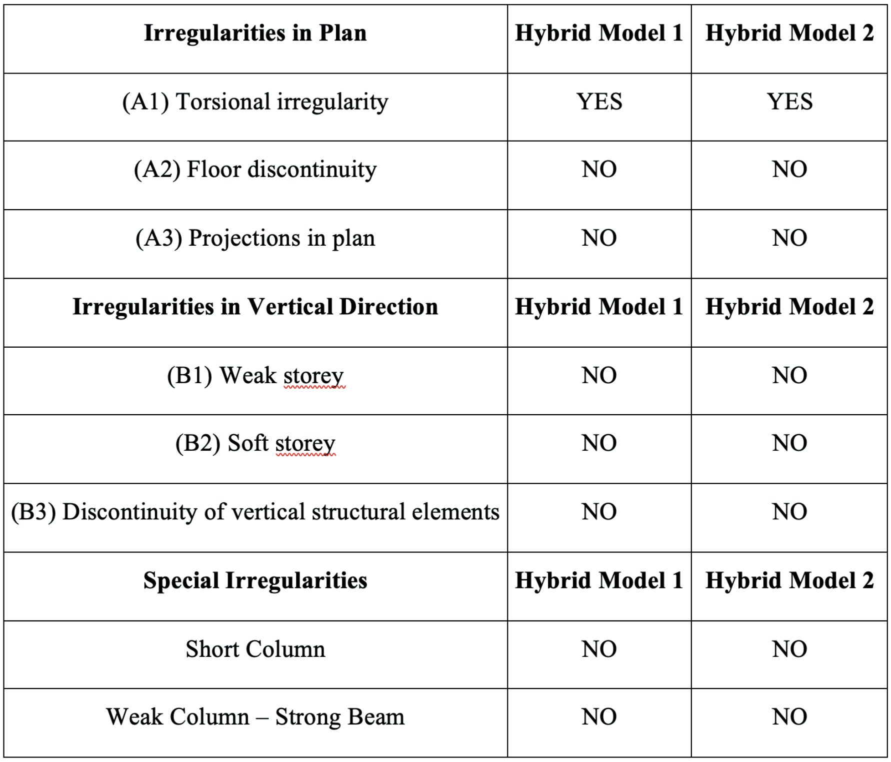
Finally, in order to make a thorough exploration of the retrofitting strategies available, two additional models adopting a hybrid use of column jacketing and shear wall additions are briefly explored. In the first hybrid model (**Figure 18a**), a low intervention approach is followed. The building is analyzed with 30 cm-thick in-frame shear walls applied along X-direction on optimal locations within the E axis. One 3.20 m shear wall is added between the axes 2–3 and 9–10 and two 3.25 m shear walls are added between axes 4–6. This is supplemented by 3.20 m shear walls separating the residential units in Y-direction (along axes 3,5,7, and 9). The concrete in the original construction is accepted as C10 class, and the reinforcement steels are accepted as S220 class. For the shear walls, the concrete class is accepted as C35 and the reinforcement steels are accepted as S420. The main reinforcements for the 3.20 m shear wall in X–Y direction are configured as 4x4 Ø 32+2x12 Ø32+2x1 Ø32 and the stirrups are selected as Ø 12/20 in the middle of the shear wall and Ø 8/13 at the shear wall ends. Moreover, the columns (not faced to the façades) in the axis of B-E-F were jacketed. The building is analyzed with 10 cm-thick jacketing applied to all the columns –the minimum thickness allowed by TEC (2018). The original concrete is accepted as C10 class, with S220 class reinforcement steel. For the jacketing, concrete is C35 and the reinforcement steel is S420. The main reinforcements are 10 Ø 32, with the stirrups selected as Ø 8/20 in the middle of the column and Ø 14/6 at the column ends (**Table 4**). The ELFM is eligible for the analysis of the structure. This model exhibits A1 torsional irregularity according to TEC (2018) (**Table 5**). The results show that the DD-2 earthquake Controlled Damage Performance Level is not satisfied in three directions (0, 90, 180) and satisfied in only one direction (270) (**Table 6**).

A second iterative hybrid model (**Figure 18b**) was created and analyzed by adding additional 10 cm jacketed columns in northeast façade (A axis) (**Table 4**) and keeping the rest of the parameters same. This model also exhibits A1 torsional irregularity according to TEC (2018) (**Table 5**). Results show that the DD-2 earthquake Controlled Damage Performance Level



	Current State			Retrofitting		
	Concrete Class (Column and Beam)	**Steel Class (Column and Beam)**	**Column Reinforcement**	**Concrete Class (Jacketing and Shear Walls)**	**Steel Class (Jacketing and Shear Walls)**	**Column/Shear Wall Reinforcement**
Hybrid Model 1	C10	S220	Main: 4x 1Ø16 - 2x 1Ø16 Stirrup: Ø8/19	C35	S420	Main: 10xØ32 Stirrup: Ø8/20 (middle), Ø14/6 (ends)
Hybrid Model 2	C10	S220	Main: 4x 1Ø16 - 2x 1Ø16 Stirrup: Ø8/19	C35	S420	Shear walls in X - Y direction Main: 4x4 Ø32+2x12 Ø32+2x2 Ø32 Stirrup: Ø8/10 (middle), Ø 12/10 (ends)

Table 4. Material properties and reinforcement details of hybrid models



Irregularities in Plan	**Hybrid Model 1**	**Hybrid Model 2**
(A1) Torsional irregularity	YES	YES
(A2) Floor discontinuity	NO	NO
(A3) Projections in plan	NO	NO
Irregularities in Vertical Direction	**Hybrid Model 1**	**Hybrid Model 2**
(B1) Weak storey	NO	NO
(B2) Soft storey	NO	NO
(B3) Discontinuity of vertical structural elements	NO	NO
Special Irregularities	**Hybrid Model 1**	**Hybrid Model 2**
Short Column	NO	NO
Weak Column – Strong Beam	NO	NO

Table 5. Hybrid models' structural irregularities result according to TEC 2018.

is satisfied in all directions (0, 90, 180, 270) (**Table 6**). This second hybrid model, while it satisfies the structural safety conditions, suffers from the same architectural disadvantages mentioned in previous models using shear walls, such as significant alterations to spatial characteristics of the residential units, the destruction and damaging a significant portion of the original building materials as well as an intervention to the façade and blurring of the Corbusier style building block by dividing the empty space on the garden level with shear walls.

	Ductility Level	Hazard Level	Performance Target	Direction	The most critical storey in the performance level	Performance level	Condition
Hybrid Model 1	A22 (mixed)	DD2	Controlled Damage	0º	1	Collapse	X
				90º	1	Collapse	X
				180º	1	Collapse	X
				270º	1	Controlled Damage	√
Hybrid Model 2	A22 (mixed)	DD2	Controlled Damage	0º	1	Controlled Damage	√
				90º	1	Controlled Damage	√
				180º	1	Controlled Damage	√
				270º	1	Controlled Damage	√

Table 6. The performance evaluation summary of hybrid models.

DISCUSSION AND CONCLUSION

Demolition of modern housing results in the loss of heritage buildings with social, architectural, and technological value. Retrofitting, rather than demolition and reconstruction, should be a solution for such modern residential heritage, which may not be durable because of material obsolescence and not built in accordance with today's earthquake regulations. The debates on the conservation of modern heritage are dominated by two points of view. The first one defines the authenticity of a structure based on its original design concept and therefore allows for a certain freedom in structural or material changes as long as the originality of the design idea is preserved. The second takes a holistic approach to the concept of authenticity, emphasizing the originality of materials, construction techniques, and structural system as well as the design idea. As a result, proponents of this approach are much more cautious about making even minor changes to the existing building. However, the emerging environmental and economic crises add weight to the authenticity of materials. Based on these facts, this paper discusses the seismic retrofitting alternatives of a modern residential heritage along with the principles of conservation.

As a significant example of modern residential architecture, the Cinnah 19 is part of Ankara's collective memory. The fact that the Cinnah 19 represents the modern social life of the capital Ankara constitutes its socio-cultural value, and the fact that it is one of the first examples of the cooperative period generates its historical value. It is also a building with documentary value thanks to the original drawings of its design and construction process, its photographs and videos, and published interviews with the architect Ersin. Inspired by Le Corbusier's Unité d'Habitation, it was designed with modern architectural principles such as the sense of proportion, modular housing units, open floor plan, the presence of permeable solar shading elements, semi-open ground floor, and the terrace roof for recreation. It also became a pioneering reference for other apartment blocks in the region. Although the reinforced concrete technology has been used in the structural systems of apartment blocks in

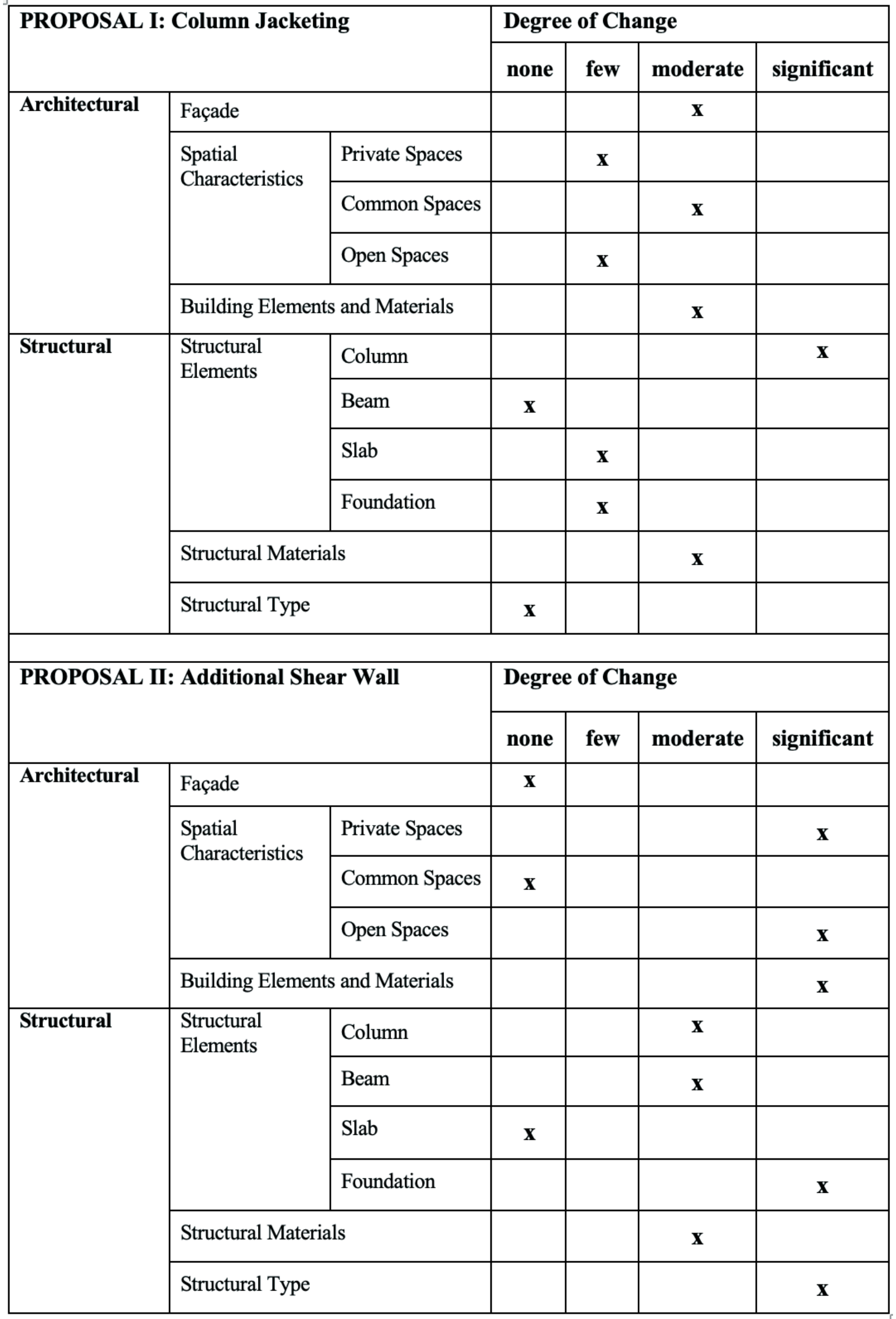


Table 7. Summary of the retrofitting options degree of changes in the building. In this table few changes indicate the changes in the finishings and invisible parts; moderate changes indicate the dimensional changes at the juxtaposition of original structures, not in dimensional changes on the elements; significant changes indicate the changes in the elevation, appearance, and dramatic changes in structure and architectural values.

PROPOSAL I: Column Jacketing			**Degree of Change**			
			none	**few**	**moderate**	**significant**
Architectural	Façade				x	
	Spatial Characteristics	Private Spaces		x		
		Common Spaces			x	
		Open Spaces		x		
	Building Elements and Materials				x	
Structural	Structural Elements	Column				x
		Beam	x			
		Slab		x		
		Foundation		x		
	Structural Materials				x	
	Structural Type		x			

PROPOSAL II: Additional Shear Wall			**Degree of Change**			
			none	**few**	**moderate**	**significant**
Architectural	Façade		x			
	Spatial Characteristics	Private Spaces				x
		Common Spaces	x			
		Open Spaces				x
	Building Elements and Materials					x
Structural	Structural Elements	Column			x	
		Beam			x	
		Slab	x			
		Foundation				x
	Structural Materials				x	
	Structural Type					x

Türkiye quite for a long time, the adaptation of the spatial layout with open volumes and galleries to this technology, the dimensions of the structural elements and the unusual (for buildings in Türkiye) application of the perforated concrete façade represent a technological achievement for its time.

Neither of the seismic retrofitting proposals will have a negative impact on the socio-cultural, historical, and documentary values of the building, since both will preserve the existence of the building. In terms of architectural value, the addition of shear walls will not affect the appearance of the façade, as they will only be implemented on the interior walls of the building. However, the intervention of column jacketing can significantly change the façade by changing the ratio of voids to the whole. On the other hand, column jacketing will create less alteration in the spatial organization than additional shear walls, one of which will close the entrance of the bathroom and change its access. One of the characteristics of the initial design will be removed also due to the closure of the fireplace chimney by a shear wall. In addition, since the additional shear walls will change the logic of the original structural system, one can say that the column jacketing is more favorable in terms of technological value.

SYMBOLS AND ABBREVIATIONS

AFAD	Disaster and Emergency Management Presidency
BIM	Building Information Modeling
BKS	Building Occupancy Class
BYS	Building Height Class
DCR	Demand Capacity Ratio
DOCOMOMO-US	Documentation and Conservation of Modern Movement - US
DTS	Earthquake Design Class
ELFM	Equivalent Lateral Force Method
I	Building Importance Factor
ICOMOS	International Council on Monuments and Sites
MSM	Modal Superposition Method
TEC	Turkish Earthquake Code

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Anahtar Sözcükler: Betonarme modern miras; modern konut; modern mimarinin korunması; betonarme binalar; sismik güçlendirme.

MODERN KONUT MİRASI İÇİN SİSMİK GÜÇLENDİRME ÖNERİSİ: ANKARA'DA CİNNAH 19 ÖRNEĞİ

Türkiye'deki şehirler, yaklaşan deprem tehdidi nedeniyle hızlı bir dönüşüm süreci geçirmekte ve bu durum, modern konutların güçlendirilmesi yerine yıkım-yeniden inşa yaklaşımına kurban gitmesine yol açmaktadır. Bu yaklaşım, büyük ölçüde Türk inşaat sektörünün güçlendirme yöntemlerinin etkinliğine olan şüpheciliğinden, sismik sönümleyiciler ve izolatörler gibi yüksek teknolojili çözümlerin ekonomik açıdan uygulanabilirliğine duyulan güvensizlikten kaynaklanmaktadır. Bu makale, Ankara'da bulunan modern bir apartman binası için geleneksel güçlendirme seçeneklerinin performansını göstermeyi amaçlamaktadır. Türkiye'de yerleşik bir endüstriyel altyapısı veya uygulama bilgisi olmayan deneysel, yenilikçi yöntemler içeren ve yüksek maliyetli güçlendirme yöntemleri bilinçli olarak çalışmanın kapsamı dışında bırakılmıştır. Çalışma, çağdaş koruma bağlamında mekânsal düzenin, inşaat teknolojilerinin ve malzemelerin ve mimari özelliklerin özgünlüğü gibi kritik konuları ele alarak, deprem yönetmelikleri doğrultusunda geleneksel ve düşük maliyetli mantolama seçeneklerine odaklanmaktadır. Bu makalede hedeflenen, seçilen vaka üzerinden, ekonomik ve sismik açıdan güvenli bir kentsel yenileme yaklaşımının, aynı zamanda modern mimari miras değerlerini de koruyacak şekilde benimsenebileceğini göstermektir.

SEISMIC RETROFITTING PROPOSAL FOR MODERN HOUSING HERITAGE: THE CASE OF CİNNAH 19 IN ANKARA

Cities in Türkiye are undergoing rapid transformation due to the impending threat of earthquakes, leading many notable examples of modern housing to fall victim to the demolition-rebuilding approach rather than retrofitting. This is largely due to the Turkish construction industry's skepticism about the efficiency of strengthening methods and the economics of high-tech solutions such as seismic dampers and isolators. This paper demonstrates the performance of conventional retrofitting options for a modern apartment building in Ankara. Experimental, innovative and costly retrofitting methods that do not have an established industrial infrastructure or application knowledge in Türkiye are deliberately excluded from the scope. The work focuses on conventional and low-cost concrete jacketing options within the guidelines of earthquake codes, addressing critical issues in the contemporary conservation context such as the authenticity of spatial configuration, construction technologies, the originality of materials, and architectural features. The aim of this paper is to show, through the selected case study, that an economically and seismically safe approach to urban renewal can be adopted in a way that also preserves the values of modern architectural heritage.

CENGİZ ÖZMEN; B.Arch, M.Sc, PhD.
Received his B.Arch (2000); M.Sc.(2002) and PhD (2008) in building science from Middle East Technical University, Department of Architecture. Primary research interests include earthquake resistant architectural design, structural systems in architecture, architectural design with respect to Turkish Earthquake Code, structural education in architecture.

CEREN KATİPOĞLU ÖZMEN; B.Arch, M.A., PhD.
Received her B.Arch (2003) in Eskişehir Osmangazi University, ESOGU; M.A.(2007) and PhD (2014) in history of architecture from Middle East Technical University. Primary research interests include architectural history, Ottoman architecture, Architect Sinan, 19th century ottoman architecture, early republican Turkish architecture, Turkish modernism.

AYÇA ÖZMEN; B.Sc., M.Sc., PhD.
Received her B.Sc. in architecture from Istanbul Technical University (2007) and her M.Sc. in architecture from Politecnico di Milano (2009). Earned her PhD. degree in architectural restoration at Yıldız Technical University (2017). Major research interests include architectural conservation, adaptive reuse, twentieth-century architectural heritage, and cittaslow movement.

EMRE KİSHALI; B.Eng, M.Sc. Ph.D.
Received his bachelor's degree from Middle East Technical University, Department of Civil Engineering in 2005. Earned his master's degree from Architectural Engineering Programme of Politecnico di Milano in 2007 and Ph.D. degree on restoration from the Building Engineering Programme of the same university in 2011. Major research areas are sustainability and conservation of architectural heritage, consolidation – strengthening, non-destructive tests and planned conservation of historic buildings.

VİLDAN ERASLAN; B.Eng
Received her bachelor's degree in civil engineering from Zonguldak Bülent Ecevit University in 2019, her master's continue in civil engineering at Kocaeli University. Primary research interests include performance and retrofitting of existing structures.

ESRA NUR EDA KÜÇÜK; B.Arch, M.Sc.
Received her B.Arch (2017) and M.Sc. (2024) in Çankaya University. Primary research interests include architectural history of Turkey's modern era.